www.drakestar.com

APRIL 2021

Sector Report

STATE OF THE ADVANCED MOBILITY INDUSTRY 2021

The Great Acceleration of Electrification and Autonomy

Vitaly M. Golomb, Partner
vitaly.golomb@drakestar.com
+1 415 683 6865

Lyle Finkler, AVP
lyle.finkler@drakestar.com

Aleksandra Lebedieva, Analyst
aleksandra.lebedieva@drakestar.com

DRAKE STAR PARTNERS

Follow our research and opinions:

Many of those who have weathered multiple economic cycles and storms said, "here we go again" in March of 2020 as the pandemic began tightening its grip on the world. Borders closed, factories shut down, everyone held their breath, not knowing how long the monster outside their door would be ravaging the world.

Though the human and economic toll is hard to fathom, this, like many crises before, opened the door to opportunity. When work stopped, many supply chains faded away, opening the door to rebuilding with a vision for the future without the inertia of legacy approaches. The pandemic also firmly implanted the concept of a crisis in people's minds. And when the air in big cities cleared up in a matter of weeks, we suddenly saw a preview of the alternative to the looming environmental catastrophe that's been talked about in vain for years.

Since the beginning of the electrification revolution, two factors have been the consistent primary market drivers: government regulations and government stimulus. This has tremendously accelerated electrification in China and Europe in the past half-decade. President Biden's administration has made it clear that it intends to prioritize new energy as a keystone environmental and economic development program. On his first day in office, the President recommitted the US to the Paris Climate Agreement. Within the first week, the administration announced that it would convert the entire US government's 645,000 vehicle fleet to electric. In the next few years, we can expect these policies to make the US the world leader in clean energy transportation and infrastructure.

While electrification went from eventual to inevitable in 2020, the promise of mainstream autonomous driving has hit the brick wall of reality. Major OEMs have reported a reduction in the autonomous driving system R&D budgets. And though assistive systems are making incremental improvements, there is a consensus that full autonomy is still years away due to tens of thousands of dollars in additional costs per vehicle and much needed further testing to pass regulatory approvals. We still believe that the first autonomous systems will be offroad or applications in controlled environments. The first truly autonomous vehicles on public roads will be specialized robotaxi companies such as Zoox, Cruise, and Waymo.

Of course, no report on the mobility sector in 2021 would be complete without mentioning the Special Purpose Acquisition Companies (SPAC) phenomenon. The boom cycle that followed the initial market drop in Q2 2020 created an outsized appetite for companies with a chance to lead the suddenly apparent future mobility revolution. SPACs are not a new concept and have been steadily growing for the past decade. There were 59 mostly unnoticed IPOs in 2019 that raised $13.6B. But in 2020, that number jumped to 248 IPOs that raised $83B. 2021 is on track to far exceed even that. From components to full vehicles, many mobility-related companies are seeing their valuations accelerate years into the future as SPAC mergers get announced to turn them into public companies. Of course, this can't last forever, but for now, it has opened the flood gates to a much faster time-to-market for these cash-hungry manufacturing enterprises.

In the following pages, you will find the results of our team's research efforts divided into three sections:

1. State of the Industry - Electric Vehicles
2. State of the Industry - Autonomous Vehicles
3. The Advanced Mobility Almanac

We hope you find this report interesting and useful in your contributions to this fascinating industry's once in a century transition and near future.

As one of the leaders in this sector, we aim to be the advisor of choice in supporting landmark financing and M&A transactions.

We'd love to hear from you.

Vitaly M. Golomb
Partner
Drake Star Partners
San Francisco
+1 415 683 6865
vitaly.golomb@drakestar.com

INSIDE THIS ISSUE

DRAKE STAR PARTNERS

A Global Leader in TMC, M&A and Corporate Finance

370+	70%	9	25+	9
Transactions	cross-border	Sector Verticals	Partners	Offices Globally

alliander OWNER OF allego SALE TO meridiam — Electric Vehicle Charging Solutions

Campanda PRIVATE PLACEMENT ACCEL INDIA, idinvest PARTNERS, MICHELIN, Groupe Arnault — E-Commerce Marketplace

chargepoint PRIVATE PLACEMENT DAIMLER, BRAEMAR, BMW i Ventures, UNSE CAPITAL, rho — Electric Vehicle Charging Solutions

ETERGO SALE TO OLA ELECTRIC — E-Mobility

FIXICO PRIVATE PLACEMENT AUTOTECH VENTURES, ORANGE GROWTH CAPITAL & Other Shareholders — Car Damage Repair Handling Marketplace

ubitricity SALE TO Shell — Electric Vehicle Charging Solutions

fortum MAJORITY SALE OF ITS CHARGE POINT OPERATOR ACTIVITIES TO AND PRIMARY CAPITAL RAISE FROM Infracapital — Electric Vehicle Charging

zenpark PRIVATE PLACEMENT edf pulse, RATP CAPITAL INNOVATION, DEMETER, MAIF Avenir, Nestadio Capital, Aventure — Smart Parking

GreenFlux Smart charging DIVESTITURE OF CHARGE POINT OPERATING DIVISION TO Joulz A portfolio company of 3i — Electric Vehicle Charging (B2B)

unu PRIVATE PLACEMENT ponooc, NRW.BANK, Michael Baum and other investors — E-Mobility

LOTUS DEBT ADVISORY — Automotive

TRAVELCAR PRIVATE PLACEMENT MAIF, PSA PEUGEOT CITROËN — P2P Car Sharing Service

M-CAPITAL & Other shareholders SALE OF onefield ZE, onefield Belgium — IT, Smart Metering and Electric Charging Vehicle Solutions

THE MOBILITY HOUSE PRIVATE PLACEMENT SPgroup AND EIB FINANCING FACILITY European Investment Bank Group — Fleet Charging and Vehicle-Grid-Integration

SnappCar PRIVATE PLACEMENT Q8 — Peer-to-Peer Car Sharing

RIMAC AUTOMOBILI CAPITAL RAISE Porsche, 骆驼股份 CAMEL GROUP — Automotive

pod POINT SALE TO EDF AND LEGAL AND GENERAL — Electric Vehicle Charging Solutions

newmotion charge smart SALE TO Shell — Electric Vehicle Charging Solutions

FREEWIRE PRIVATE PLACEMENT $50,000,000 RIVER STONE — Battery Integrated High Power EV Charging

mobilitymixx SALE TO HITACHI Inspire the Next — Mobility

AWARD-WINNING INVESTMENT BANKING

Over 25 Awards in recognition of superior results in complex transactions worldwide

DEAL OF YEAR AWARDS

THE M&A ATLAS AWARDS WINNER	THE M&A ATLAS AWARDS WINNER	THE M&A ATLAS AWARDS WINNER	THE M&A ATLAS AWARDS WINNER	THE M&A ATLAS AWARDS WINNER	THE M&A ADVISOR
WINNER America's Deal of the Year 2020	WINNER Cross Border Investment Bank of the Year 2020	WINNER Cross-Border Deal of the Year 2019	WINNER Media/Entertainment Deal of the Year (Mid-Market) 2019	WINNER Corporate Deal of the Year 2019	M&A AWARD WINNER M&A Deal of the Year 11TH ANNUAL INTERNATIONAL M&A AWARDS 2019 WINNER

THE M&A ATLAS AWARDS WINNER
WINNER
Cross Border M&A Deal of the Year
2018

THE M&A ADVISOR
M&A AWARD WINNER
Telecommunication Services Deal of the Year
17TH ANNUAL INTERNATIONAL M&A AWARDS
2018 WINNER

THE M&A ADVISOR
M&A AWARD WINNER
Energy Deal of the Year
2ND EMEA CORPORATE GROWTH AWARD
2018 WINNER

THE M&A ADVISOR
M&A AWARD WINNER
Transaction of the Year (over €50mm - €75mm)
2ND EMEA CORPORATE GROWTH AWARD
2018 WINNER

THE M&A ADVISOR
M&A AWARD WINNER
Transaction of the Year (over €50mm - €75mm)
2ND EMEA CORPORATE GROWTH AWARD
2018 WINNER

THE M&A ADVISOR
M&A AWARD WINNER
Information Technology Deal
16TH ANNUAL M&A AWARDS
2017 WINNER

FINANCEMONTHLY DEAL MAKER OF THE YEAR AWARDS 2017
Drake Star Partners
Newmotion Acquired by Shell

THE M&A ADVISOR
INTERNATIONAL M&A AWARD WINNER
Europe Deal of the Year
9TH ANNUAL INTERNATIONAL M&A AWARDS
2017 WINNER

FINANCEMONTHLY DEAL MAKER OF THE YEAR AWARDS 2017
Drake Star Partners
IMS Internet Media Services (IMS) to acquire a majority stake in Httpool

THE M&A ADVISOR
INTERNATIONAL M&A AWARD WINNER
Information Technnology Deal of the Year
15TH ANNUAL INTERNATIONAL M&A AWARDS
2016 WINNER

THE M&A ADVISOR
INTERNATIONAL M&A AWARD WINNER
Cross Border Deal of the Year (Over $50mm to $100mm)
8TH ANNUAL INTERNATIONAL M&A AWARDS
2016 WINNER

THE M&A ADVISOR
INTERNATIONAL M&A AWARD WINNER
TMT Deal of the Year ($100mm to $1bn)
7TH ANNUAL INTERNATIONAL M&A AWARDS
2015 WINNER

THE M&A ADVISOR
INTERNATIONAL M&A AWARD WINNER
TMT Deal of the Year ($100mm to $1bn)
7TH ANNUAL INTERNATIONAL M&A AWARDS
2015 WINNER

THE M&A ADVISOR
INTERNATIONAL M&A AWARD WINNER
Restructuring Deal of the Year ($50mm to $100mm)
6TH ANNUAL INTERNATIONAL M&A AWARDS
2014 WINNER

THE M&A ATLAS AWARDS WINNER
WINNER
Technology & Telecom Deal of the Year
2014

2014 ACG New York CHAMPION'S AWARDS
WINNER
Technology, Media, Telecom Deal of the Year (Up to $100mm)

12TH ANNUAL M&A ADVISOR AWARDS 2013 WINNER
Technology, Media, Telecom Deal of the Year ($100M to $500M)

FIRM OF YEAR AWARDS

THE M&A ATLAS AWARDS WINNER
Cross-Border Boutique Investment Bank of the Year
2019

ACQ5 Global Awards 2016
US (NY) – Boutique Investment Bank of the Year (Growth Industries), Drake Star Partners
US (NY) - Boutique Investment Bank of the Year (Growth Industries)

DealMakers GLOBAL AWARDS 2016
BEST
WINNER
Corporate Finance Firm Germany
2016

THE M&A ADVISOR
INTERNATIONAL M&A AWARD WINNER
Leadership Award Gregory Bedrosian
11TH ANNUAL INTERNATIONAL M&A AWARDS
2016 WINNER

ACQ5 Global Awards 2015
US (NY) - Leading M&A Dealmaker of the Year, Gregory Bedrosian
2019

ACQ5 Global Awards 2015
US (NY) - Boutique Investment Bank of the Year, (Growth Industries)

2014 ACQUISITION INTERNATIONAL M&A AWARDS
Leading Advisory Firm of the Year
2014

THE M&A ATLAS AWARDS WINNER
Top 10 Boutique Investment Bank of the Year
2014

Visit us at: *www.drakestar.com*

Citations and sources are available upon request through **https://www.drakestar.com/contact**.

DRAKE STAR GLOBAL MOBILITY TEAM

San Francisco / Silicon Valley

Vitaly M. Golomb
Partner
vitaly.golomb@drakestar.com

Tel Aviv

Ruby Chen
Associate Partner
ruby.chen@drakestar.com

New York

Lyle Finkler
Associate Vice President
lyle.finkler@drakestar.com

Connor Cunningham
Analyst
connor.cunningham@drakestar.com

London

Aleksandra Lebedieva
Analyst
aleksandra.lebedieva@drakestar.com

Amsterdam

Frank Verbeek
Managing Partner
frank.verbeek@drakestar.com

Dominique Houde
Partner
dominique.houde@drakestar.com

Sherief Rahim
Principal
sherief.rahim@drakestar.com

Manus Weber
Principal
manus.weber@drakestar.com

Bas Hendriks
Senior Associate
bas.hendriks@drakestar.com

Marlon Brand
Associate
marlon.brand@drakestar.com

Senior Advisory Team

Carl-Peter Foster
Automotive OEMs
GEELY VOLVO BMW GM OPEL

Michel Taride
Fleets, rental cars, and Smart Cities
Hertz WORLD TRAVEL & TOURISM COUNCIL C4Ventures

Hein Van Der Zeeuw
Semiconductors
PHILIPS suncycle NXP elkerliek IQ

Mel Kroon
Energy and Energy Transition
TenneT DNHK VGZ TKH GROUP Fokker

Omar Hatamleh
Aerospace, Connected Vehicles
NASA INTERNATIONAL SPACE UNIVERSITY ISU

Jelle Vastert
Sustainable Energy, EVs
TESLA better place lyft VANMOOF SB Energy

MOBILITY INDUSTRY 2020 UPDATE

COVID-19'S MACRO-LEVEL IMPACT ON AUTO INDUSTRY

Covid-19 is one of the most unprecedented shocks to the modern economy. McKinsey anticipates a decline in global discretionary consumer spending of 40-50%, paired with a reduction of 10% in GDP. The traditional automotive industry is one of the most hardly affected industries by the pandemic, as automakers and suppliers face stock market volatility, a sharp decline in vehicle sales, public transit use, and factory shut-downs. At the height of the crisis, over 90% of the factories in China, Europe, and North America were closed.

Accordingly, industry research and surveys confirmed the challenges the industry faced in 2020 and beyond, while the market players repositioned themselves to absorb the shock, both in supply and in demand. McKinsey predicts vehicle manufacturing to decline by 7.4 million units in 2020 and estimates a profits decline of the top twenty global auto manufacturers by approximately $100 billion. Similarly, other industry analysts expect the 2020 automotive market to fall about 10-15% in China and 15-25% in Europe and the USA. The IBM survey of new car buyers shows that for 30% and 25% of respondents, personal finances and global economic outlook are substantial factors that significantly impact their decision.

In this environment, automakers and mobility tech startups have to adjust their business models. With the ridership plummeting, ride hailers have experienced declines of up to 60-70%, and many micromobility and car sharing players have suspended their services. At the same time, corporate players had to reevaluate their strategic priorities and investments in emerging technologies. Economic uncertainty, in combination with, predominantly, low-margin and capital intensive businesses in the mobility space, pulled back investments from financial investors to early-stage mobility tech startups.

Although the mobility field faces near-term challenges and disruptions, the long-term view on the market is bullish. There will be a lasting impact on mobility, as the pandemic has triggered a change in the macroeconomic environment, regulatory trends, technology, and consumer behaviors. Consequently, as the mobility space emerges from this crisis, we are likely to see new normality with new disruptive products and services including ride sharing and delivery platforms, shared scooter and bike services, and connected and autonomous vehicle technology.

Source: McKinsey. (2020). Safeguarding our lives and our livelihoods: The imperative of our time.
CBInsights. (2020). The Future of Transportation: Impact of Covid-19 on Mobility.

4 stages: Emerging trends based on each stage

Crisis
- OEMs halt production
- Public transport and shared mobility take a hit

Adjustment
- Consumer preferences change rapidly, mobility service providers and automakers must adapt

Recovery
- Automakers and suppliers collaborate to tackle costly R&D
- Prioritization of electrification given favorable tailwinds
- Exploring more feasible applications for autonomy

Vision
- Tech giants and public/private partnerships drive transformation in the mobility space

1 year from Covid-19 start → 5 years from now

Source: CBInsights

MAJOR CHALLENGES FACED BY THE AUTO INDUSTRY

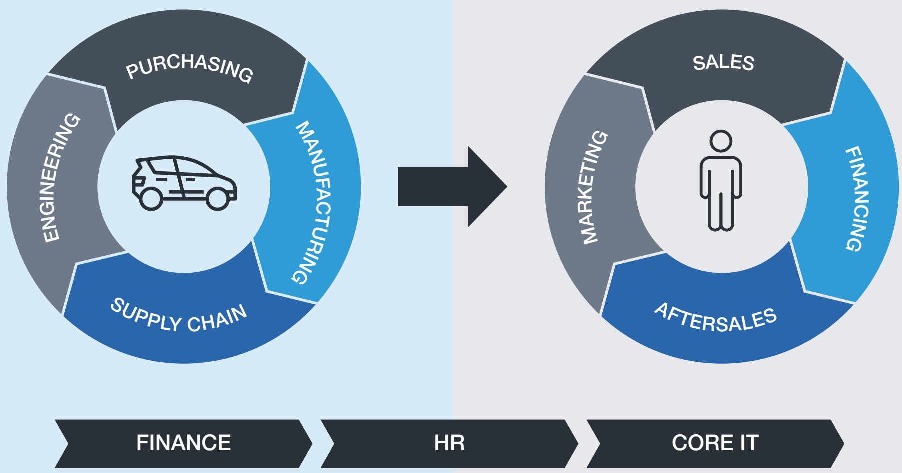
ALONG THE WHOLE AUTOMOTIVE VALUE CHAIN:
FOUR MAJOR CHALLENGES AMID THE COVID-19 CRISIS

1. Limited Supply of Vehicle Parts

Starting in China, suppliers around the globe placed production lines in quarantine or shut them down completely. Also, legal and trade restrictions, such as closed borders, increased the shortage of required parts and limited distribution of supplies.

2. Shut down of Manufacturing

A limited parts supply and a just-in-time production strategy, coupled with quarantine measures and a reduced workforce, lead OEMs to shut down their production. This is enhanced by the need to secure liquidity and reduce overproduction due to the decrease in sales.



3. Declining Working Capital/ Liquidity

A decline in cash inflow resulted from the drop in demand while short-term liabilities and salaries still need to be paid. Cash reserves are likely to be exhausted within a few months.

4. Drop in New Vehicle Sales

Politically enforced measures to contain the virus such as implementing curfews, closing factories, offices, dealerships and the resulting dismissals of short-time workers, as well as the fear of a recession, are likely to lead to a decrease in sales numbers.

Source: Accenture. (2020). Impact on the Automotive Industry: Navigating the Human and Business Impact of COVID-19.

LIKELY WINNERS AND LOSERS FROM COVID-19

The pandemic is having a substantial negative impact on the automotive and mobility space. However, not all segments have been affected in the same way. Some that can benefit from the opportunities created by the crisis.

WINNERS

- **Electrification.** Although the impact of Covid-19 will vary in different countries, the overall sentiment of the segment is expected to be positive. The main drivers include local, crisis-induced financial incentives and increased environmental awareness.

- **Private micromobility.** This segment was hit by pandemic early on; however, the post-lockdown use of privately owned bikes and e-scooters rose globally. This should be further elevated as cities create more bike lanes and governments offer incentives.

- **Last-mile delivery.** This was an already growing segment, but the pandemic further accelerated its market penetration due to a massive boost in e-commerce and home deliveries. Many incumbents increasingly invest in last-mile delivery technologies, while micromobility providers are pivoting to provide delivery services.

- **Autonomous cargo transportation.** The pandemic-driven rise in e-commerce and the social distancing measures should drive more investment in AV tech for deliveries both on roads and sidewalks.

- **Digital platforms.** The Direct-to-Consumer mobility companies have been less affected by the virus, as they continued to operate and sell vehicles. Pandemic has pivoted consumers preferences from traditional dealers to pure online sales and contactless deliveries.

- **Dealership tools.** As consumer preferences revert to online to browse and shop for products, most traditional service providers are adapting quickly to match the D2C Tesla and Carvana's online platform models. Companies involved in digitalizing processes for car sales and services will benefit.

LOSERS

- **Automotive supply chain.** The supply chain is a clear loser. As auto incumbents face plummeting sales, they have to reduce costs and revise budgets. According to a CLEPA survey, 90% of the auto suppliers expect revenues to fall in 2020 and 84% plan to cut investments.

- **Shared micromobility.** At a rise of the pandemic, micromobility providers had to reduce or suspend services facing a massive drop in valuations. However, once the industry manages to control strict hygiene protocols, it will regain traction as it remains an effective solution for urban transit.

- **Ride sharing, car sharing.** Ride hailers have experienced declines of up to 60-70%, as riders have reverted to personal cars, walking or biking. Vehicle operators are implementing the hygiene standards, but with limited effect as it is difficult to deploy standardized rules to protect drivers and riders.

- **Passenger AV.** As OEMs cut R&D costs, they will prioritize electrification, software integration and safety-inducing ADAS. AV startups have yet to become profitable, and so they have been struggling the most. However, mature companies will continue to forge ahead as AVs remain in the future of transportation.

- **Public transit.** Ridership has fallen 80-90% worldwide and remains heavily impacted. A consumer survey conducted by BCG showed that 40-60% of respondents would be using public transit less or much less frequently.

- **Shuttles and robotaxis.** In the near/mid-term, these vehicles will likely suffer from less investment in AV technologies and social distancing measures. The more mature players generate revenue from pilots and limited commercial deployment, which will be restricted in the coming months.

CHANGES IN URBAN-MOBILITY PREFERENCES

As the pandemic continues, social distancing, personal safety and hygiene standards will impact mobility behavior and preferences. Many people will switch to the transport that diminishes the risk of infection, but it will depend on pre-pandemic habits.

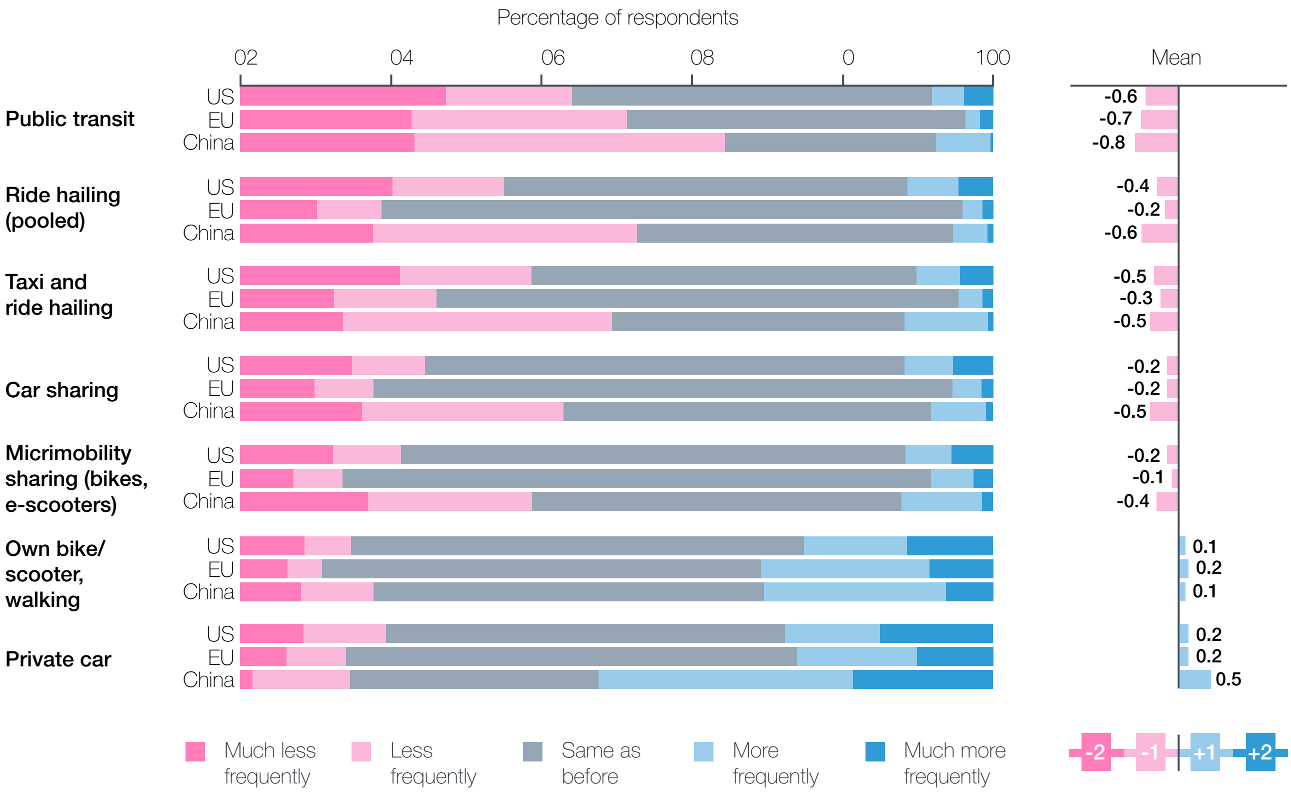
BCG has surveyed 5,000 residents of major cities in the US, China, and Western Europe, which shows that 40-60% of all respondents said they would revert from using public transit to walking, biking, or driving. It also finds that shared-mobility providers will face a decline in demand but not as sharp as public transit. These results are consistent with the IBM study, which anticipates that 46% and 29% of respondents will use public transportation and ride-sharing options less often, respectively. In China, about 60% of respondents said they were more likely to buy a car post lockdown. In contrast, a significantly smaller percentage of respondents in the US and the EU are willing to buy a car after the crisis.

The sales of bikes in the US are booming, with combined sales in bikes and related accessories growing 75% to $1B compared to April 2019. At the same time, British Cycling expects 14 million Britons to pick a bike over a car. Although, shared mobility is less appealing during the pandemic, around 67-76% of heavy users of shared mobility pre-pandemic will continue to do so using solo or pooled ride hailing, car sharing, bike and e-scooter sharing.

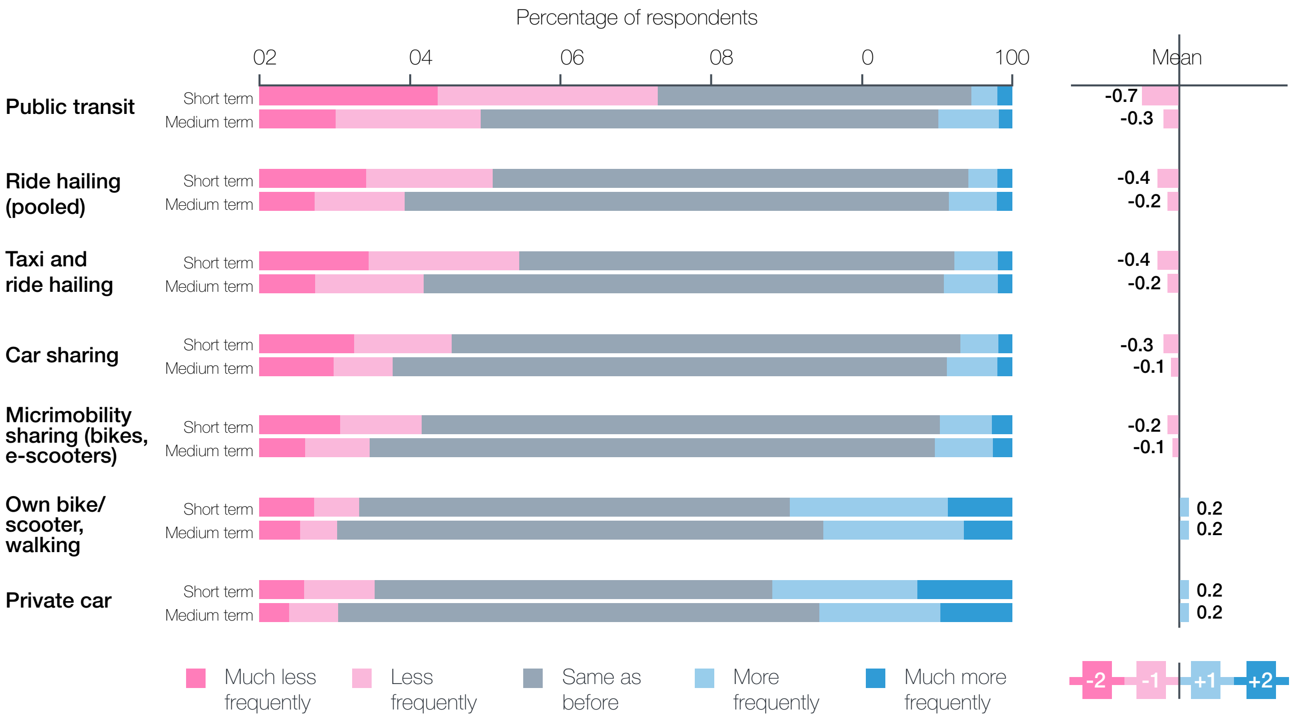
Respondents to BCG survey indicated that over time, as the crisis fades, their safety concerns will not be nearly as acute, and their use of shared mobility and public transit will increase. Micromobility solutions will also pick up more quickly if strict disinfection protocols are installed.

Source: Marc Amblard, Orsay Consulting. (2020). Future of Mobility: Likely Winners and Losers. BCG. (2020). HOW COVID-19 WILL SHAPE URBAN MOBILITY.
BCG. (2020). HOW COVID-19 WILL SHAPE URBAN MOBILITY. McKinsey. (2020).
The impact of COVID-19 on future mobility solutions. IBM. (2020). IBM Study: COVID-19 Is Significantly Altering U.S. Consumer Behavior and Plans Post-Crisis.

CHANGE IN URBAN-MOBILITY USE IMMEDIATELY POST-LOCKDOWN



CHANGE IN URBAN-MOBILITY USE OVER TIME



Source: BCG survey (5,000 urban residents in China, the EU, and the US).

ACCELERATED INDUSTRY-CONSOLIDATION MOVES

Despite the pandemic, many experts believe that the long-term vision of the next-generation mobility stays intact and is driven by the adoption of connected, autonomous, shared and electric technology. The short to medium-term projections show that both incumbents and startups of the mobility ecosystem will experience significant disruption.

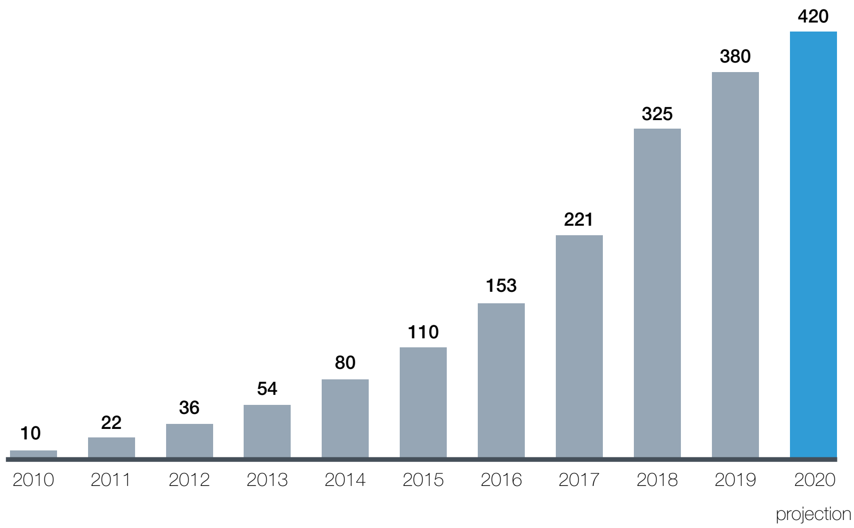
Automotive OEMs and suppliers had to preserve cash and cut their investments in the mobility technologies given the closure of production, decline in sales, and future economic uncertainties. The industry now sees increased consolidation and collaboration between the automakers and industry incumbents to fund the next generation technologies and other discretionary projects. Incumbents will also have to collaborate rather than compete moving forward as many of these technologies have high upfront costs but have yet to turn a profit.

According to McKinsey, the number of autonomous technologies, connectivity, electrification, and shared mobility (ACES) partnerships have increased by a factor of 40 over the past decade.

A number of these partnerships have created joint ventures or spinouts such as GM's Cruise Automation. A few acquisitions and investments in the AV space include Apple's acquisition of Drive.ai, Amazon's acquisition of Zoox and its investment in Aurora, Ford and Volkswagen investment in ArgoAI, Toyota's investment in Pony.ai, and Magna's investment in MayMobility. Automakers and auto suppliers have also been collaborating on developing electric vehicle and platforms including partnerships of Ford and Volkswagen, Toyota and Suzuki, Mazda and Subaru and CATL, BMW and Jaguar Land Rover. At the same time, GM is building an EV-ecosystem partnering with a network of leaders in the charging, ride sharing, infrastructure, battery and vehicle development fields, such as Uber, Nikola, LG Energy Solution, EVgo, Honda. In December 2020, LG Electronics and Magna International established a joint venture to build electric cars components. Lastly, the announced merger of Groupe PSA and Fiat Chrysler Automobiles (FCA) would create one of the world's largest car firms, Stellantis.

THE PAST DECADE HAS SEEN A FORTYFOLD INCREASE IN THE NUMBER OF ACES[1] PARTNERSHIPS, WITH A HEAVY FOCUS ON ELECTRIFICATION AND SHARED MOBILITY

ACES[1] partnerships by year, total

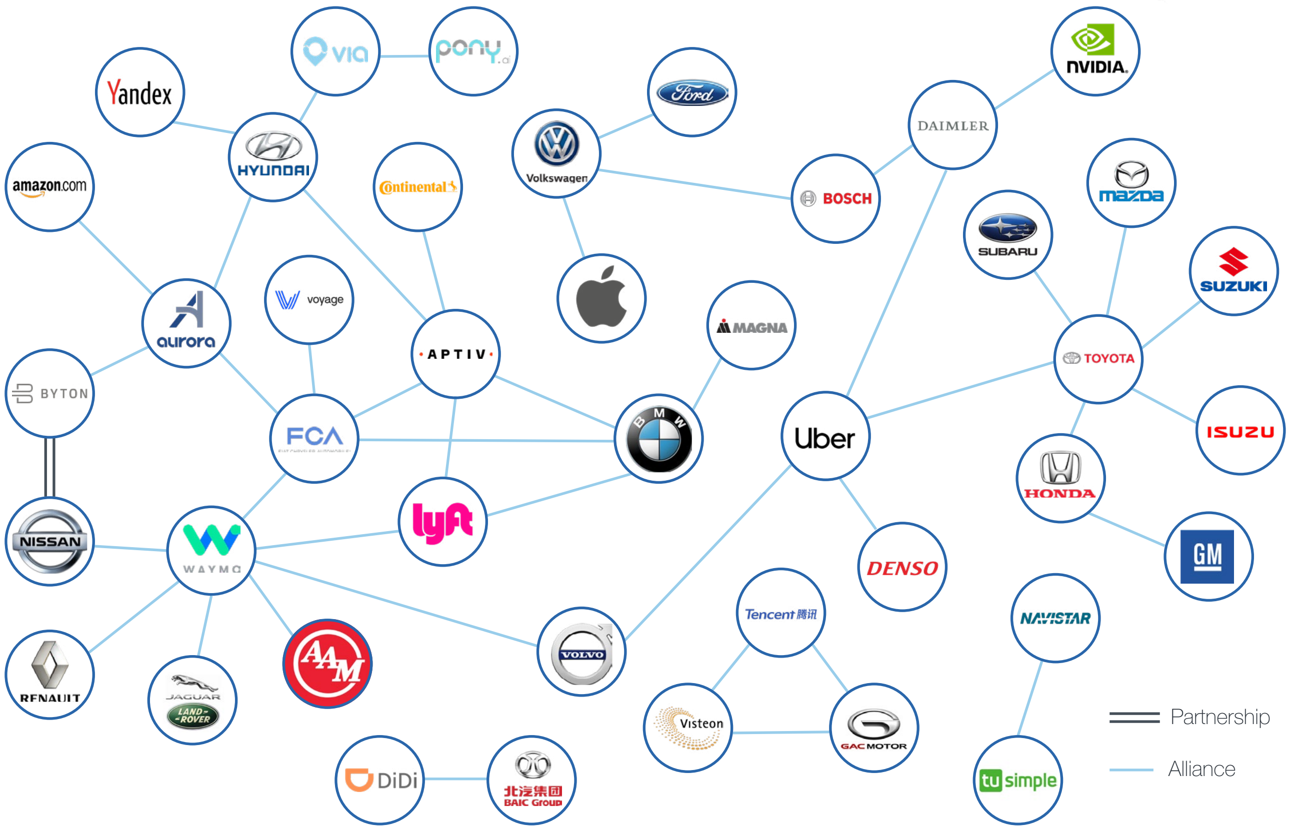


[1]Autonomous technologies, connectivity, electrification, and shared mobility.
Source: McKinsey Moves Database; press search

Source: [CBInsights. (2020). The Future of Transportation: Impact of Covid-19 on Mobility. PitchBookBehavior and Plans Post-Crisis.]

AUTO GIANTS ARE PARTNERING WITH TECH FIRMS
AND MOBILITY SERVICE PROVIDERS

Autonomous driving partnerships across automakers, Tier 1 suppliers, autonomous driving developers, and mobility service providers



Source: CBInsights

MAJOR AUTO PLAYERS REASSESS NEAR-TERM PRIORITIES

Over the short to mid-term, the current crisis will push back the development of the advanced technologies and reduction of corporate spending on long-term projects such as autonomous driving and micromobility. Developers of autonomous driving are likely to focus on more feasible applications such as advanced driver assistance and fully autonomous delivery vehicles. Some incumbents have postponed or cancelled their AV development. For example, Audi announced that it would stop integration of Level 3 automation into its A8 model, while Daimler and BMW who paused their AV-focused collaboration.

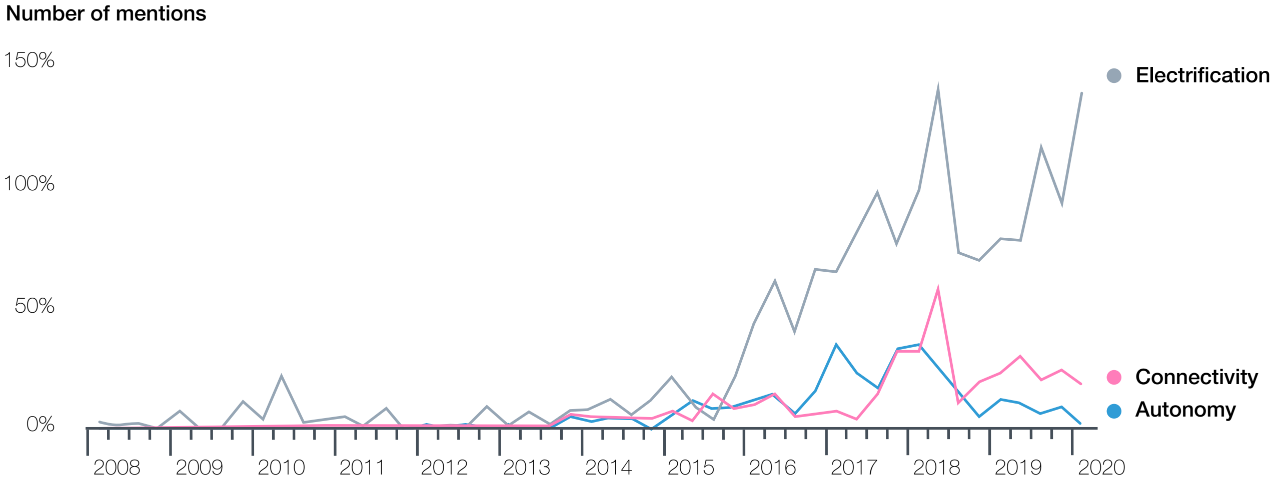
Whereas the electrification trend may slow down marginally overall, but may even accelerate in some countries due to the regulatory support, increase the environmental awareness of consumers, and falling battery costs. Although, some near-term EV model launches may be delayed, manufacturers so far are sticking to their long-term electrification commitments. AlixPartners anticipates EV R&D and capital expenditures to reach $255B globally by 2023 and 207 electric models on the market by 2022.

In the next 18 months, GM, Ford, Nissan, Volvo along with startups Polestar and Rivian are planning to have EVs in production. Tesla also continues to scale its existing portfolio while preparing to add new vehicles, including its Cybertruck.

Over the long term, however, autonomous and connected vehicles together with other solutions that support physical distancing are likely to benefit.

AUTO SUPPLIERS ARE FOCUSED ON ELECTRIFICATION

Mentions of terms related to electrification[1], autonomy[2], and connectivity[3] on Tier 1 supplier[4] for earning calls



[1]Terms include "electrification," "EV," "electric vehicle";[2]Terms include "autonomous," "AV," "self-driving," "driverless";[3]Terms include "connected," "connectivity"; [4]Auto suppliers include American Axle & Manufacturing, Autoliv, Aptiv, BorgWarner, Continental, Cummins, Faurecia, Infineon, Lear Corporation, Magna International, Visteon

TECH COMPANIES COULD SHAPE FUTURE OF TRANSPORTATION

Technology companies with relatively insulated business models are in a unique position to increase their presence in the future mobility space. In contrast, traditional automakers are forced to focus on their core business models and delay long-term projects such as AVs. According to PitchBook, no major automakers participated in the top autonomous vehicle deals of 2020.

Tech giants with cash reserves and strategic interest in transportation and mobility are enhancing their influence in the field by funding and acquiring advanced mobility-tech. Some of the active tech players in the space include Alphabet, Amazon, and Apple, among others.

Alphabet-owned Waymo raised a $3.0B external financing round led by Silver Lake, CPPIB, and Mubadala. Amazon acquired struggling robotaxi startup Zoox for $1.3B, and Intel acquired urban mobility platform Moovit for $900M.

In July 2019, a subsidiary of General Motors - Cruise Automation - received $3.4B of development capital from SoftBank and GM. In 2018, Intel acquired Mobileye for $14.9B, representing the largest corporate acquisition in the space so far.

Sources: https://www.motorauthority.com/news/1127984_audi-gives-up-on-level-3-autonomous-driver-assist-system-in-a8; https://techcrunch.com/2018/06/20/automakers-electric-autonomous-spending/; https://techcrunch.com/2020/08/05/chargepoint-raises-127m-as-electric-vehicle-adoption-grows-among-fleet-operators/ CBInsights, PitchBook

Parent company / Acquirer	Subsidiary / Target	Date	Deal size ($M)	**Lead investor**
Amazon	Zoox	June 2020	1,300	**Amazon**
Alphabet	Waymo	May 2020	3,000	**Silver Lake, CPPIB, Mubadala**
Omnitracs	VisTracks	May 2020	N/A	**Omnitracs**
Intel	Moovit	May 2020	900	**Intel**
General Motors	Cruise	July 2019	3,400	**SoftBank, GM**
Intel	Mobileye	July 2018	14,900	**Intel**

Source: CBInsights, PitchBook

ONLINE CAR SALES TO SEE BOOST IN RECOVERY

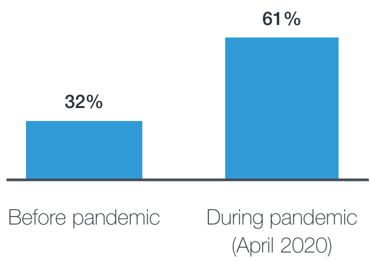
The auto commerce space is going more digital, shifting the way cars are sold, leased, and financed. The consumer survey showed that the share of consumers who are willing to buy the car online increased to 61% in April 2020 from 32% before the pandemic. Industry experts predict this pandemic to boost demand for end-to-end contactless online car buying, including touchless financing approval and home delivery.

In China, car sales have spiked as consumers returning to work avoided public transportation because of exposure concerns. Chinese automaker Geely is now offering a full contactless car buying experience, with keys delivered by drone. Beyond the current crisis, this shift to online from brick-and-mortar exacerbated by stay-at-home-orders will likely persist in the long term.

Online auto commerce startups such as Shift, Blinker and Digital Motors are well-poised to benefit from growth in this market. While incumbent automakers and dealers must adapt by investing in online marketplace applications and dealership enablement technologies to succeed. For example, the Volkswagen Group has agreed to purchase the remaining stake in diconium, to expand its digital sales solutions.

A shift towards online has aided in subscription services. Although some automakers had subscription sales available before, more of them started offering such services during Covid-19. In Q1 2020, Nissan launched the ClickMobi car subscription services in Japan; Toyota launched the Kinto subscription service across Europe; JLR launched the Pivotal vehicle subscription schemes in the UK, offering a six-month subscription, and expects subscription services to account for 10% of all car sales in the US and Europe by 2025.

SHARE OF CAR BUYERS OPEN TO BUYING CARS ONLINE (BEFORE VS. DURING COVID-PANDEMIC)



Source: CBInsights

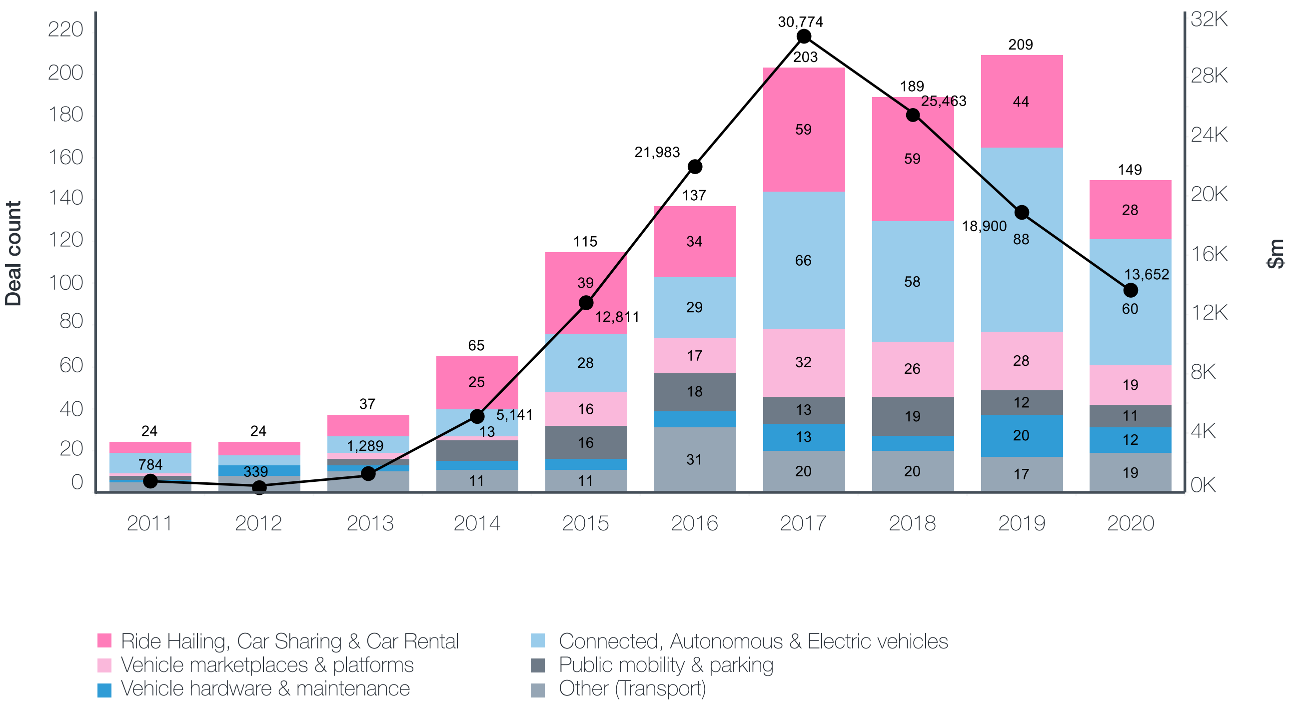
NOTABLE VC DEALS IN AUTO COMMERCE

Company	Date	Deal size ($M)	Deal size ($M)	**Lead investor**
Kavak	01-Sep-20	397.2	1,150	**Greenoaks Capital Partners, SoftBank Group, DST Global**
Auto1 Group	30-Jul-20	291.3	N/A	**Farallon Capital Management and the Baupost Group**
Guazi	06-May-20	200	N/A	**SoftBank Group, Sequoia Capital China**
Cazoo	23-Jun-20	156	1,249	**DMG ventures**
Drivezy	08-Jun-20	100	400	**SoftBank Group**
XLG	02-Jun-20	97	N/A	**N/A**
Getaround	20-Apr-20	63	N/A	**SV Frontier**

Source: PitchBook

VC DEAL ACTIVITY IN MOBILITY

HISTORICAL VIEW OF INVESTMENTS IN TRANSPORT ENTERPRISES 2011-2020



Source: CVC

Source: CBInsights, PitchBook

NOTABLE VC DEALS IN THE MOBILITY SPACE 2020

Company	Closed date	Deal size ($M)	Post-money valuation ($M)
Northvolt	29-Sep-20	600	N/A
Rappi	24-Sep-20	300	3,500
Weltmeister	09-Sep-20	1,470	N/A
Kavak	01-Sep-20	397.2	1,150
Kymeta	25-Aug-20	215	375
SpaceX	18-Aug-20	1,900	46,000
Lime	07-May-20	170	510
Waymo	12-May-20	3,000	30,750
Didi Bike	20-Apr–20	1,000	N/
Samsara	15-May-20	700	5,400
Didi Autonomous Driving	29-May-20	400	N/A
DoorDash	18-Jun-20	400	16,000
Deliveroo	17-Apr-20	575	N/A
Xingsheng Selected	22-Jun-20	400	N/A
Ninja Van	05-May-20	279	N/A
Lilium	09-Jun-20	275	1,511
GO-JEK	17-Mar-20	3,000	N/A
Grab	25-Feb-20	886	N/A
Pony.ai	25-Feb-20	462	3,000
Joby Aviation	15-Jan-20	590	2,600
Via (Automotive)	30-Mar-20	200	2,050
Hesai	03-Jan-20	173	650

Source: PitchBook

INDUSTRY UPDATE - ELECTRIC VEHICLES

EV SALES DOWN BUT PENETRATION UP

As the Covid-19 pandemic hit China and now global, total car sales between January and April 2020 dropped by about one-third from the same period in 2019, with around 9 million fewer cars sold. EV sales and the entire battery supply chain dropped following the overall auto sales crash.

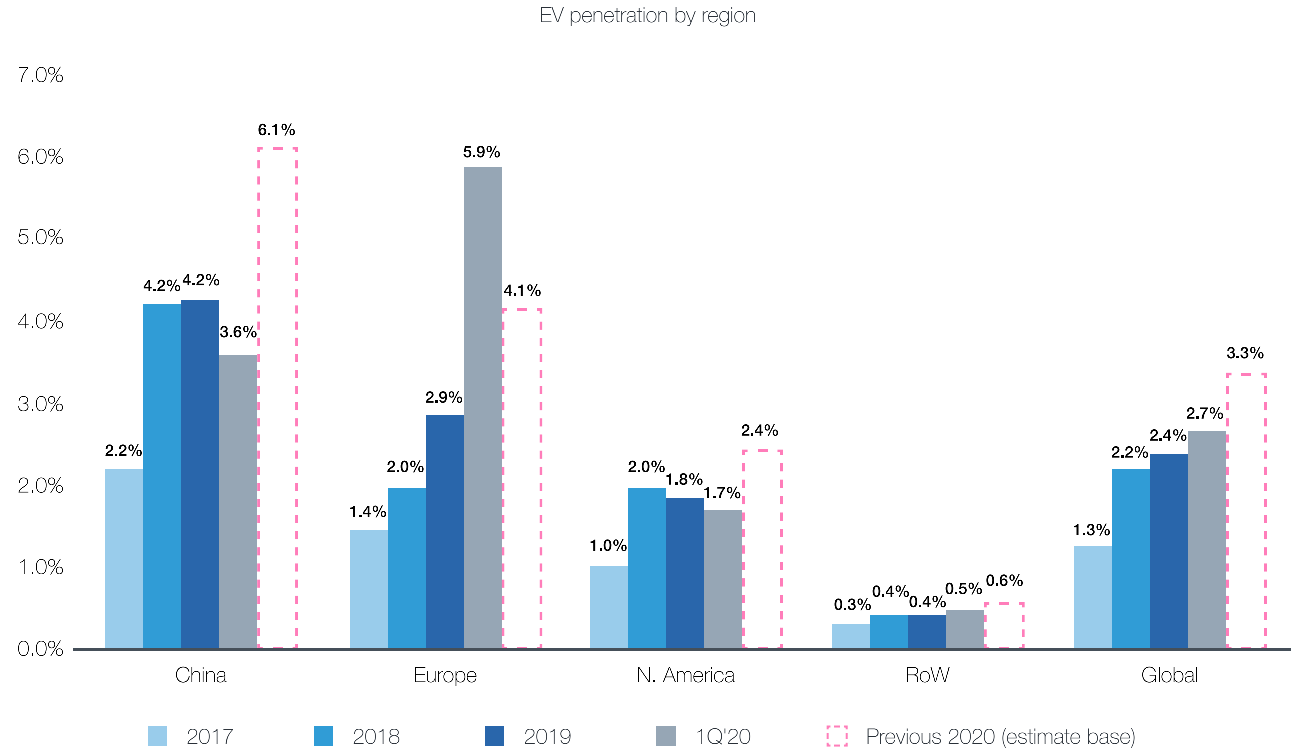
According to the Bernstein report, the total auto sales declined 26% YoY (Q1'20), while EV sales fell 13% YoY. Initially, Bernstein forecasted a 42% increase in EV sales in 2020. Among the regions, China had the most significant drop in EV sales of -50% YoY.

However, global EV penetration rates still trended up, reaching 2.7% in Q1'2020, compared to 2.4% in 2019, and 2.2% in 2018. Europe mainly powered this growth as EV penetration in China, and North America weakened in Q1'2020. Europe rate instead spiked from 2.9% in 2019 to 5.9% for Q1'2020.

Overall, Bernstein analysis shows a 10-31% fall in 2020 EV sales projections, with an 8% YoY decline in 1H 2020 (24% lower than its original estimates). In comparison, BloombergNEF forecasts global EV sales to decline by 18% in 2020, reaching 1.7 million units sold. Also, EV sales are expected to perform better than ICE vehicles, due to a backlog of orders, new models, and supportive policy in Europe and China. BNEF forecasts EVs to represent 10% of global passenger vehicle sales by 2025, rising to 28% in 2030 and 58% in 2040.

Source: Sanford C. Bernstein & Co., LLC's. (2020). Global Energy Storage & Electric Vehicles - Electric Revolution 2020 Update: Implications from Covid-19.

GLOBAL EV PENETRATION (AS PORTION OF ENTIRE CAR MARKET) IN Q1'20 CONTINUES TO INCREASE POWERED BY EUROPE (AS CHINA AND NORTH AMERICA BOTH UNDERPERFORMED)



Source: Bernstein & Co.

POST COVID-19 SCENARIOS OF EV RECOVERY - GLOBAL

Covid-19 and the following decline in the global economic outlook will harm the automotive industry and, thus, electric vehicle sales. However, the severity and scale of its impact will depend on the pace of virus containment and global recovery, government response, and consumer personal finances.

Bloomberg presents three possible scenarios of the pandemic impact on future EV sales.

- **Scenario 1 (bullish):** In this case, Bloomberg predicts global 2020 EV sales to increase by about 3%, assuming fast market recovery driven by strong policy response and growing demand for new EV models. Under this scenario, Covid-19 has no lasting impact on EV sales.

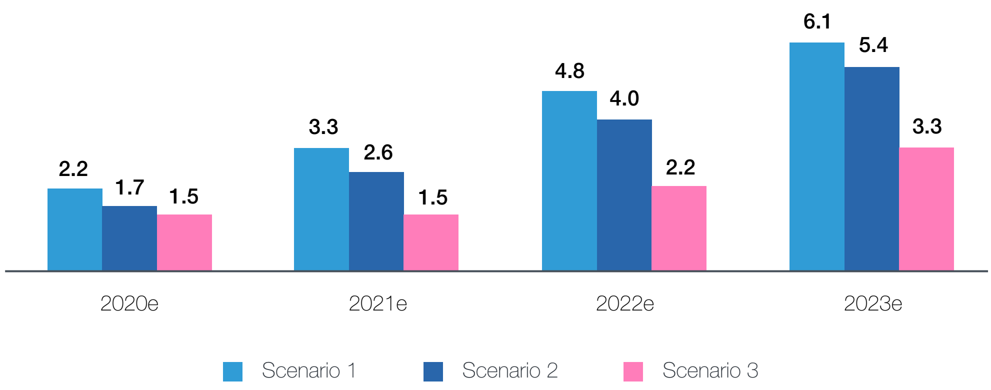
- **Scenario 2 (base case):** It predicts a decline of 18% in global 2020 EV sales compared to 2019. This scenario assumes a somewhat 'v-shaped' recovery, with EV sales recovering to 2.6 million by 2021 and 4.0 million by 2022.

- **Scenario 3 (bearish):** Under this scenario, Covid-19 has a prolonged impact, as it assumes the virus spread until 2022 and slow economic recovery. EV sales continue to fall into 2021 as automakers push back vehicle launches. The market starts growing again in 2022 and hits 3.3 million in 2023.

However, Bernstein has a slightly more optimistic view on the Covid-19 impact on 2020 EV sales. In the most bullish scenario, the company estimates a +26% YoY growth in 2020 for global EV sales, which is 10% lower to its pre-pandemic forecast for 2020. The base case scenario assumes no YoY growth in 2020 EV sales, implying a 7% YoY growth to 2H20 EV sales globally. While the most bearish case shows that with 0% YoY growth in 2H20, global EV sales would decline 3% YoY, reducing approximately 2 million units unsold.

GLOBAL EV SALES FORECAST UNDER THREE SCENARIOS

Annual EV sales (million)



Source: BloombergNEF

POST COVID-19 SCENARIOS OF EV RECOVERY - REGIONAL

Strong policy support, stimulus measures, ambitious fleet electrification targets and local automakers' commitment, drive Europe, China and South Korea through the worst in all three scenarios. In the U.S., however, a lack of federal support on the above measures means EV sales are hit harder.

Europe

With the overall European automotive market experiencing a sharp decline due to the Covid-19, EV sales bucked the trend. EV sales in the largest European car markets reached over 145,000 units in the Q1'2020, 90% YoY growth. This is primarily due to strict emission regulations in the region, which the government plans to keep intact. At most, they might defer or reduce penalty payments for the OEMs. Shared-mobility solutions and EVs might see greater uptake during the crisis and even more afterwards. The EV market might see additional tailwinds if the government approves the green-mobility incentives that are currently under discussion.

Source: Sanford C. Bernstein & Co., LLC's. (2020). Global Energy Storage & Electric Vehicles - Electric Revolution 2020 Update: Implications from Covid-19. BloombergNEF. (2020). Electric Vehicles Short-Term Outlook: Covid-19.

TRENDS IN EUROPE BY CATEGORY

	Macroeconomic developments	Consumer behavior	Regulatory developments	Technology readiness
2020-21 crisis years	• Auto factories closed • Stocks plummet	• Shift away from shared mobility and public transit to reduce risk of infection • Remote working and closed borders lead to a standstill	• Strict CO_2 emission regulation • Diesel ban in selected major cities • Potential government incentives to stimulate the purchase of new electric vehicles	• Demand drop, and shortage of capital puts pressure on start-ups • Investments in autonomous-driving technology cut back in favor of short-term cash management
2025 potential scenario for "next normal"	• Automotive industry recovered • Car sales slightly below pre-crisis levels	• Consumers use multiple modes of transport	• Major city centers are car free • Shared and electric mobility increase in urban environments	• Autonomous-driving developmente slows down and focus is on level-4 highway pilots • Shared micromobility market consolidated, and healthy market winners emerge

Source: McKinsey

China

As China was the first country hit by Covid-19, it is now furthest along in its recovery from the pandemic. Although the government reduced its EV subsidies in 2019, it has now extended the EV subsidies by another two years to support and promote EV growth. In the future, the government might increasingly place limits on private-car ownership in cities, with limited exceptions for EVs. Electric and shared-mobility solutions will dominate urban environments. Overall, McKinsey predicts quick recovery but a lower growth rate in the future.

TRENDS IN CHINA BY CATEGORY

	Macroeconomic developments	Consumer behavior	Regulatory developments	Technology readiness
2020-21 crisis years	• Temporary shutdown of auto factories, slight supply restrictions • Slowing global demand leads to a decline in exports	• Shift away from shared mobility and public transit in fear of infection	• Strict emission regulations • Extended state subsudies and tax breaks for electric vehicles	• Demand drop, and shortage of capital puts pressure on start-ups • Crisis catalyzes introduction of autonomous-delivery robots as enabler of physical distancing
2025 potential scenario for "next normal"	• Car sales recovered quickly, but growing at a slower pace because of strict regulation	• Multiple forms of transport used	• Licensed private-vehicle ownership restricted via plate lotteries • Shared and electric mobility dominates urban environments	• Players double-down on autonomous-vehicle technology • Market consolidated; healthy market winners emerge

Source: McKinsey

North America

In the United States, the EV growth and penetration depend mainly on the regulations and oil prices. Whereas Europe and China are actively implementing policies to reduce greenhouse gas (GHG) emissions, the USA, on the contrary, has weakened CAFE requirement (1.5% increase p.a.) under Trump administration. While EV sales could return to pre-Covid-19 projections in one to two years, the specific timing depends on two factors: if and when oil prices also return to pre-Covid-19 levels and the new emission regulations and EV stimulus under Biden's administration.

TRENDS IN NORTH AMERICA BY CATEGORY

	Macroeconomic developments	Consumer behavior	Regulatory developments	Technology readiness
2020-21 crisis years	• Auto factories closed, with some automotive workers losing jobs • Stocks and oil prices plummet	• Shift away from shared mobility and public transit to reduce risk of infection • Uptake in single-occupancy modes • Decrease in vehicle miles traveled due to remote working	• $2 trillion economic-stimulus package may help some OEMs and mobility players • Corporate Average Fuel Economy regulations may be weakened	• Autonomous-vehicle testing temporarily suspended • Demand drop, and shortage of capital puts pressure on start-ups
2025 potential scenario for "next normal"	• Auto industry recovered and plants reopened • Car sales back to precrisis levels	• Road-based mobility dominates; adoption of electric vehicles might level off	• Policies to reduce private-car ownership are dropped • Weakened emossion regulation slows doen e-mobility transition	• Players double-down on investment in autonomous vehicles • Market consolidated; healthy market winners emerge

Source: McKinsey

Source: McKinsey. (2020). McKinsey Electric Vehicle Index: Europe cushions a global plunge in EV sales.
McKinsey. (2020). The impact of COVID-19 on future mobility solutions.

GOVERNMENT RESPONSE TO COVID-19 IN EV FIELD

Despite the negative impact of Covid-19 on the automotive market overall and particularly electric vehicles, it shifted the focus of consumers, governments and regulators worldwide towards everything "clean and green". For instance, China recently extended the New Energy Vehicle (NEV) mandate, France and Germany announced an increase to its EV stimulus, and Europe is strengthening its CO2 emissions standards and monetary incentives to encourage EV adoption post-pandemic.

In China, to offset the Covid-19 drag on auto and EV sales, the government has extended the EV subsidies through 2022 that were about to expire, as well as prolonged the purchase-tax exemptions of NEVs, increased quota and relaxed purchase constraints on the passenger vehicle purchase. China has also postponed the implementation of the China 6 emissions standards until 2021 to support ICE OEMs. Overall, China is planning a gradual transition from direct to more indirect forms of subsidies and incentives (including increasing support for charging infrastructure and other support services). The EV subsidy level in China will be cut by 10% YoY in 2020, 20% YoY in 2021 and 30% YoY in 2022.

2020 is the target year of the European Union's CO2 emissions standards, limiting average CO2 emissions to 95g/km of new car sales. Although this standard may be put on hold for six to twelve months, the long-term policies remain intact and positive for EVs. Germany increased electric car purchase subsidies in February, and the impacts of the system introduced in Italy in 2019 to encourage electric cars started to affect the market. Many European cities are rapidly restructuring the use of urban space and creating more walking and cycling lanes. All of the above contributed to a rising EV penetration in the EU in 2020.

In the USA, the weakening of the CAFE/emissions standards could further decelerate the EV adoption. In March 2020, the government revised fuel-economy standards and finalized the Safer Affordable Fuel-Efficient (SAFE) vehicles final rule, reducing a 2026 target of 54 mpg to of 40 mpg. However, newly-elected president Joe Biden has promised $400 billion in public investment in clean energy, incentives for the car buyers, accelerated battery technologies research and 500,000 new EV charging stations by the end of 2030. New measures may significantly increase EV penetration in the USA.

MICROMOBILITY PLAYERS ADAPT & INNOVATE

The global lockdown is profoundly affecting service provider valuations, workers employed in the sector, and the speed of industry consolidation.

In the short-term, the impact of Covid-19 on micromobility seemed to be negative, as lockdown and stay-at-home orders prevented consumers from traveling. The micromobility service-providers faced a greater challenge as consumers shifted away from the shared mobility platforms. According to Apple data, there was a 60-70% drop in the number of passenger kilometers traveled by private and shared micromobility vehicles in Europe and the United States.

However, the implementation of new citywide policies on micromobility should mediate the virus's negative impact, stimulating a shift from car ownership towards private or shared vehicles. For instance, European cities converting dozens of kilometers of car lanes into cycle paths (e.g. Milan, Paris, Brussels).

In the mid- and long-term, the sector will recover as consumers are more willing to regularly use micromobility for longer trips. In China, bike share operators Hellobike, Mobike, and Didi Chuxing reported ridership increases of over 150% as lockdown restrictions were lifted. McKinsey consumer survey shows a 9% increase for the use of private micromobility on a regular basis and a 12% increase for shared micromobility compared to pre-pandemic levels.

It also predicts a full recovery and a boost of 5-10% in the number of passenger-kilometers traveled by 2030. This change in consumer pattern could also stimulate private ownership in the micromobility market (70% of McKinsey respondents said they would consider a purchase of e-scooter for the commute).

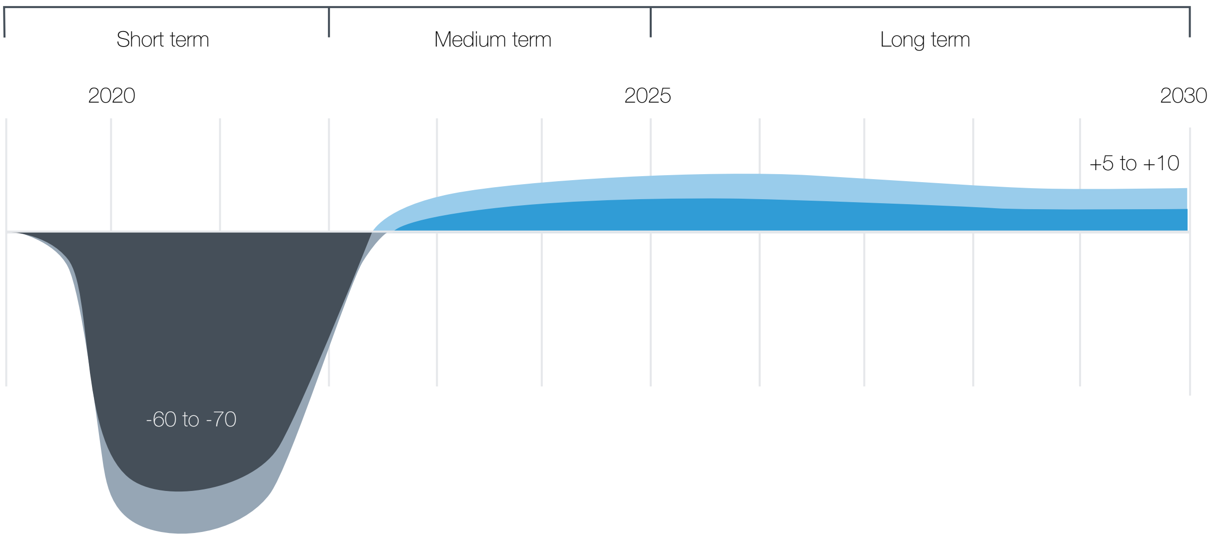
In the near term, significant space consolidation of micromobility providers seems inevitable, as synergies could improve the run rate for many operators, who were yet to become profitable even before the pandemic. For example, In May, Uber announced it was leading a $170M Series E round in Lime.

To stay afloat the D2C micromobility companies invest more in innovation, extending the features of the bikes' and scooters' features, making them more comfortable, easier to ride, connected, and safer. A few examples include FAZUA and Cowboy that are implementing new connectivity features into their bikes. While Wheels and TIER Mobility partnered with NanoSeptic and Protexus, respectively, to offer anti-bacterial handlebars.

Other sharing operators are exploring new revenue models, including subscriptions, to create long-term engagement with their customers and enhance stickiness.

THE MICROMOBILITY SECTOR IS EXPECTED TO MAKE A STRONG POSTPANDEMIC RECOVERY

Impact of COVID-19 crisis on global shared and private micromobility



- Lockdowns result in fewer commuting and leisure activities, limiting travel
- Hygiene laws result in short-term shutdowns
- Using shared transportation is perceived health risk

- Micromobility (with fewer points of contact and ease of maintaining physical distancing) is considered less risky than other shared modes of transportation
- Lockdown causes changes in customer behavior and mobility patterns (more people try private micromobility modes for first time and take longer trips because of a shift in use cases

- Because of a higher awareness of hygiene, micromobility is preferred over public transportation
- Quiet and green transportation modes that avoud congestion are preferred
- Cities deincentivize and regulate private-car travel while investing in bicycle infrastructure as an alternative

Source: McKinsey

Source: International Energy Agency. (2020). Global EV Outlook 2020. McKinsey. (2020). The future of micro-mobility: Ridership and revenue after a crisis. Intertraffic. (2020). HOW COVID-19 PUSHES MOBILITY INNOVA-TIONS. Cate Lawrence. (2020). Innovation is helping micromobility companies navigate COVID-19.

VC ACTIVITY IN THE EV SPACE

TAKE AWAYS

Although in 2019 VC funding of EV startups was weak, driven mainly by investment pullback from Chinese EV companies, it picked up substantially at the end of the year, rising 31% over H2 2018. This upward trend continued in Q1 2020. Some of the notable deals include Arrival's $111.4M Series A, TELD New Energy's $193M Series A round and Infraprime Logistics Technologies' $100M early-stage VC round.

Although in Q2 2020, EV funding was down 34.3% from Q1 2020, reaching $384M, EV startups raised a large $3.9B in Q3 2020, up 279.8% QoQ and 67.0% YoY. The growth of capital invested is driven by investor enthusiasm for the electrification of transportation. Standout deals in Q2 / Q3 2020 include QuantumScape's $200M Series F, led by Volkswagen, Breakthrough Energy Ventures, and Capricorn Investment Group, ChargePoint additional $100M to its $600M Series H, and Nanotech Energy's $28M Series C, valuing the company at $228M, Weltmeister's $1.5B Series D, Northvolt's $600M early-stage VC round, and Xpeng's $500M Series C1.

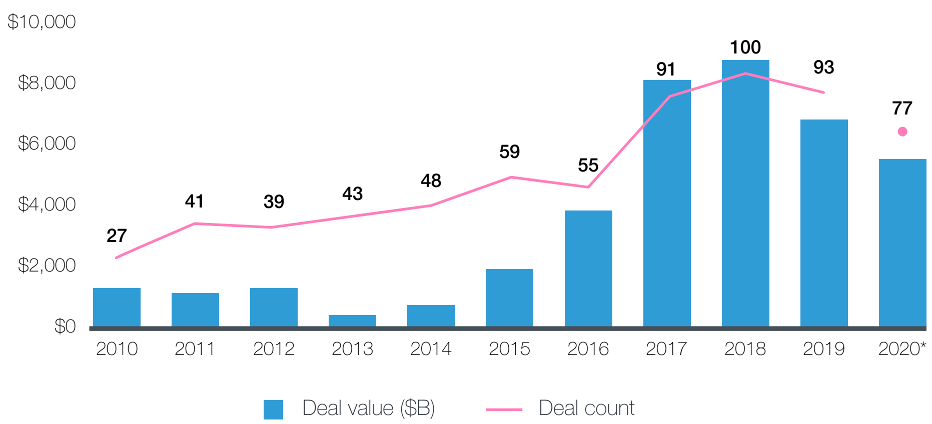
Additionally, internal R&D and corporate investment in electrification increased in 2020 and drove much of the capital invested in the EV space. In 2020, GM and Hyundai Motor Group announced its plans to invest $20B and $87B, respectively, in electric vehicles and related technology through 2025.

Despite, the pullback of investments in micromobility in 2019, VC activity increased in 2020 as physical distancing has highlighted the need for micromobility services. In Q2 2020, venture investment in micromobility companies totaled $1.4B, up from $354M in Q2 2019 and $285M in Q1 2020. However, in the Q3 2020 VC investment in micromobility startups was down 67.8% QoQ and 82.2% YoY, the deal count was up 11.1% QoQ and 17.6% YoY, with most deals closing at the early stage.

Notable deals in the Q2 / Q3 2020 include Didi Bike's $1.0B round led by Legend Capital and SoftBank China, Lime's $170M emergency financing round led by Uber (at a valuation haircut of nearly 80%), TIER Mobility's $122M Series B led by Goodwater Capital and Mubadala Ventures, Vanmoof's $40.3M Series B, and Neuron Mobility's $30.5M Series A.

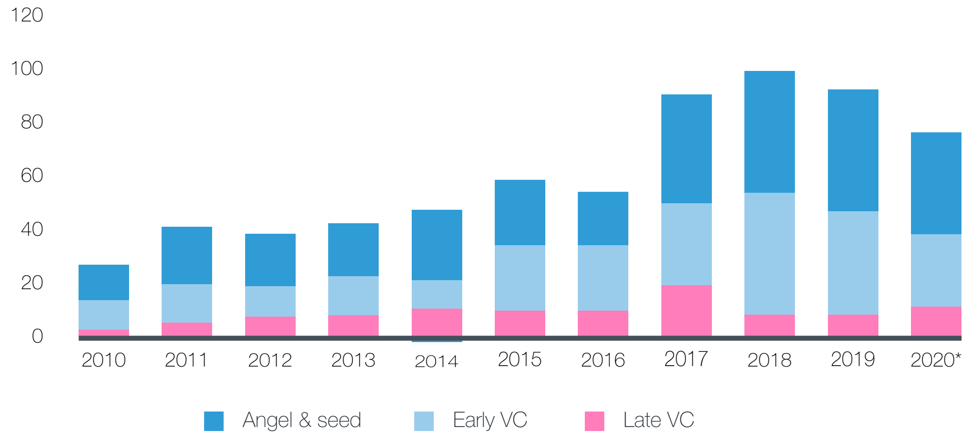
The special purpose acquisition firms (SPACs), or "blank check" companies, have been behind some of the most high-profile public listings of the last 12 months, including EV startups Canoo, Chargepoint, Faraday Future, Fisker Inc, Hyliion, Lordstown Motors, Nikola Motors, QuantumScape, Romeo Power, and XL Fleet. SPACs in EV space accounted for more than $6 billion invested in 2020.

ELECTRICITY VEHICLES VC DEAL ACTIVITY



*Source: PitchBook - Geography: Global - *As of September 30, 2020*

ELECTRICITY VEHICLES VC DEALS (#) BY STAGE



*Source: PitchBook - Geography: Global - *As of September 30, 2020*

TRANSACTIONS IN THE EV SPACE

ELECTRIC VEHICLES VC DEALS

Company	Date	Subsegment	Deal size ($M)	Post-money valuation ($M)	Deal stage
Sono Motors	16-Dec-20	Passenger cars	54	N/A	Later Stage VC
Proterra	15-Oct-20	Electric bus & shuttle	200	N/A	Later Stage VC
Arrival	14-Oct-20	Electric bus & shuttle	118	3,500	Later Stage VC
Zero Motorcycles	21-Oct-20	Electric motorcycles	10.4	N/A	Later Stage VC
Weltmeiste	09-Sep-20	Passenger cars	1,470	N/A	Series D
Canoo	31-Aug-20	Passenger cars / Electric bus & shuttle	110	N/A	Corporate
Xpeng	03-Aug-20	Passenger cars	300	N/A	Series C2
Hozon	20-Jul-20	Passenger cars	N/A	N/A	Series C
Rivian Automotive	11-Jul-20	Passenger cars	2,500	N/A	PE Growth
Karma Automotive	08-Jul-20	Passenger cars	100	N/A	Later Stage VC
Zero Motorcycles	11-May-20	Electric motorcycles	8.3	N/A	Later Stage VC
OLA Electric	12-Mar-20	Passenger cars	1	N/A	Series B
Arrival	29-Jan-20	Electric bus & shuttle	N/A	N/A	Early Stage VC
Sono Motors	21-Jan-20	Passenger cars	59.0	N/A	Early Stage VC
HNF Nicolai	09-Jan-20	Electric Motorcycles	N/A	N/A	Later Stage VC
Byton	27-Dec-19	Passenger cars	N/A	N/A	Series C1
Weltmeister	19-Nov-19	Passenger cars	100	N/A	Series D
Leapmotor	03-Aug-19	Passenger cars	52.3	1,033.7	Series A1
Gugu Energy	07-Jul-19	Electric motorcycles	9	N/A	Series A
Bordrin	03-Jun-19	Passenger cars	363.8	N/A	Early Stage VC
AIWAYS	29-May-19	AIWAYS	146.1	N/A	Early Stage VC
Faraday Future	30-Apr-19	Passenger cars	1,250	N/A	Series B
DEARCC	14-Apr-19	Passenger cars	297.8	N/A	Early Stage VC

Source: PitchBook

Company	Date	Subsegment	Deal size ($M)	Post-money valuation ($M)	Deal stage
WiTricity	29-Oct-20	Charging Infrastructure	34	N/A	Later Stage VC
Northvolt	29-Sep-20	Charging Infrastructure	600	N/A	Early Stage VC
Star Charge	24-Sep-20	Charging Infrastructure	125.1	1,200	Series A
ChargePoint	05-Aug-20	Charging Infrastructure	127	N/A	Series H
Swiftmile	15-Jul-20	Charging Infrastructure	11.07	N/A	Series A
QuantumScape	16-Jun-20	Battery Technology	200	2300	Series F
Nanotech Energy	18-May-20	Battery Technology	27.5	227.5	Series C
Fermata Energy	12-May-20	Vehicle to grid	4.2	N/A	Later Stage VC
AVID Technology (Electrical Equipment)	01-May-20	EV Powertrain	N/A	N/A	Later Stage VC
ZAF Energy Systems	30-Apr-20	Battery Technology	22	N/A	Series A
FreeWire Technologies	23-Apr-20	Charging Infrastructure	25	46.1	Series B
Twaice	25-Mar-20	Charging Infrastructure	12.15	49.96	Series A
TELD New Energy	05-Mar-20	Charging Infrastructure	192.9	1,115	Series A
Lightning Systems	01-Mar-20	EV Powertrain	47	N/A	Later Stage VC
Ample	24-Feb-20	Charging Infrastructure	24.5	184.5	Series B
Driivz	19-Feb-20	Charging Infrastructure	11	N/A	Series C
Infraprime Logistics Technologies	30-Jan-20	Commercial vehicle fleet	100	N/A	Early Stage VC
Infinitum Electric	05-Dec-19	MotorTech	12.5	45	Series B
Sila Nanotechnologies	25-Nov-19	Battery Technology	218.8	1,038.8	Series E
Group 14 Technologies	21-Nov-19	Electric Vehicles	18.1	48.1	Series A
EV Connect	22-Oct-19	Charging Management	12	77	Series B
Volta Charging	10-Sep-19	Charging Infrastructure	20	140	Series C2
Yasa	10-Sep-19	MotorTech	22.3	109.8	Later Stage VC
RomeoPower	05-Aug-19	Battery Technology	4	N/A	Early Stage VC
GreenFlux	09-Apr-19	Charging Management	N/A	N/A	Series B
Amprius	22-Mar-19	Battery Technology	35	487	Series E1
DEPsys	15-Mar-19	Charging Management	13.1	32.4	Series B
Ubitricity	05-Mar-19	Charging Infrastructure	22.7	60.9	Series C
Protean Electric	16-Jul-19	MotorTech	N/A	N/A	Accelerator/ Incubator
The Mobility House	27-Jun-19	Charging Infrastructure	N/A	N/A	Later Stage VC

Source: PitchBook

Company	Date	Subsegment	Deal size ($M)	Post-money valuation ($M)	Deal stage
Voi.	01-Dec-20	E-Bikes and E-Scooter Sharing	160	N/A	Series C
Neuron Mobility	29-Sep-20	Network Operators	30.5	N/A	Series A
VanMoof	16-Sep-20	E-Bikes and E-Scooter Sharing	40.3	N/A	Series B
Movo	28-Aug-20	Network Operators	15.4	N/A	Corporate
Marti	25-Jul-20	Network Operators	27.4	N/A	Early Stage VC
Cowboy	23-Jul-20	Network Operators	26	N/A	Series B2
Voi.	16-Jul-20	E-Bikes and E-Scooter Sharing	29.6	266.2	Early Stage VC
Superpedestrian	17-Jun-20	E-Bikes Supplier	55.1	N/A	Series B2
TIER Mobility	10-Jun-20	E-Bikes and E-Scooter Sharing	122	300	Series B
Lime	05-Jun-20	E-Bikes and E-Scooter Sharing	170	510	Later Stage VC
Tembici	03-Jun-20	E-Bikes Supplier	47	N/A	Series B
Beam (Other Transportation)	31-May-20	Network Operators	26	N/A	Series A
VanMoof	12-May-20	E-Bikes Supplier	13.61	N/A	Later Stage VC
Didi Bike	17-Apr-20	E-Bikes and E-Scooter Sharing	150	N/A	Early Stage VC
Zhang Fei Chong Dian	04-Apr-20	Network Operators	9.9	N/A	Early Stage VC
Revel	13-Mar-20	E-Bikes and E-Scooter Sharing	6	43.4	Seed Round
Ride Report	12-Mar-20	Management & Analytics Platforms	10	N/A	Series A
Bird Rides	27-Jan-20	E-Bikes and E-Scooter Sharing	75	2,850	Series D2
Rad Power Bikes	27-Jan-20	Vehicle Suppliers	25	N/A	Later Stage VC
Cityscoot	26-Dec-19	E-Bikes and E-Scooter Sharing	26.2	130.7	Series C
Reby	13-Dec-19	Network Operators	3	N/A	Seed Round
Neuron Mobility	09-Dec-19	Network Operators	18.5	N/A	Series A
Blue Duck (Scooter)	07-Nov-19	Network Operators	30	200	Series A
Skip (Automotive)	18-Sep-19	E-Bikes and E-Scooter Sharing	36.5	136.5	Early Stage VC
Unagi	06-Sep-19	Vehicle Suppliers	4	14	Seed Round
Hellobike	15-Jul-19	E-Bikes and E-Scooter Sharing	400	N/A	Later Stage VC
WIND Mobility	08-Jul-19	E-Bikes and E-Scooter Sharing	50	N/A	Series A
dott (scooters)	01-Jul-19	E-Bikes and E-Scooter Sharing	33.9	N/A	Series A
Pony	22-May-19	Network Operators	2.5	N/A	Early Stage VC
Movo (Automotive)	10-Apr-19	Network Operators	22.6	N/A	Series A

Source: PitchBook

URBAN AIR MOBILITY VC DEALS

Company	Date	Subsegment	Deal size ($M)	Post-money valuation ($M)	Deal stage
HopFlyt	10-Jun-20	Air Taxis	0.04	N/A	Seed Round
Lilium	09-Jun-20	Air Taxis	275	1,000	Series C
Vita Inclinata Technologies	01-Jun-20	Air Taxis	20	N/A	Series B
Skyryse	27-May-20	Air Taxis	2.5	N/A	Early Stage VC
Volocopter	21-Feb-20	Air Taxis	95.3	N/A	Series C
Joby Aviation	15-Jan-20	Air Taxis	590	2,600	Series C
Electric Visionary Aircrafts	04-Dec-19	Air Taxis	0.2	N/A	Accelerator/ Incubator
AeroMobil	18-Jul-19	Air Taxis	N/A	N/A	Series A
Daedalean	11-Jul-19	Air Taxis	11.9	N/A	Early Stage VC
Zunum Aero	10-Jul-19	Air Taxis	50	200	Series B

Source: PitchBook

NOTABLE VC EXISTS

Company	Financing Date	Subsegment	Exit Value ($M)	Acquirer/ Index	Deal stage
Lion Electric	30-Nov-20 (announced)	Electric bus & shuttle	1,510	Northern Genesis Acquisition	Reverse Merger
Arrival	18-Nov-20 (announced)	Electric bus & shuttle	260	CIIG Merger Corp.	Reverse Merger
Fisker Inc.	30-Oct-20	Passenger cars	N/A	Spartan Energy Acquisition SPAC of Apollo Global Management	Reverse Merger
Lordstown Motors	26-Oct-20	Trucking	N/A	DiamondPeak Holdings	Reverse Merger
Romeo Power	05-Oct-20	Charging Infrastructure	N/A	RMG Acquisition	Reverse Merger
Hyliion Inc.	01-Oct-20	Trucking	1,100	Tortoise Acquisition Corp.	Reverse Merger

Source: PitchBook

Company	Financing Date	Subsegment	Exit Value ($M)	Acquirer/ Index	Deal stage
ChargePoint	24-Sep-20	Charging Infrastructure	2,400	Switchback Energy Acquisition Corporation	Reverse Merger
XL Fleet	18-Sep-20	Trucking	N/A	Pivotal Investment Corporation II	Reverse Merger
QuantumScape	03-Sep-20	Charging Infrastructure	N/A	Kensington Capital Acquisition Corp.	Reverse Merger
Xpeng	27-Aug-20	Passenger cars	9,300	NYSE	PIPE
Canoo	18-Aug-20	Passenger cars / Electric bus & shuttle	N/A	Hennessy Capital Acquisition Corp IV	Reverse Merger
Lixiang Automotive Inc.	30-Jul-20	Passenger cars	380	Nasdaq	PIPE
Nikola Motor	03-Jun-20	Trucking	N/A	VectoIQ	Reverse Merger
Nio (NYS: NIO)	29-Apr-20	Passenger cars	989.3	NYSE	PIPE
Circ	27-Jan-20	Network operator	N/A	Bird Rides	Merger/ Acquisition
Tesla (NAS: TSLA)	14-Feb-20	Passenger cars	2	Nasdaq (2PO)	Public Investment 2nd Offering
POD Point	13-Feb-20	Charging Infrastructure	N/A	EDF	Merger/ Acquisition
Pushme	13-Feb-20	Battery Technology	N/A	TIER Mobility	Merger/ Acquisition
Chargepoint Services	17-Jun-19	Charging Infrastructure	N/A	ENGIE	Merger/ Acquisition
Scoot	03-Jun-20	Network operator	N/A	Bird Rides	Merger/ Acquisition
Vantage Power	12-Apr-19	MotorTech	22.3	Allison Transmission	Merger/ Acquisition
Alta Motors	27-Feb-19	Motorcycles	N/A	BRP	Merger/ Acquisition
Greenlots	02-Feb-19	Charging Infrastructure	N/A	Shell	Merger/ Acquisition

Source: PitchBook

INDUSTRY UPDATE - AUTONOMOUS VEHICLES

NEAR-TERM SHIFT AWAY FROM FULLY AUTONOMOUS VEHICLES, BUT LONG-TERM VIEW IS BULLISH

Given the negative impact of the current crisis on the automotive industry, OEMs are facing financial pressure. They have been forced to focus on their core businesses, leading to reduced funding in long-term innovative projects such as autonomous driving. This could delay the development and deployment of autonomous technology (including AVs) in the near term. For instance, companies like Waymo, Cruise, Argo.AI, and Pony.AI were forced to suspend testing due to corona virus concerns. However, big players that have a long-term view, such as Toyota and GM, are expected to continue to invest in ambitious, multi-annual projects in-house or with partners

The Global Semiconductor Alliance (GSA) KPMG survey of 22 top-level executives at global semiconductor companies found that 27% of respondents expect to have a negative impact from Covid-19 on investment, growth and adoption of AVs. While 9% think the virus would positively affect AVs and 59% believe it will have a neutral impact. Overall, the industry leaders expect to have a less negative effect of the virus on 5G, artificial intelligence and IoT applications than AVs.

The GSA and KPMG survey also found that nearly two-thirds of the respondents said that they faced supply-chain shortages during the pandemic. A total of 27% said that supply issues had impacted chip sales, while 36% said they experienced shortages but without a significant impact on revenue.

Also, according to an IHS market survey, 65% of 46 companies in the auto integrated circuit (IC) supply chain expect delays in new technology deployment or product development. In particular, industry experts predict a significant delay in development and deployment of Level 4/5 automation, while market incumbents and startups partially shift towards L2+/ ADAS solutions.

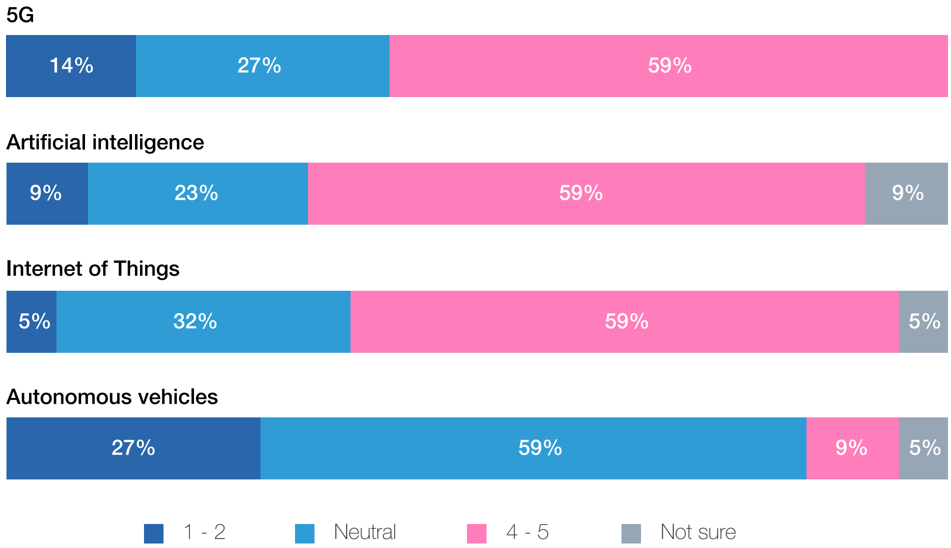
As the rest of the mobility tech space, industry leaders expect AV to experience significant consolidation and cooperation among peers allowing strong players to emerge. This will also contribute to increased adoption of AVs in goods transportation.

Although investments from automakers are expected to decline, financial investors and tech companies with large cash reserves and strategic interests in transportation invest heavily in the space and are likely to increase their stakes in the space. However, early-stage AV startups will face more difficulties in capital raise, as investors focus on mature players.

Over the long term, however, autonomous vehicles could benefit as they support social distancing. Customer demand for AVs is expected to increase, making them more attractive to investors. All in all, industry experts still have a bullish sentiment towards the long-term development and deployment of autonomous vehicles.

WHAT IMPACT WILL COVID-19 HAVE ON THE INVESTMENT, GROWTH, AND ADOPTION OF THE FOLLOWING APPLICATION END MARKETS?

(Please rate on a 1 to 5 scale, with 1 = significantly negative impact and 5 = significantly positive impact.)



Source: KPMG & GSA

Source: Matt Hamblen, FierceElectronics. (2020). COVID-19 cuts into self-driving chips, on top of crushing car sales. KPMG & GSA. (2020). The impact of COVID-19 on the semiconductor industry.

COVID-19 MAY DECIMATE THE AV FIELD BUT ALSO BROADEN & ACCELERATE THE AVS' USE CASE

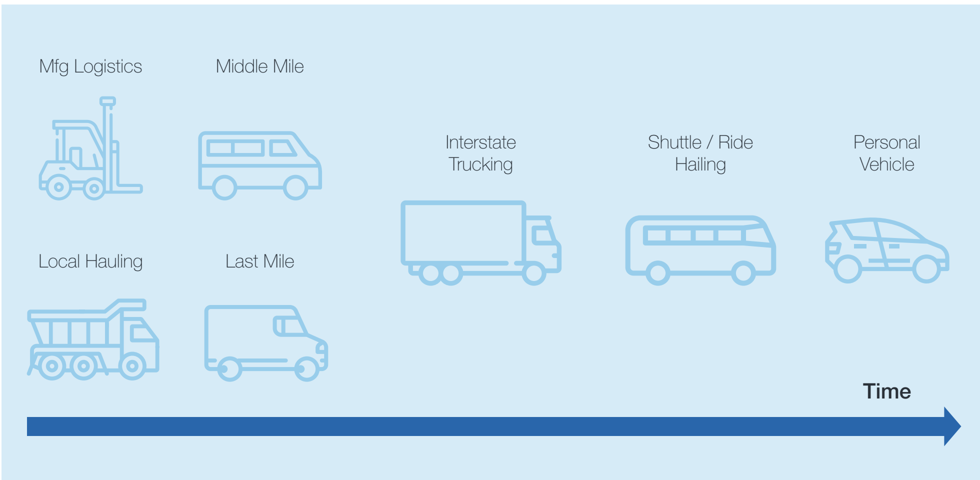
Social distancing measures and stay-at-home orders drove demand for the autonomous delivery, strengthening the use case for robot drivers and shuttered labs and factories. For instance, from March 2020, Starship Technologies and Postmates have been offering autonomous at-home food delivery services in some markets. Starship, which was previously tested on college campuses, has pivoted to provide at-home delivery.

AVs have been largely used for the delivery of medical supplies. For example, healthcare provider Mayo Clinic and Florida's Jacksonville Transportation Authority used AVs to move tests from a drive-through location to a lab, with no human supervision on isolated routes. Nuro, a key leader in the space, has partnered with CVS to perform autonomous prescription deliveries in Houston, Texas in the US. Zipline has been using its drone technology to deliver of personal protective equipment and essential medical supplies to US hospitals.

The pandemic provides an opportunity for the city and municipal governments to encourage people to change the way they travel, including making greater use of AVs, whether buses or otherwise. There are also further opportunities to expand the use of AVs for freight and in closed environments such as industrial, port and mining areas.

Thus, experts anticipate that there will be faster adoption of the commercialized autonomous vehicle applications in the medium term, with initial use cases focused on limited locations, such as closed campuses and communities, or areas reserved for logistical activities. Whereas, mass roll outs of AVs are less likely in the near or medium term. The technology is still undertaking a fine tuning process, and the process of mapping new locations is capital intensive and time-consuming.

USE CASE PRIORITIES RESHUFFLED



Source: [Bloomberg Hyperdrive. (2020). The State of the Self-Driving Car Race 2020.](#) [Marc Amblard, Orsay Consulting. (2020).](#) [The Crisis Reshuffles the Deck in the AV Space.](#) [KPMG. (2020). 2020 Autonomous Vehicles Readiness Index.](#)

9 OF 10 CARS MAY OFFER ADVANCED SAFETY SYSTEMS BY 2030

Even before the current crisis, AV developers were quietly changing market expectations and extending the timeline for mass Level 4/5 roll outs. The pandemic has hastened industry consensus on the adoption timeline for autonomy and that widespread Level 4/5 autonomy will be a long-term (10+ years) trend.

To date, the front-runner is a Google spin off - Waymo - the only platform taking passengers in fully driverless vehicles. Other OEMs are pushing promised timelines. Ford moved the launch of its autonomous service from 2021 to 2022, Daimler backed away from its statement of having 10,000 sentient taxis on the streets by 2021. At the same time, Tesla has not fulfilled its promise of operating one million robotaxis on the road by 2020. While AV startups and tech companies present robotaxis, Amazon-owned Zoox has unveiled its electric self-driving taxi in December 2020.

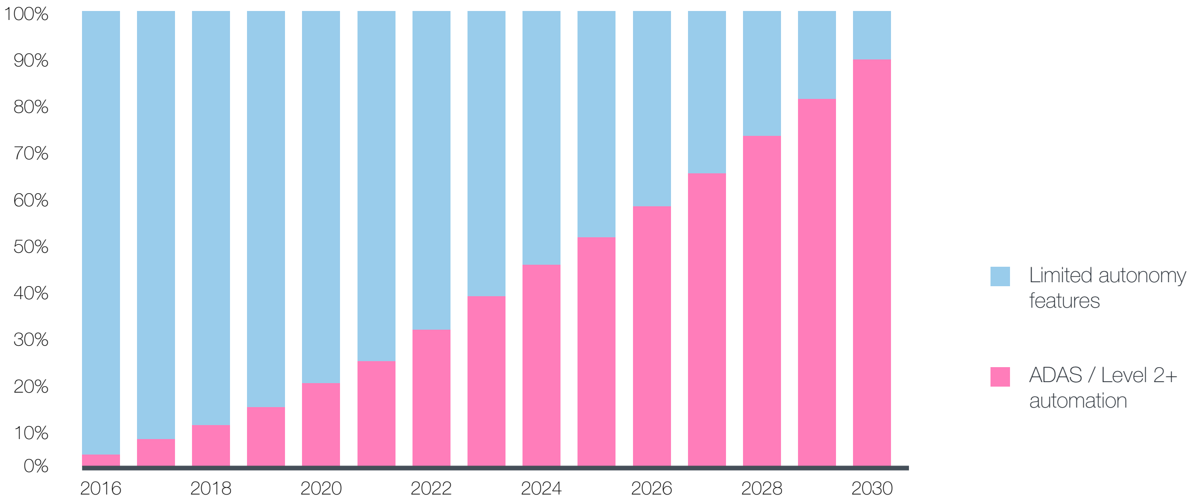
Despite the extended timeline for the Level 4/5 automation, many companies working on AV offer Advanced Driver Assistance Systems (ADAS) in their vehicles. ADAS includes features like lane-keeping assist and automatic emergency braking that are sometimes referred to as 'Level 2+ automation'. Adoption of these features is growing fast, mainly due to consumer demand for safer vehicles. Automakers are happy to provide these features because they increase the average selling prices of their vehicles. At the same time, vehicle safety policies are also pushing for adoption of ADAS as more countries seek to reduce the number of deaths and injuries that result from road accidents

According to research by LexisNexis Risk Solutions, ADAS vehicles showed a 27% reduction in bodily injury claim frequency and a 19% reduction in property damage frequency.

BloombergNEF expects 90% of new passenger vehicle sales in 2030 to have ADAS features, either as optional or standard. It argues that the growing adoption of ADAS features today will play a determining role in developing the value chain for fully autonomous vehicles and increasing deployment of AVs, or robotaxis, in the 2030s.

Research conducted by MarketsandMarkets shows that the global market for ADAS will increase from $27B in 2020 to $83B by 2030, which represents an impressive 12% annual growth rate for semi-autonomous driving systems.

BNEF'S OUTLOOK FOR ADVANCED DRIVER ASSISTANCE SYSTEM (ADAS) ADOPTION



Source: BloombergNEF

Source: [BloombergNEF. (2020). 9 of 10 Cars May Offer Advanced Safety Systems by 2030.](#) [Matt Hamblen, FierceElectronics. (2020). COVID-19 cuts into self-driving chips, on top of crushing car sales.](#)

THE PANDEMIC STIMULATED DEPLOYMENT OF AVS IN CHINA

In 2019, the Chinese government started lifting restrictions for autonomous vehicles and made it easier to test AVs on public roads in more cities and with fewer controls.

Before the pandemic, AVs were not as widely used in China and had limited technical capabilities. This crisis has stimulated digital transformation and development in China and thus accelerated the adoption of AVs into people's everyday lives, as they helped to improve safety and deliver supplies.

Throughout the country, hospitals and cities started using AVs to fight the virus by transporting necessary medical supplies and food to healthcare professionals and the public and disinfecting hospitals and public surfaces to reduce the spread of corona virus. For instance, Baidu Apollo, autonomous vehicle platform, partnered with Neolix, a local self-driving startup, to deliver food and supplies to the Beijing Haidian Hospital. It has also partnered with iDriverPlus to provide AVs to sixteen hospitals nationwide.

Post-pandemic, China is aiming to push "new infrastructure", a new technology-driven structural upgrade of the economy, by further developing 5G networks, constructing more data centers across the nation, and revamping local city management systems with emerging technologies.

An instrumental component of China's development of smart cities is Vehicle-to-Everything (V2X). This comprehensive technology enables vehicles to communicate with the environment, aiming to make autonomous vehicles safer, more intelligent, more economical, and convenient.

Baidu has become integral to the development and transition towards smart cities. Recently, the company released the ACE Transportation Engine (Autonomous driving, Connected road, Efficient mobility), a full-stack solution helping cities build intelligent transportation systems.

As of May 2020, seven Chinese cities permit AVs to carry passengers in designated areas. At the same time, seven companies — such as Baidu, Didi Chuxing, WeRide and AutoX Technologies — have deployed over 150 robotaxis in these cities, and they plan to operate a total fleet of 300 vehicles by the end of 2020.

The country's goal is to commercialize robotaxis by the end of 2025. BloombergNEF expects China to have the largest autonomous-vehicle market by 2040 as the country's domestic AV technology ecosystem matures.

Source: Baidu, MIT Technology Review. (2020). How corona virus is accelerating a future with autonomous vehicles. KPMG. (2020). 2020 Autonomous Vehicles Readiness Index. BloombergNEF. (2020). China Backs Self-Driving Development With Robotaxi Pilots.

VC ACTIVITY IN THE AV SPACE

TAKE AWAYS

Venture investment in autonomous vehicle startups hit record levels in 2019, driven by outsized deals such as Aurora's $600.0M Series B round led by Sequoia Capital. Corporate investment from automakers has driven some of the largest deals in the space. For example, SoftBank, Honda, and GM $4.0B investment in Cruise Automation, Ford commitment to invest $4.0B in AV development, and Volkswagen commitment of $2.6B into Ford-owned Argo AI.

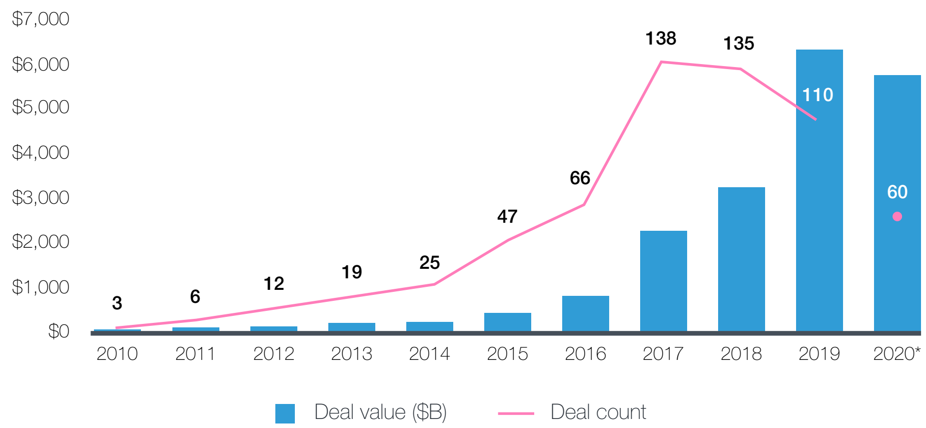
In Q2 2020, venture investment in AVs reached a record of $3.8B, up from $1.8B in Q2 2019 and $1.3B in Q1 2020. This was largely driven by Waymo's $3B late-stage round led by Silver Lake, CPPIB, and Mubadala at a post-money valuation of $30.8B. Standout deals include Didi Autonomous Driving's $500M early-stage VC round led by SoftBank as well as Inceptio Technology's $100M Series A. Additionally, Amazon made its largest bet in the space to date, acquiring Zoox for $1.3B.

In Q3 2020, VC funding into AV reached $673.1M, down 82.1% QoQ and down 43.9% YoY. However, the total venture investment in AV is expected to reach a record high in 2020, with $5.8B invested through the first three quarters. Significant deals include Kymeta's $215.0M Series BB1, Luminar's $170.0M late-stage VC deal, and Semidrive's $73.3 million Series A.

Historically, a significant portion of VC investment in the space has gone towards startups focusing on developing full-stack autonomous solutions, such as Nuro, Aurora, and Pony.AI. This is beginning to change as investors expand its focus towards companies that specialize in a single aspect of autonomy, such as mapping or localization, or otherwise augmenting autonomous vehicle space. A significant portion of VC investment in the vehicle space is going to companies focused on lidar and lidar-based perception solutions. In 2019, the lidar industry received a record-high $1.3B in VC funding.

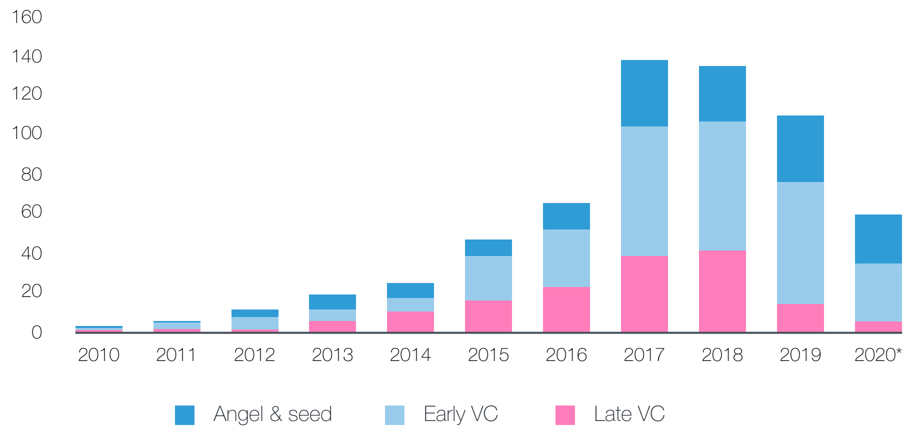
Following the wave of SPACs in the EV space, AV startups were the next to go public through SPAC in 2020. Major AV SPACs at the end the year include, Velodyne's reverse merger with SPAC Graf Industrial, Luminar's combination with SPAC Gores Metropoulos, and Porsche-backed Aeva's merger with SPAC InterPrivate Acquisition. PitchBook predicts a second wave of SPACs in 2021 focused on self-driving space, with lidar companies debuting the wave.

AUTONOMOUS VEHICLES VC DEAL ACTIVITY



*Source: PitchBook | Geography: Global | *As of September 30, 2020*

AUTONOMOUS VEHICLES VC DEALS (#) BY STAGE



*Source: PitchBook | Geography: Global | *As of September 30, 2020*

Source: PitchBook

TRANSACTIONS IN THE AV SPACE

FULL STACK VC DEALS

Company	Date	Subsegment	Deal size ($M)	Post-money valuation ($M)	Deal stage
WeRide	23-Dec-20	Passenger cars & Robotaxis	200	N/A	Series B
TuSimple	25-Nov-20	Trucking Stack	350	N/A	Series E
Gatik	23-Nov-20	First-Last Mile Delivery	25	58	Series A
PlusAI	21-Nov-20	Trucking Stack	100	N/A	Later Stage VC
Inceptio Technology	09-Nov-20	Trucking Stack	120	N/A	Early Stage VC
Nuro	09-Nov-20	Passenger cars & Robotaxis / First-Last Mile Delivery	500	4,000	Later Stage VC
Pony.ai	05-Nov-20	Passenger cars & Robotaxis	267	N/A	Later Stage VC
Locomation	16-Oct-20	Trucking Stack	17	N/A	Seed Round
Clearpath Robotics	22-Sep-20	Agricultural Applications	35.4	N/A	Early Stage VC
Seegrid	15-Sep-20	Logistics Applications	52	N/A	Series B
Almotive	22-Jun-20	Passenger cars & Robotaxis	20	N/A	Later Stage VC
Locomation	08-Jun-20	Trucking Stack	5.98	N/A	Seed Round
Clearpath Robotics	01-Jun-20	Agricultural Applications	29	N/A	Series C
Didi Chuxing	29-May-20	Passenger cars & Robotaxis	500	N/A	Series A
Waymo	12-May-20	Passenger cars & Robotaxis	3,000	30,750	Later Stage VC
Inceptio Technology	26-Apr-20	Trucking Stack	100	N/A	Series A
Neolix Technologies	29-Mar-20	Logistics Applications	28.6	N/A	Series A1
Boxbot	05-Mar-20	First-Last Mile Delivery	16	53	Series A
Vi Pioneers	05-Mar-20	Industrial Applications	14.3	N/A	Series A2
FiveAI	03-Mar-20	Passenger cars & Robotaxis	41	216	Series B
Pony.ai	25-Feb-20	Passenger cars & Robotaxis	462	3,000	Series B
Vecna Robotics	07-Jan-20	Logistics Applications	50	225	Series A1
Udelv	01-Dec-19	First-Last Mile Delivery	1.5	N/A	Early Stage VC
May Mobility	27-Nov-19	First-Last Mile Delivery	50	220	Series B
Wayve	18-Nov-19	Passenger cars & Robotaxis	20	N/A	Series A
Ghost Locomotion	28-Oct-19	Passenger cars & Robotaxis	32.8	210	Series C

Source: PitchBook

FULL STACK VC DEALS

Company	Date	Subsegment	Deal size ($M)	Post-money valuation ($M)	Deal stage
Verdant Robotics	18-Oct-19	Agricultural Applications	11.5	29	Seed Round
Einride	10-Oct-19	First-Last Mile Delivery	25	N/A	Series A
Embark Trucks	25-Sep-19	Trucking Stack	70	520	Series C
Built Robotics	19-Sep-19	Industrial Applications	33	177.9	Series B
Voyage	12-Sep-19	Passenger cars & Robotaxis	31	155	Series B
Aurora (Automotive)	09-Sep-19	Passenger cars & Robotaxis	69.5	3,069.5	Series B1
Starship (Electronics)	20-Aug-19	First-Last Mile Delivery	40	200	Series A
Tier IV	18-Aug-19	First-Last Mile Delivery	109	N/A	Series A
Optimus Ride	12-Jul-19	Passenger cars & Robotaxis	11.1	176.1	Series B1
Oxbotica	01-Jul-19	Passenger cars & Robotaxis	9.9	57.3	Early Stage VC

Source: PitchBook

AV COMPONENTS VC DEALS

Company	Date	Subsegment	Deal size ($M)	Post-money valuation ($M)	Deal stage
Uhnder	01-Nov-20	Radar	45	345	Series C
Ouster	08-Sep-20	Lidar	42	72.2	Series B
Luminar	08-Sep-20	Lidar	170	N/A	Later Stage VC
Ouster	26-Jun-20	Lidar	20.9	35.9	Series B
Psionic	24-Jun-20	Lidar	1.27	N/A	Seed Round
NewSight Imaging	18-May-20	Lidar	7	N/A	Series A
Regulus Cyber	18-May-20	Lidar	4	N/A	Series B
Enview	08-May-20	Lidar	12	46	Series A1
Zvision	07-Apr-20	Radar	9.9	N/A	Series A1
SOS Lab	01-Apr-20	Lidar	8	N/A	Series A
Trilumina	13-Mar-20	Lidar	15	N/A	Series B
AEye	11-Mar-20	Lidar	10.2	N/A	Later Stage VC
SiLC Technologies	04-Mar-20	Lidar	12	N/A	Seed Round
Cepton Technologies	05-Feb-20	Lidar	50	615.5	Series C
Opsys Technologies	07-Jan-20	Lidar	23.5	65.8	Series B
Seoul Robotics	18-Dec-19	Lidar	5	N/A	Early Stage VC
Arbe	16-Dec-19	Radar	32	N/A	Series B
Slightech	03-Dec-19	Cameras	1.4	N/A	Later Stage VC
Vayyar	20-Nov-19	Radar	109	N/A	Series D
Metawave	05-Nov-19	Radar	30	200	Series A
Lumotive	17-Sep-19	Lidar	4	N/A	Early Stage VC
Aeva	22-Aug-19	Lidar	60	460	Series B
TriEye	21-Aug-19	Cameras	19	N/A	Series A
Echodyne	01-Aug-19	Radar	20	140	Series B1
PRENAV	08-Jul-19	Lidar	9.5	30	Series A
Luminar	24-Jun-19	Lidar	100	900	Later Stage VC
Innoviz Technologies	11-Jun-19	Lidar	170	575	Series C

Source: PitchBook

AV SYSTEMS VC DEALS

Company	Date	Subsegment	Deal size ($M)	Post-money valuation ($M)	Deal stage
Horizon Robotics	22-Dec-20	Perception Software	150	N/A	Later Stage VC
Percepto Robotics	22-Nov-20	Perception Software	45	72.5	Later Stage VC
Minieye	28-Oct-20	Perception Software	40	N/A	Later Stage VC
Semidrive	28-Sep-20	Processors	73.3	484.9	Series A
Kymeta	25-Aug-20	Perception Software	215	375	Later Stage VC
Edge Case Research	11-May-20	Simulation / Dev Tools	8	N/A	Later Stage VC
Phantom AI	06-Mar-20	Perception Software	21.7	86.7	Series A
SambaNova Systems	25-Feb-20	Processors	250	2,500	Series C
Graphcore	02-Feb-20	Processors	162.3	1,644.9	Series D2
Kneron	10-Jan-20	Processors	40	N/A	Series A2
Cerebras	27-Nov-19	Processors	88	1708	Series D
Tactile Mobility	29-Oct-19	Processors	9	N/A	Later Stage VC
Prophesee	28-Oct-19	Perception Software	27.9	N/A	Early Stage VC
Realtime Robotics	16-Oct-19	Processors	11.7	N/A	Series A
Calmcar	18-Sep-19	Perception Software	14.1	N/A	Series A1
Scale AI (Software)	05-Aug-19	Perception Software	100	1,000	Series C
Mythic	12-Jun-19	Processors	30	240.2	Series B1

Source: PitchBook

URBAN AIR MOBILITY VC DEALS

Company	Date	Subsegment	Deal size ($M)	Post-money valuation ($M)	Deal stage
Skydio	13-Jul-20	UAV	98.3	423.3	Series C
Elroy Air	07-Apr-20	UAV	6.8	24.3	Series A
AirMap	25-Mar-20	UAV	31.8	161.8	Series C
Clobotics	15-Jan-20	UAV	10	N/A	Early Stage VC
Pyka	24-Dec-19	UAV	11	33	Early Stage VC
PrecisionHawk	09-Dec-19	UAV	32	N/A	Series E
Dedrone	04-Dec-19	UAV	27.4	N/A	Later Stage VC

Source: PitchBook

URBAN AIR MOBILITY VC DEALS

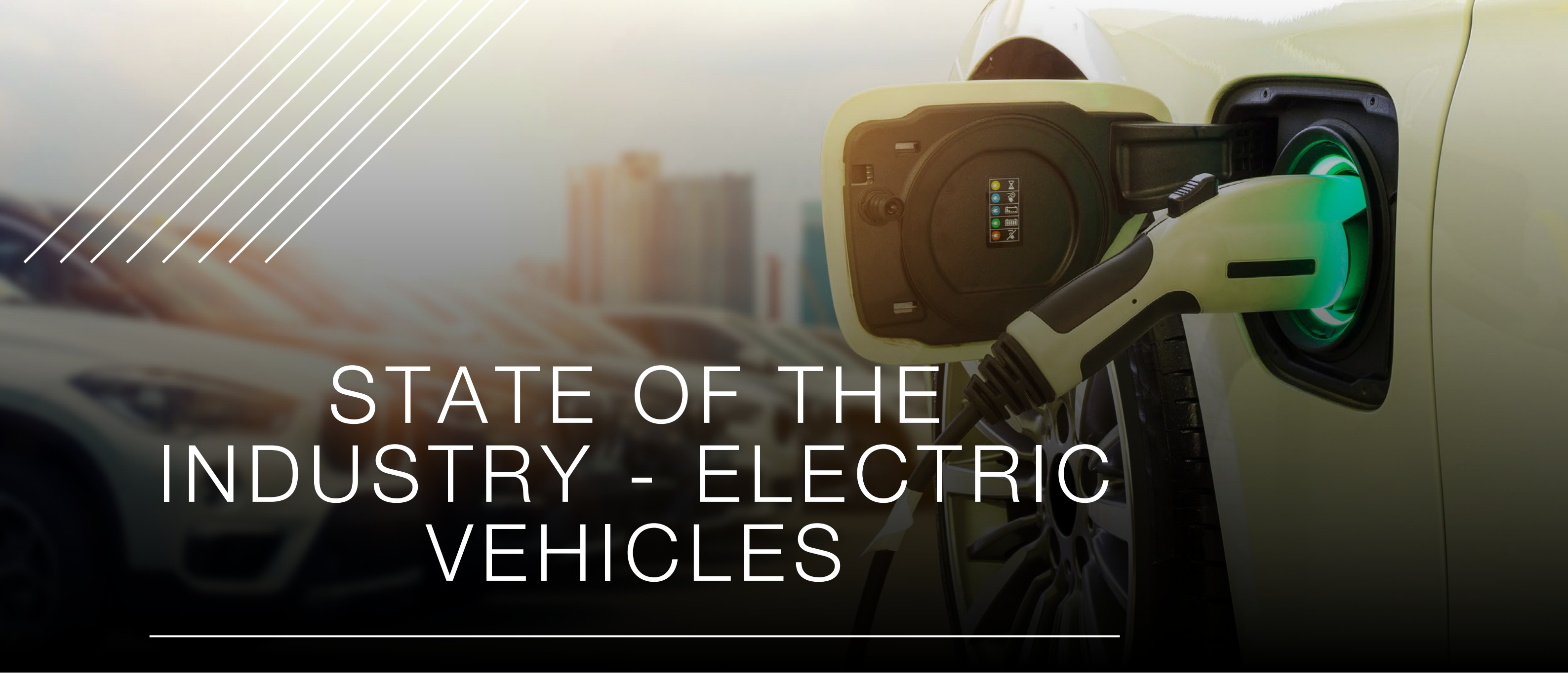
Company	Date	Subsegment	Deal size ($M)	Post-money valuation ($M)	Deal stage
SkySpecs	18-Nov-19	UAV	17	N/A	Series C
DroneDeploy	13-Nov-19	UAV	35	235	Series D
D-Fend Solutions	24-Sep-19	UAV	28	182.8	Series B
Drone Racing League	24-Jun-19	UAV	26.4	176.4	Series C
Fortem Technologies	13-Jun-19	UAV	14.5	74.5	Series A1

Source: PitchBook

NOTABLE VC EXISTS

Company	Date	Subsegment	Deal size ($M)	Post-money valuation ($M)	Deal stage
Aeva	02-Nov-20	Lidar	N/A	InterPrivate Acquisition	Reverse Merger
Luminar	24-Aug-20	Lidar	3,400	Gores Metropoulos Inc.	Reverse Merger
Cambricon Technologies	20-Jul-20	Processors	3,657.4	STAR	IPO
Vayavision	07-Jul-20	Perception Software	N/A	LeddarTech	Merger/Acquisition
Velodyne LiDAR	02-Jul-20	Lidar	N/A	Graf Industrial Corp.	Reverse Merger
Zoox	28-Jun-20	Full Stack	1,300	Amazon.com	Merger/Acquisition
Marble Robot	17-Jun-20	Logistics	N/A	Caterpillar	Merger/Acquisition
Foresight Autonomous Holdings	11-Jun-20	Cameras	80	FRSX	PIPE
Artisense	14-Feb-20	Lidar	N/A	Kudan	Merger/Acquisition
LatentLogic	12-Dec-19	Simulation	N/A	Waymo	Merger/Acquisition
DeepScale	01-Oct-19	Perception	N/A	Tesla	Merger/Acquisition
Scotty Labs	21-Aug-19	Teleoperation	N/A	DoorDash	Merger/Acquisition
drive.ai	25-Jun-19	Full Stack	77	Apple	Merger/Acquisition

Source: PitchBook



STATE OF THE INDUSTRY - ELECTRIC VEHICLES

ARE WE READY FOR FULLY-ELECTRIC VEHICLES?

We tend to forget that electric cars are as old as cars themselves. The first practical electric car was invented in 1884, and in 1900, more than a third of all vehicles on the road were electric. By the 1930s, factors such as the low cost of crude oil, the cheaper Ford assembly line, and the introduction of the highway system drove the electric cars away.

Today is a much different story. The global automotive industry is a massive $2T market, and a number of factors are driving its newly electrification. This shift is notably historical as it is, de facto, also shaking the $1.4B global energy industry[1]. Likewise, electric cars could wipe out as much as $21 trillion in revenues for the oil, gas, and coal industry by 2040[2].

Changes in customer preferences, technological breakthroughs, government subsidies, and environmental policies drive this revolution. Many governments are starting to create favorable environments for EV growth through regulations and financial incentives. About 20 major cities worldwide announced their plans to ban the internal combustion engine (ICE) vehicles by 2030[3]. While many countries are planning to ban the sale of ICE through 2040. Tightened regulations and bans are pushing established manufacturers to adapt. Global automakers, such as Volkswagen, Daimler, Volvo, have made massive investments and build aggressive strategies to electrify their fleets for the next decade.

On the consumer side, indeed, the vehicles provide a range of benefits from lower running costs to lower maintenance bills. However, their cost premium at purchase, lower driving range and a lack of infrastructure are still obstacles to mass adoption. As of now, government subsidies were the main support to the increase in demand.

Significant technology improvements have also increased the attractiveness of EVs for consumers. Since about a decade ago, batteries had consistently shrunk in weight and cost, and have increased in capacity and charging speed. As EV prices keep falling and technology keeps improving, the total cost of EV ownership is expected to reach price parity with ICE counterparts between 2022 and 2025, according to Deloitte, McKinsey, and Bloomberg reports[4].

As of 2019, there were 7.2 million passenger electric vehicles on the road globally, a 40% growth from early 2018[5]. However, EV penetration is still nascent, 1.8% in the US, 2.9% in Europe, and 4.2% in China. The global EV fleet is estimated to account for 10.5 million of light vehicles and 800,000 of medium and heavy commercial vehicles by the end of 2020. Despite the lack of consensus regarding the EV tipping point, some experts, such as BloombergNEF, estimate that EV sales will pass 58% by 2040[6].

Source: [1] [2] [3] [4a] [4b] [5] [6a] [6b]

AN OVERVIEW OF THE ELECTRIC VEHICLE MARKET

As of today, passenger cars have been the biggest adopters of electrification. However, commercial, mass transit vehicles, and micromobility vehicles, such as e-scooters and e-bikes, are also catching up and shouldn't be overlooked.

At the end of 2019, there were more than 7.2 million passenger EVs on the road globally, a 40% growth from 2018, according to Bloomberg[7]. Battery electric vehicles (BEVs) accounted for 67% of the world's electric car fleet in 2019. In terms of countries, in 2019, China was by far the largest market for electric cars, representing nearly half of the global EV fleet. Europe accounted for 25% of the world's EV stock in 2019, followed by the US, representing 20%. However, Europe has seen the highest EV penetration in Q1 2020, reaching 5.9%[8].

Worldwide, BEV sales rose 14% in 2019 relative to 2018, while plug-in hybrid electric vehicles (PHEV) sales declined 10%. BEVs accounted for almost three-quarters of worldwide electric car sales in 2019.

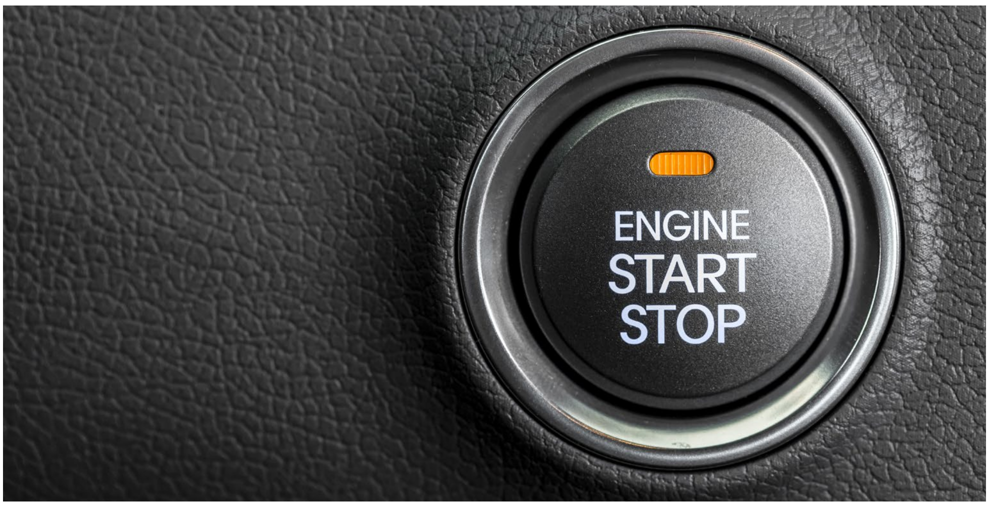
However, despite growing sales and record-high market shares of electric cars in 2019, there was a significant slowdown in the overall growth of EV sales compared with 2018. There are three main reasons: contracting vehicle markets, reduction in EV purchase subsidies in some key regions; and consumer expectations of further technology improvements and new EV models.

The worldwide best selling passenger EV maker was Tesla in 2019, with 367,820 units sold globally. BYD, 24.6% of which is owned by Berkshire Hathaway, was the second seller with 229,506 EV units sold. They were followed by BAIC, SAIC and BMW. In terms of models, the world's best selling EV was the Tesla Model 3 with over 300,000 units sold. The second-best in 2019 was BAIC EU-Series - the first non-Tesla model to exceed 20,000 in a single month[9].

Since 2010 battery costs have fallen by over 85% and a battery energy density increased by 20-100%. The variety of EV models has mushroomed, with 250 models available in 2019 compared with about 70 in 2014. Due to technological progress in fast charging, the charging time is less of a concern, particularly for long distance travel.

In regards to battery electric trucks, 155,000 units were sold globally in 2018 according to Interact Analysis. Even though China saw a small decline in sales due to a reduction in state-sponsored subsidies, there was an increase of over 60% elsewhere in the world[9a]. According to McKinsey, the e-trucks could reach between 15% and 34% sales penetration by 2030[10].

On the other hand, urban electric buses represent the fastest-growing segment of the market. According to McKinsey, the vehicles grew at a CAGR of over 100% from 2013 to 2018, compared with a 60% CAGR for fully electric passenger cars[11].



In 2019, the global electric bus fleet was about 513,000 units, up 17% from 2018. Although, China experienced the YoY registrations drop by about 20% in 2019 - due to a decrease in purchase subsidies - it is still accounted for 98% of total eBus fleet[12]. While the number of eBuses has increased in Europe and the United States. Bloomberg predicts eBuses to comprise over 67% of the global bus fleet in 2040[13].

Last but not least, micromobility is a strong segment in the electric vehicle market. With increasing urbanization, people's daily trip range has shrunk with over half of all the US and Europe trips being under 5 miles. This has led to a surge in the development of docking or dock less bikes and scooters, e-scooter and e-bikes manufacturers. According to MarketsandMarkets, the global e-bike market is projected to reach $38.6B by 2025, growing at a CAGR of 9.01%[14].

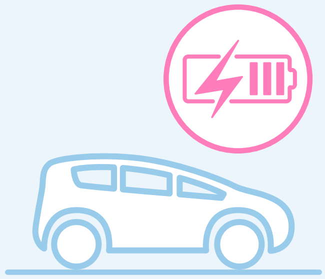
Overall, according to BloombergNEF, there are over 500,000 e-buses, almost 400,000 electric delivery vans and trucks, and 184 million electric mopeds, scooters and motorcycles on the road globally.

Some additional breakthroughs are worth being mentioned. The increasing global demand for the fastest and most economical modes of transportation is powering the R&D behind new projects such as hyperloop and passenger electric aircraft. The idea of flying cabs that carry passengers short distances over urban areas is also attracting attention. Morgan Stanley Research projects a total addressable market of the electric vertical take-off and landing to be $1.5T by 2040[15].

A growing number of start-ups and established aviation companies, including Boeing and Airbus, are working on development of eVTOL, or electric vertical take-off and landing. In 2019 and 2020, several pilot flights of small battery electric aircraft have been completed, including Lilium Jet, Vahana test flights in 2019, among others. In December 2019, the first fully-electric commercial passenger aircraft flight took place, when a retrofitted seaplane took a 15-minute flight from Vancouver, British Columbia. In July 2020, ZeroAvia, the first hydrogen-powered plane, completed the first phase of test flights. In December 2020, Joby Aviation's four-passenger prototype received the first airworthiness approval by the US. Air Force of an eVTOL aircraft.

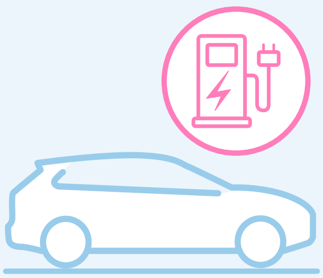
Source: [7] [8] [9] [9a] [10] [11] [12] [13] [14] [15]

PASSENGER ELECTRIC VEHICLE TYPES EXPLAINED



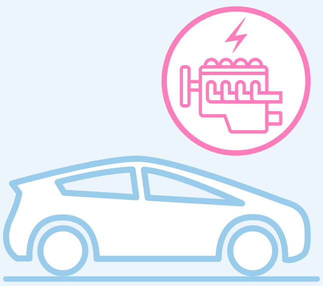
Battery electric vehicles (BEVs): Battery electric vehicles are fully-electric vehicles that utilize high capacity rechargeable battery packs with stored chemical energy. The battery power supplies energy to electric motors and in-vehicle electronics. BEVs are highly energy efficient, have zero tailpipe emissions and much quieter engine noise. Vehicles are charged at home from an electrical charging outlet or at public stations. They support Level 3 charging, direct current (DC) fast charging and regenerative braking. DC fast charging can charge 80% of a battery within 30 minutes, while regenerative braking can recapture as much as 32% of the total energy use – as recently reported by Tesla Model S drivers.

Examples: *Tesla, Audi e-tron, Jaguar I-Pace, Mercedes EQC, Toyota Rav4 EV, BMW i3, Ford Focus Electric*



Plug-in hybrid electric vehicles (PHEVs): The plug-in hybrid electric vehicles, also known as extended-range electric vehicles, are powered by both fossil fuels and electricity. PHEVs can be charged from an electrical outlet and from regenerative braking technology. Before petrol or diesel engine engages to extend the range of the trip, these vehicles can run on electricity for 10 to 40 miles on average.

Examples: *Toyota Prius Hybrid. Honda Civic Hybrid, Toyota Camry Hybrid*



Hybrid electric vehicles (HEVs): The hybrid electric vehicles use a combination of internal combustion engine and electric motor. In comparison to BEVs and PHEVs, they cannot be charged from a charging station. Instead, a battery is charged through regenerative braking and the internal combustion engine. The latter engine can power the generator, which in turn produces electricity and stores it. Last but not least, an in-vehicle computer controls both motors and optimizes their usage according to driving style.

Examples: *Toyota Prius Hybrid. Honda Civic Hybrid, Toyota Camry Hybrid*

Source: https://www.evgo.com/why-evs/types-of-electric-vehicles/; https://www.ucsusa.org/clean-vehicles/electric-vehicles

FUEL CELL VEHICLES

A fuel cell electric vehicles (FCEV) is a type of e-car that unlike BEVs produces the electricity on board through the fuel cell. Hydrogen reacts with oxygen in the fuel cell, thereby generating electrical energy directed to the electric motor or battery.

As a result, FCEVs are more ecological as they only emit water vapor and warm air. However, it is not totally emission-free as the production of hydrogen consumes a considerable amount of electricity, with the overall emissions bill ultimately depending on the method of production.

In terms of range, FCEVs have similar performance to some of the future battery-powered EVs. One of the major advantages of the fuel cell vehicles is the quick refilling time of the tank – a matter of minutes - comparable to a petrol/diesel car. One problem, however, is the lack of hydrogen filling stations within the available mile's range. It is also still very expensive to manufacture fuel cell systems, mainly due to the usage of platinum for the catalytic converter.

In 2019, FCEVs' total sales were 12,350, bringing the global fleet to approximately 25,000 vehicles, including passenger cars, buses and trucks[16]. However, passenger cars account for the majority of FCEV sales and stocks. Toyota (Mirai), Hyundai (Nexo) and Honda (Clarity Fuel Cell) cars dominate the market.

BloombergNEF predicts that FCEVs will account for about 1% of the global passenger vehicle fleet in 2040, considering a significant cost decline in green hydrogen production. However, Bloomberg says that FCEVs will be more widely deployed in commercial vehicles and buses due to hydrogen's higher energy and power density. By 2040, FCEVs will account for 1.5% of the medium-duty truck sales, 3.9% of heavy-duty and 6.5% of municipal bus global annual sales[17].

Similarly, Gartner argues that fuel cell technology is better suited for high-power applications and thus will dominate the larger vehicle segment, such as trucking and public transport. However, according to Gartner, fuel cell technology is still six to eight years away from market adoption.

Some countries are actively discussing the deployment of a hydrogen refueling infrastructure - California, China, parts of Europe, Japan and South Korea - and so they are expected to have a higher adoption rate of FCVs.

Source: [16] [17]

EV INFRASTRUCTURE & BATTERY TECHNOLOGY EXPLAINED

EV CHARGING - TECHNOLOGY EXPLAINED

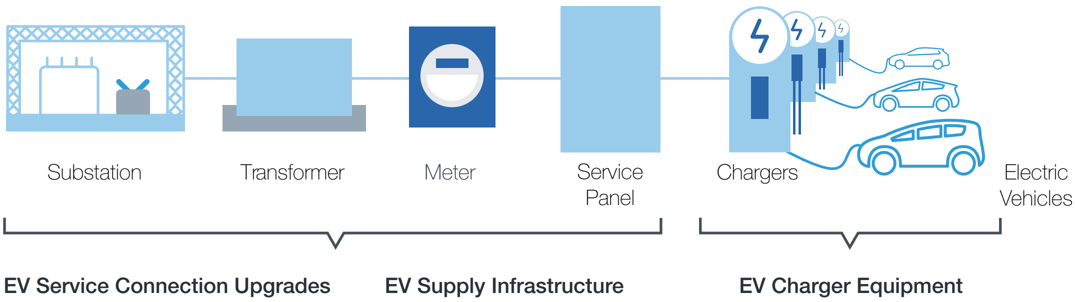
Chargers are ranked in order by their respective charging speed. The US Society of Automotive Engineers (SAE) classifies them in such manner: Level 1, Level 2, and Level 3.

Level 1 outlets can deliver 5 miles of range per hour of charging (RPH) and would typically charge an EV for an 80-mile journey within sixteen hours. These chargers require minimal infrastructure and therefore are found at home or at work.

Level 2 outlets deliver between 12 RPH and 25 RPH and would typically charge an 80 mile range battery within four hours. These chargers, on the other hand, require specific infrastructure, and therefore are found at work and at public stations.

Level 3 outlets, also known as direct current (DC) fast charging, provide the fastest charging speed currently available to mass market. The technology converts alternating current (AC) into direct current (DC) electricity. These chargers deliver over 100 RPH, can charge 80% of a battery within 30 minutes and are found at dedicated stations.

Some countries are actively discussing the deployment of a hydrogen refueling infrastructure - California, China, parts of Europe, Japan and South Korea - and so they are expected to have a higher adoption rate of FCVs.



Source: EEI and the Institute for Electric Innovation (IEI)

Source: EEI and the Institute for Electric Innovation (IEI). (2018). Electric Vehicle Sales Forecast and the Charging Infrastructure Required Through 2030.

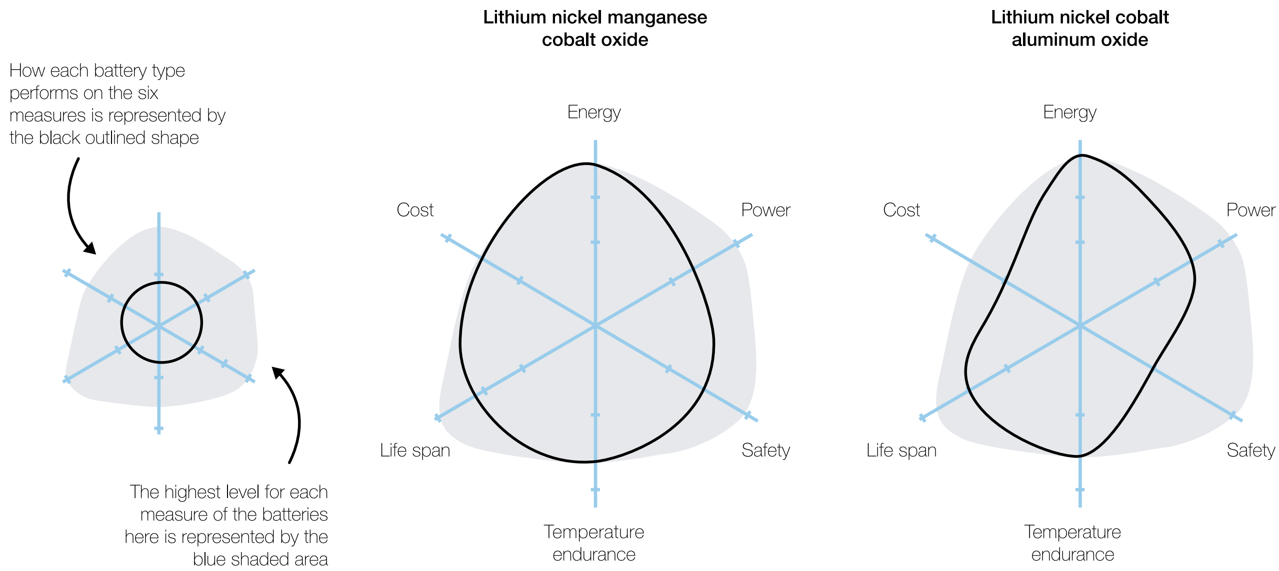
EV BATTERY - TECHNOLOGY EXPLAINED

EV batteries consist of cells, modules and packs. Simply put, a group of cells form a module and a group of modules form a pack.

The most advanced battery chemistry being currently produced at scale is lithium-ion. A lithium-ion battery consists of two electrodes, an electrolyte and a separator in the middle. The separator enables lithium ions to move back and forth between the anode and the cathode. The anode of a lithium-ion battery is mostly made of graphite.

The cathode is made up of a number of materials, depending on the purpose of the battery. However, lithium, cobalt, nickel and manganese are the most common. The diagram below shows how different cathode materials can affect a battery's performance.

A cathode made of nickel, manganese, and cobalt is one of the most widely used lithium technologies. The graphite anode consists of layered sheets of carbon atoms. When the battery is discharged, lithium ions are placed between cathode slices. In charging state, each lithium ion is forced to travel from the cathode through the liquid electrolyte, where a separator ensures that only lithium ions pass through to the graphite anode. When the battery is fully charged, lithium ions are placed between the slices of the anode. As the energy is being consumed, the lithium ions gradually flow back to the cathode, until none are left in the anode.



Source: Akshat Rathi, Quartz. (2019). How we get to the next big battery breakthrough. Battery University. (2019). BU-301a: Types of Battery Cells.

The power capacity is determined by the charging and discharging speed of the battery. However, an increase in the charging speed, which forces lithium ions out of the cathode too fast, can damage the battery electrodes and eventually break them. Therefore every charge and discharge weakens the battery electrodes. For this reason the longer a battery is used, the shorter its lifespan will be.

POUCH VS CYLINDRICAL CELLS

A cylindrical cell has high specific energy (in addition to being mechanically stable) and is easy to manufacture. The cell design offers added safety features, such as pressure relief. The design also provides valuable cycling ability and offers a longer battery life. However, a cylindrical cell is heavy and not space-efficient, which causes the packaging density to be low.

A pouch cell uses laminated architecture in a bag and offers a cost-effective, flexible and lightweight solution to battery design. These cells provide the best space utilization, achieving up to 95% of packaging efficiency. Large pouch cells can deliver high load currents. However, they best perform under light loading conditions and with moderate charging. In addition, exposure to humidity and high temperature can reduce the lifespan of the battery. Swelling is also a big concern as pouch cells can swell by 8-10% over 500 cycles. This phenomenon must be taken into account when designing battery modules.

A prismatic cell is thin, light, and offers an effective use of space. Its shape offers increased flexibility in its design. However, prismatic cell can be more expensive to manufacture and less efficient in thermal management. It is worth mentioning that this cell has a shorter cycle life than a cylindrical design, and some swelling is also expected.

Most of the electric car manufacturers use pouch cells as they offer greater capacity than cylindrical cells. However, the contrarian EV manufacturer, Tesla, prefers cylindrical cells that set its vehicles apart, which is an interesting angle that high-performance EV Rimac has used, and automotive startup Rivian is considering for its new battery models.

Cylindrical cells provide a few advantages and enhance performance, flexibility, and cost control. Among the three types of cells available, these cells are the most cost-effective to produce in terms of cost per kWh. In the Tesla Model S/X and Model 3, the metallic protection around the cylindrical cells acts as scaffolding and provides structural rigidity to the battery. Additionally, cylindrical cells feature a pressure relief mechanism. As in high-powered situations, the internal pressure is distributed over the entire battery pack instead of being highly concentrated in a particular battery section.

Source: [Battery University. (2019). BU-301a: Types of Battery Cells.]

THERE IS NO ONE-SIZE-FITS-ALL LITHIUM-ION BATTERY

Rechargeable lithium-ion technology has existed for decades. It was invented by an Exxon Mobil Corp. researcher in the 1970s and eventually commercialized by Sony in 1991. It is now the most commercially popular rechargeable battery. Indeed, lithium-ion batteries are dominating the EV market. The batteries provide the best "charge to weight" solution. Additionally, their features allow manufacturers to produce lighter and smaller batteries at a lower price point for a similar performance. Other benefits include low maintenance and lack of memory effect, which results in an increased life cycle.

For the next decade, the Li-ion battery is likely to dominate the EV market. Mainly due to the following reasons: (1) this is well-established technology; (2) large investments in Li-ion manufacturing and supply chains constitute a barrier to entry for alternative technologies; (3) other technologies are still at a range of lower technology readiness levels.

Despite the fact that lithium-ion batteries satisfy the current needs of manufacturers, lithium-ion is not the ultimate solution to EVs. The batteries are fragile and require protection circuits to ensure operational safety. They are vulnerable to extreme temperatures, yet ironically, they also require high temperatures to operate, which in the long run negatively affects energetic performance, lifetime and safety. Adding on to chemical issues and limited recycling capacity, this type of battery also has high production costs. These drawbacks explain the on-going investment and research in new technologies, and the reason why there is not a single standard cell format yet.

Currently, most batteries include different variations of cobalt, graphite and nickel, on top of lithium-ion. The industry needs a standardized battery; one that can operate under various and, possibly, extreme temperatures.

The next-generation of Li-ion battery technology, which is expected to enter the market within five to ten years, is likely to have low nickel content and use either nickel cobalt aluminum oxide (NCA) (with less than 10% nickel) or nickel manganese cobalt (NMC) 811 cathodes.

Battery type	Electric vehicles	Anode	Cathode (excl Lithium)
NCA	Tesla Model 3 Tesla Model S Tesla Model X	Graphite	Nickel (80%) Cobalt (15%) Aluminum (5%)
LMO	Nissan Leaf BMW i3 Chevy Volt	Graphite	Manganese (100%)
NMC	Nissan Leaf BMW i3 Chevy Volt	Graphite	Manganese (33%) Cobalt (33%) Nickel (33%)

Source: C Iclodean et al 2017 IOP Conf. Ser.: Mater. Sci. Eng. 252 012058. PwC. (2018). The Outlook for Electric Vehicles.

NEXT GENERATION BATTERY TECHNOLOGY

The traditional lithium-ion battery technology is nearing its full potential. This is why newcomers and industry incumbents are actively investing in and researching the next-generation of batteries. The promised technology should provide a higher power-to-weight and size ratio, charge faster, and be significantly safer.

While some of the players are developing new lithium-ion batteries (such as metal-air, silicon, and graphene), others are pursuing completely novel battery chemistries. Among others, lithium-silicon and solid-state are the most promising near-term chemistries which can improve performance, hold more energy, and last longer at a lower cost.

Recent developments of lithium-solid state battery technology show that life cycle – the technology's main challenge – is improving. Solid-state batteries have cells that are made of solid and "dry" conductive material. They have proven themselves to be a solution to the existing lithium-ion counterparts' intrinsic problems being smaller, cheaper, safer, and with higher-capacity. However, the complicated manufacturing process and high cost of solid-state batteries are still critical hurdles. Various OEMs and research groups have prototyped this technology, including Toyota, Volkswagen, Ford, BMW, Honda, Hyundai and Nissan. If some have announced that they are planning to utilize solid-state batteries, no manufacturer or supplier has succeeded yet in manufacturing them in series production. In December 2020 Toyota has introduced its solid-state battery and promised to unveil the prototype in 2021[18].

Other automakers focus on the developing entirely new technologies. For example, Honda is developing a fluoride-ion battery. The car maker claims that the battery can offer up to 10x more energy density than lithium-ion counterparts. Although it might be a viable option, the technology poses a fundamental threat of overheating as the battery operates at over 300 degrees Fahrenheit. Honda, nonetheless, has provided reassurances that these risks are limited[19]. Tesla and GM are currently focusing on development of lithium-iron EV batteries.

Startups are also racing to develop more efficient ways to store energy. Two of the new technologies from newcomers are carbon nanotubes and sodium-oxygen batteries. The former, on top of a longer lifespan, can store significantly more electricity by weight while keeping the charge. The latter can have high specific energy and an equilibrium discharge potential as well as high abundance of sodium.

Last but not least, some market players expect significant progress in super capacitors. The next-generation of super capacitors may be able to store more energy than a lithium-ion battery while still releasing its energy up to 10x faster. A scenario would be one full charge in minutes for more than double the current driving limit of an electric car. However, the promised technology is still in R&D at this time.

Indeed, there is a furious development race between incumbents and newcomers, and the winner stands to profit from a high two-digit billion market opportunity.

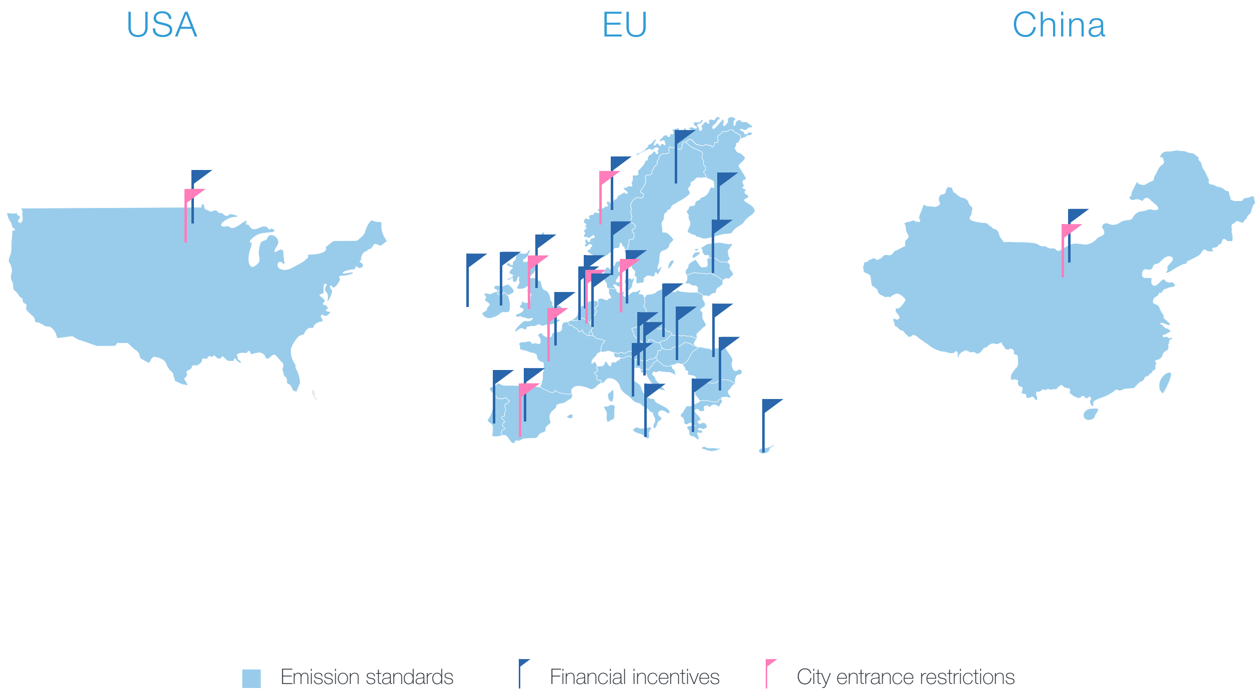
EMERGING TECHNOLOGIES IN ENABLING POWER AND ENERGY TECHNOLOGIES ON TIME TO ADOPTION

Technology Grouping	1 to 3 Years (Short Range)	3 to 6 Years (Midrange)	6 to 8 Years (Long Range)
Battery/Energy Storage	Solid-State Lithium Batteries	Printet/Flexible Batteries	Lithium-Air Batteries
	Silicon-Dominant Anode Lithium Ion Batteries	Extreme- Temperature Batteries	Aluminum-Air Batteries
	Nanomaterial Supercapacitators		

Source: Gartner (September 2020)

Source: [18] [19]
International Energy Agency. (2020). Global EV Outlook 2020.

WHAT DRIVES EV ADOPTION



In the past few years, growing environmental awareness has led to increased electric vehicles' demand. However, at this point, the market is mainly driven by financial incentives from governments and regulators.

POLICY AND REGULATION:

Emission standards:

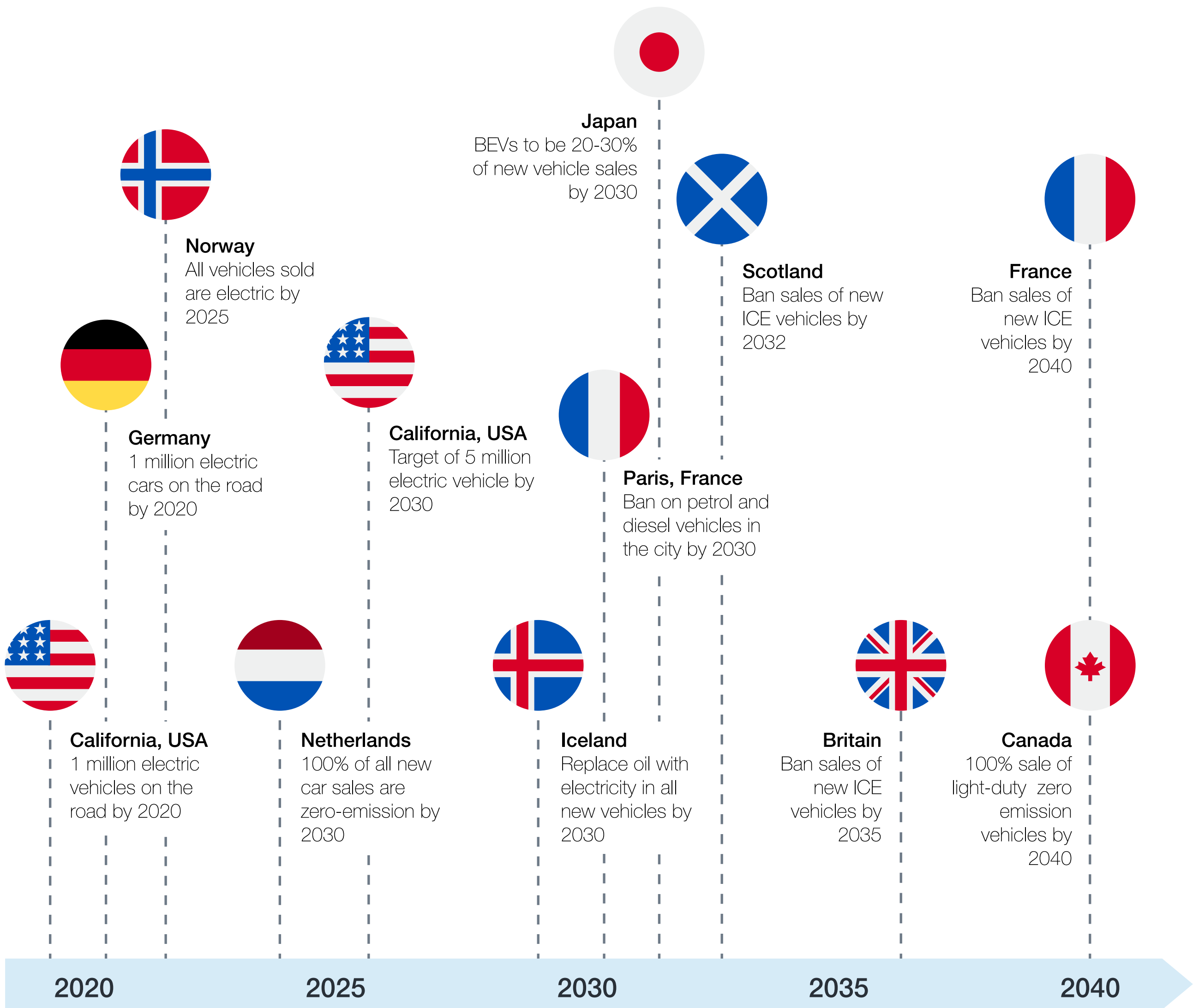
Today, 60% of global car sales are covered by China's New Energy Vehicle mandate, the European Union CO2 emissions standard or a zero-emission vehicle mandate (in selected US states and Canadian provinces). The 28 members of the EU set new emission standards to target a 37.5% reduction in car emissions by 2030. As an intermediate step, car makers in all member countries are forced to reach fleet-wide average emissions of 95 grams of CO2 per kilometre by 2020 or pay a fine of above $100 per additional g/km above the target[20]. 17 countries have announced 100% zero-emission vehicle targets or the phase-out of internal combustion engine vehicles through 2050. More specifically, California, France, and the United Kingdom plan to end sales of ICE-powered vehicles by 2040[21]. Ahead of such deadlines at state or country-level, most major cities around the world already have a number of emission regulations in place.

Financial incentives:

Governments have been introducing several measures from subsidies to VAT and vehicle registration tax exemptions. In the US, the federal Internal Revenue Service (IRS) has introduced tax credits of up to $7,500 per new EV purchased for domestic use. In Europe, 24 EU member states offer electric vehicles stimulus in the form of tax exemptions or reductions. Additionally, 11 of these countries offer bonus payments or premiums to EV buyers. For instance, in the Netherlands, fully electric cars are exempt from ownership, purchase, registration and road taxes, and the country provides an 80% reduction on company car taxes. Norway has also enforced a 25% VAT tax exemption on EVs[22].

City entrance restrictions:

Approximately 20 cities worldwide have announced plans to ban gasoline and diesel cars by 2030 or 2040. Paris, London and Copenhagen are just a few of them. In 2017, former California Governor Jerry Brown expressed California's interest in following such measures. Other methods include the UK's plans to introduce zero-emission zones across all city centers by 2025. Post-pandemic major cities have also implemented new citywide policies stimulating the use of bicycles and scooters. Milan, Paris, Brussels converting dozens of kilometers of car lanes into cycle paths.



Source: [20] [21] [22]

TIMELINE OF STRATEGIC OEM TARGETS FOR EVS

2020

- **Tesla:** China plant production begins with capacity of **.5m EV's a year**
- **JLR:** To invest **£1bn** to build electric cars in the UK
- **SAIC/VW:** Invest **$2.33bn** in two separate Chinese electric vehicle players
- **Toyota/BYD: Joint venture** to develop pure EVs
- **BYD and Hino:** sign a strategic business alliance agreement for commercial BEVs development

2021

- **BMW:** Electrify European market - **25%** by 2021; **1m** EVs on road by 2021
- **Toyota:** targets **30k** EV sales
- **Mazda:** releases first EV

2022

- **Fiat Chrysler: 30** new battery-powered or hybrid vehicles by 2022 **60%** of cars in Europe to be hybrid or fully electric
- **Renault-Nissan-Mitsubishi: 12 electrified** and **8 pure EVs** in range; **42%** of European sales to be EVs by 2022 (Nissan)
- **Honda:** All European mainstream models to be electrified by 2022 (instead of 2025)
- **Ford: 40 EVs** in "global portfolio"; To invest **$11.5bn** on EV models by 2022

2023

- **BMW: 25** EVs in range by 2023
- **GM:** "On track" to meet **20 EV models** target by 2023
- **VM Group: 1m** EV sales

2025

- **VW Group: 25%** global sales to be electric; Up to **3m** BEVs annually by 2025, including **1.5m** by the VW brand
- **Toyota:** Target of **5.5m** total EV sales and **.5m** sales in 2025
- **BMW:** Electrify European market - **33%** by 2025
- **GM: ~1m** Electrify European market - **33%** by 2025
- **Volvo:** Reach **1m** total EV sales by 2025 EV's to represent **50% of global sales**
- **Hyundai:** To invest **$87bn** in vehicle electrification by 2025; EV range to expand to **44** models by 2025; Target of **670k** annual EV sales by 2025

2030

- **BMW:** Electrify European market - **50%** by 2030
- **Mazda:** All models EVs/hybrids by early 2030s
- **Honda: 2/3rd** of **global** sales EVs
- **VW Group: 70 new** electric models by 2028 instead of the 50 previously planned; **40%** global sales to be electric by 2030
- **Daimler:** EV's to make up more than **50% of sales**
- **GM:** Cadillac to be **majority EV**

Source: Deloitte

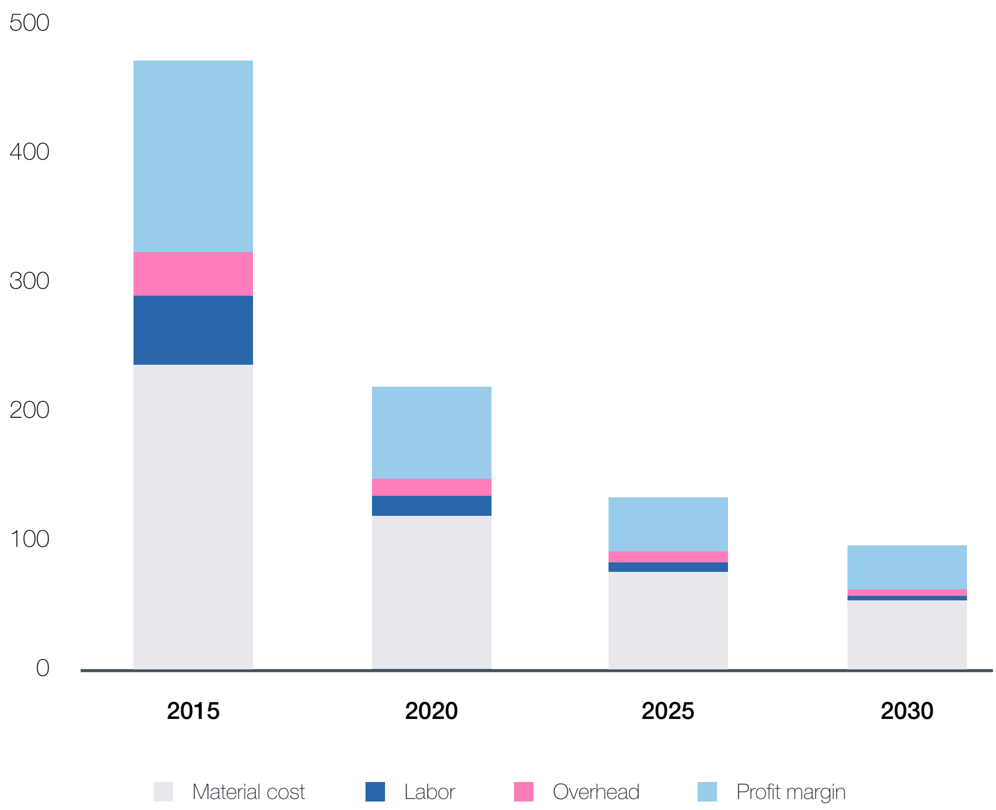
BARRIERS TO EV ADOPTION

Regarding customer demand, it is true that EVs bring a range of benefits to car buyers, as they require lower maintenance/running costs, provide quieter rides, connectivity, and full access to some major cities. However, there are still some critical obstacles to overcome. In the last decade, a number of industry surveys and studies have highlighted that the price premium over ICE vehicles, lack of charging infrastructure and a limited driving range remain the main barriers to EV sales growth today.

COST/PRICE PREMIUM

Currently, batteries can account for more than 40% of the total cost of EVs. However, technological developments, economies of scale, and government subsidies are significantly lowering their price. In 2020, battery prices are expected to reach about 135$/kWh on average, approximately a 13% decline compared with 2019 and 89% lower than a decade ago. Further cost cuts will come as the scale of battery production increases and the design of battery packs becomes more efficient. Furthermore, the total cost of ownership should account for 40% to 50% lower service, maintenance and repair costs, due to substantially fewer moving parts. In the US, the average cost of operating an EV is estimated at $485 a year, which is less than half of the $1,117 required to operate an ICE-powered vehicle[23]. Therefore, EVs are a more economical option in the long run, and their cost is on par with its ICE counterparts.

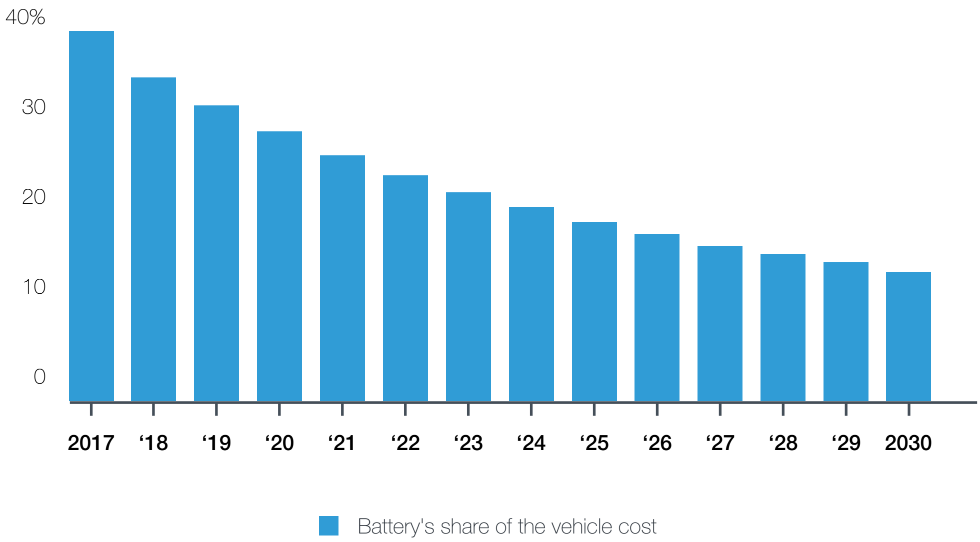
SALES PRICE PREDICTION (DOLLAR/KWH)



Source: [23]
Will Mathis, Bloomberg Green. (2020). Cheaper Batteries, More Chargers for Electric Car Buyers in 2020.

BATTERY'S SHARE OF THE VEHICLE COST

Batteries are an electric car's most expensive part, but less so each year



Source: BloombergNEF

LACK OF INFRASTRUCTURE

The development of new batteries is expected to reduce the additional demand for charging stations. However, broad and reliable national networks are still required to accommodate this major technological shift. OEMs, suppliers, and even large oil companies are investing in the deployment of such networks. To answer this challenge, many startups have emerged, the ecosystem and new charging technologies have been invented, such as wireless charging station or inductive charging.

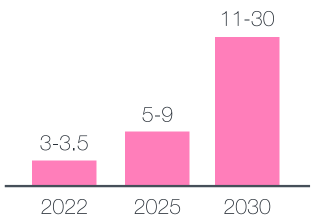
In 2019, there were about 7.3 million chargers worldwide, of which about 6.5 million were private, light-duty vehicle slow chargers. Publicly accessible chargers accounted for 12% of global chargers in 2019, 60% higher than in 2018[24]. Convenience, cost-effectiveness and various of support policies are the main drivers for the prevalence of private charging.

THE ELECTRIC VEHICLE MARKET IN 2030 WILL REQUIRE MORE THAN 55 MILLION CHARGERS IN BUILDINGS, CONSUMING AT LEAST 525 TWH PER YEAR

Commercial vehicles | Personal vehicles

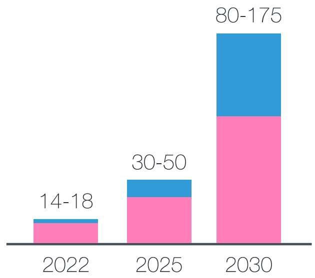
United States

Passenger EV charger count, M



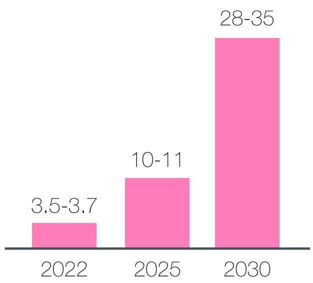
Commercial charger count, M

Power demand, TWh



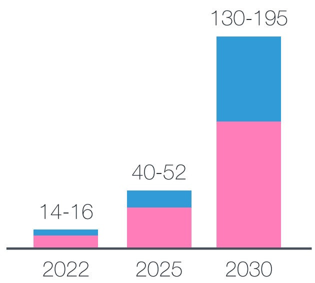
EU-27 plus the United Kingdom

Passenger EV charger count, M



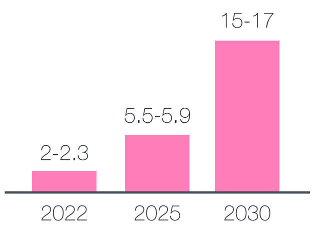
Commercial charger count, M

Power demand, TWh

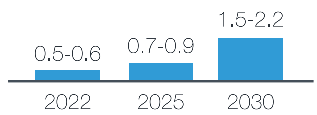


China

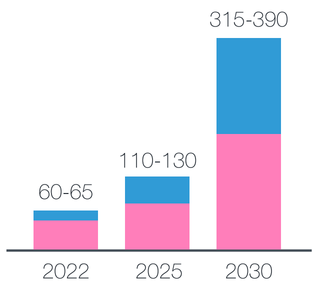
Passenger EV charger count, M



Commercial charger count, M

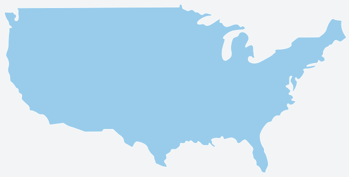


Power demand, TWh



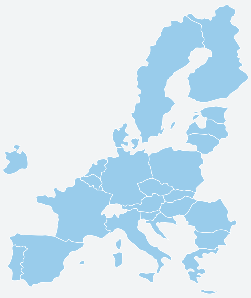
Source: McKinsey & Company

GOVERNMENT SUPPORT REMAINS ONE OF THE MAIN DRIVERS



In the US, the FCA diesel emissions settlement is forcing the deployment of such infrastructure. For instance, Electrify America, a subsidiary of Volkswagen, will lead a $2B Zero Emission Vehicle (ZEV) investment plan until 2027 which aims to develop reliable EV charging infrastructure and related activities[25]. In 2019, the US Congress extended the federal charging infrastructure tax credit in. It covers up to 30% of the installation cost of new EVSE through 2020.

In China, as early as 2015, several measures have been put in place to develop a charging network that would support 5,000,000 EVs by 2020. All new residential buildings will be required to install EV charging infrastructure and large public buildings will devote 10% of their parking to such charging outlets[26]. In 2019, China accounted for 80% of publicly accessible fast chargers compared to 47% of the world's electric light-duty vehicle stock. In 2020, The State Grid has announced plans to increase investment in charging stations. The City of Beijing has outlined a policy to provide up to $28,300 in subsidies per station for operators.



In the EU, the AFID has required EU members to set deployment targets for publicly accessible chargers for 2020, 2025 and 2030, with an indicative ratio of one charger per 10 electric cars. At the start of 2020, the number of publicly accessible charging points in the EU was around 165,000[27].

The European Green Deal target is one million charging points across the EU by 2025. As of May 2020, 12 EU members have introduced regulations which require new and renovated buildings to be equipped with EV charging infrastructure.

DRIVING RANGE

Following a number of government incentives and measures, many car manufacturers joined the race of electrification. BMW announced plans to produce 25 electrified models with at least 10 of them being fully electric by 2025[28]. In the meantime, Daimler communicated its intention to electrify its line of Mercedes cars and target electric models to account for 15-25% of its total sales by 2025[29]. GM is also planning to release 20 electric cars to the market within the next five years. In Oct 2019, Volvo, owned by Geely, unveiled its first 200 miles range fully-electric car and pledged that half of its fleet will be electric by 2025[30].

Until recently, BEVs could travel up to 200 miles on a full charge. Within the next decade, technological breakthroughs may enable electric vehicles to significantly over-perform their ICE-counterparts in terms of driving range. They range from lithium-air, alternative metal-ion chemistries, solid-state technology and higher energy capacitors. As of today, the next step up in driving range announced by the leading EV makers is primarily based on:

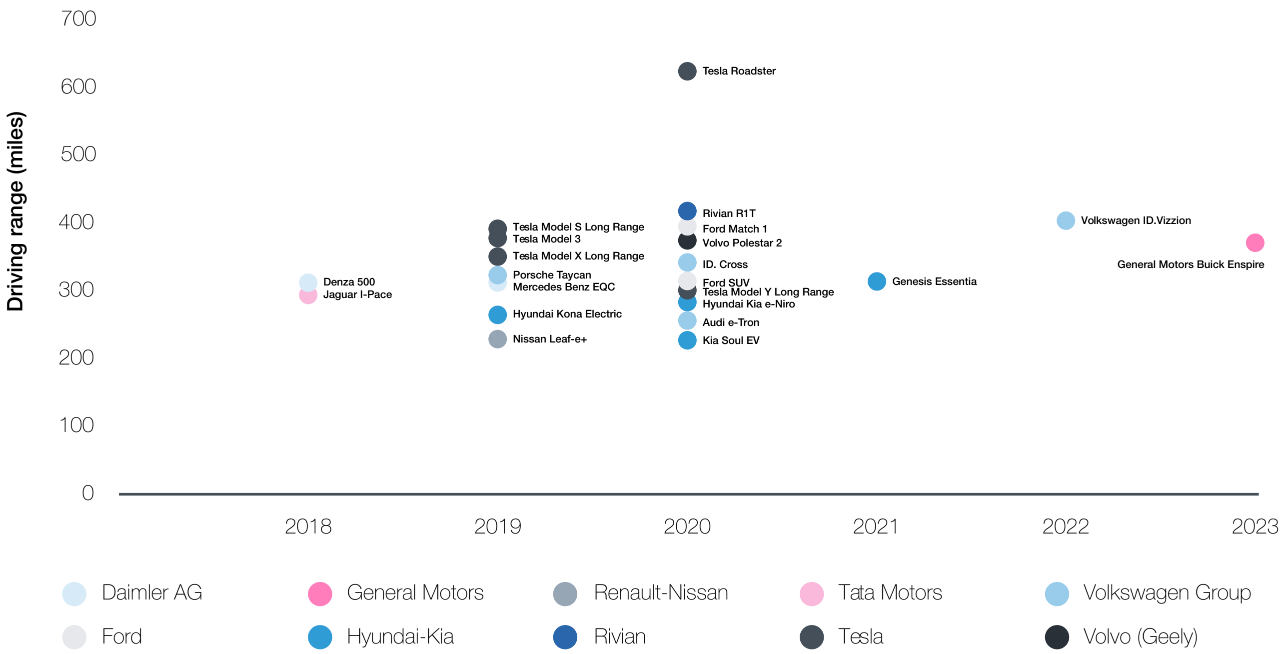
- Improved charge discharge through the refinement of existing lithium-ion battery chemistries
- Higher energy density through the introduction of new materials and optimized pack design
- Extended battery life through new battery management technologies and optimized cooling

Source: [24] [25] [26] [27] [28] [29] [30]

DRIVING RANGE BY YEAR OF COMMERCIALIZATION (NEDC CYCLE)

Car model	Driving range (miles)	Year
Denza 500	310	2018
Jaguar I-Pace	292	2018
Tesla Model S Long Range	400	2019
Tesla Model 3 Long Range	350	2019
Tesla Model X Long Range	328	2019
Mercedes Benz EQC	259	2019
Nissan Leaf-e+	239	2019
Hyundai Kona Electric	258	2019
Porche Taycan	310	2019
Audi e-Tron	249	2020
ID.Crozz	311	2020
Tesla Model Y Long Range	315	2020
Hyundai Kia e-Niro	280	2020
Tesla Roadster	620	2020
Ford SUV	300	2020
Volvo Polestar 2	310	2020
Ford Match 1	370	2020
Kia Soul EV	225	2020
Rivian R1T	400	2020
Genesis Essential	310	2021
Lucid Air	406	2021
Volkswagen ID.Vizzion	400	2022
General Motors Buick Enspire	370	2023

DRIVING RANGE BY YEAR OF COMMERCIALIZATION (NEDC CYCLE)



Source: Deloitte. (2019). New market. New entrants. New challenges. Battery Electric Vehicles.

CHINA IS LEADING THE GLOBAL EV RACE

In absolute terms, China leads the EV market with impressive sales. Yet, according to McKinsey, there is still a massive gap to fill. Passenger electric vehicles represent less than 5% of the total number of cars in circulation[31]. The adoption rate is an interesting metric that shouldn't be left alone. In this regard, some of the Nordic countries perform remarkably well, and the US, despite being the third largest market, also shows much room for growth

A surprising leader in terms of EV adoption is Norway. In the past four years, its EV penetration has increased from 11% to 32%, and in 2018, electric vehicles accounted for 49.1% of total vehicles sold. By 2025, the Norwegian government targets to solely sell electric cars[32].

The United States has been lagging behind Asia and Europe in terms of electric vehicle adoption, with EVs representing 2.1% of total vehicle sales[33]. Although the United States accounted for 20% of the global electric car fleet, its sales fell by 10% in 2019 versus 2018. Also, the spread of EVs across the states are not equally spread. For example, in California, EV sales account for about 10%, while in half of other US states EV sales are barely surpassing the 1% mark[34].

On top of accounting more than half of 2019 global sales, China's EV penetration rose from 0.3% in 2017 to 4.2% in 2019. In 2019, 3.4 million electric cars were in China, accounting for 47% of the global EV fleet, Europe, with 1.7 million electric cars, represented 25% of the global stock, and 1.5 million units in the United States represented 20%. China also has more home and work chargers than any other part of the world. Chinese government is determined to make electric vehicle manufacturing one of its top strategic focus areas. As of today, there are nearly 100 EV models available. Businesses and consumers are heavily incentivized to buy subsidized electric vehicles. Since beginning of 2019, China's New Energy Vehicle (NEV) credit system began enforcement. It forces foreign and the domestic automakers to reach a certain percentage of EVs out of their total car production or import. Being the largest market for EVs to date, Western automakers are therefore constrained to shift to electric even sooner. For instance, Volkswagen sells 40% of its cars in China and thus cannot ignore the tougher measures in place.

Given the country's targets of 20% annual EV sales by 2025, experts predict Chinese regulations and policies on EVs to tighten further. According to a Bloomberg report, in 2030 electric vehicles sales are expected to represent almost 40% of total car sales in China[35].

Favorable government policies and ease of receiving government support have surged the number of EV start-ups in China to nearly 500. This abundance of startups, combined with the established market incumbents, may temper the risk of overcapacity in the future. According to Fitch, the aggregate production capacity of electric vehicles could potentially reach 20 million units in 2020, which is ten times over the 2-million-unit government target[36].

EV SALES GROWTH: SHIFT FROM CHINA TO EUROPE

In 2019, the global EV sales surpassed 2 million units, with China remaining the leading position in EV and accounting for over 50% of global sales. However, the total 2019 sales in China declined by 2% compared with 2018. On the other side, in Europe, the second-largest electric car market, the EV sales in 2019 increased by 50% relative to 2018[37].

Furthermore, in 2019, Europe recorded the highest share of sold electric cars relative to the total car sales. The top two countries were Norway at 56% and Iceland at 22%. In the Netherlands, the EV market share increased from 6% to 15% in 2019. Germany had the highest sales volume at 109,000 units in 2019, 61% greater than in 2018. France, Netherlands and the UK each have sales volumes over 50,000 units in 2019[38].

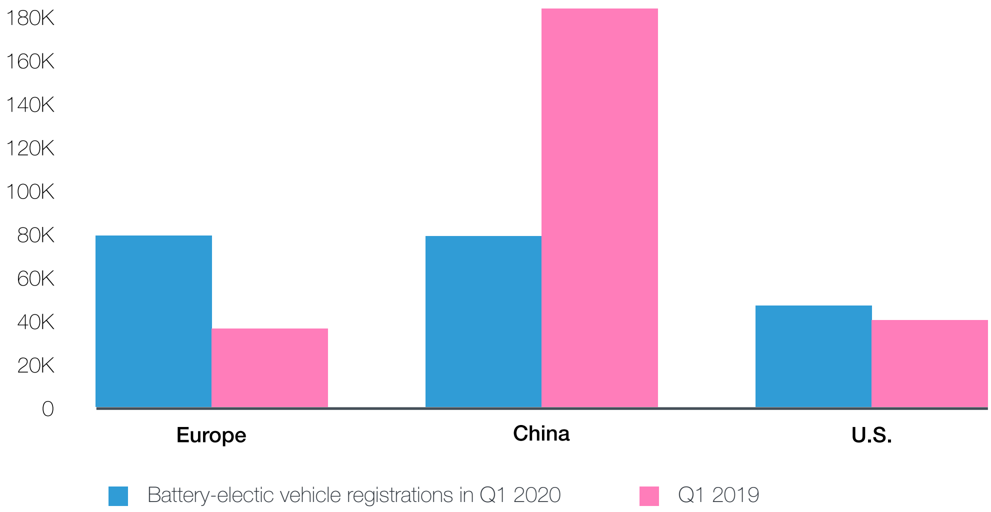
Additionally, Financial Times claims that Europe has surpassed China in attracting investment for EV and battery development, securing a total of €60B investments in 2019. In contrast, China received €17.1B in 2019. For 2018 the respective figures were €3.2B and €22B[39].

European car makers have to invest in zero-emission technologies to comply with EU rules to reduce the carbon emission to an average of 95g/km by 2021. For instance, Volkswagen has pledged to invest €33B into electric technology over the next four years aiming to bring 75 battery-powered models to market by 2029. The company has also invested in battery technologies, including €900M in JVs with Northvolt. Additionally, China's CATL and US Tesla are spending €1.8B and €4B on their battery plant and factories, respectively, in Germany. Also, in 2019, seven EU countries approved a €3.2B fund for the development of batteries over the next decade.

Source: [31] [32] [33] [34] [35] [36] [37] [38] [39]

NARROW LEAD

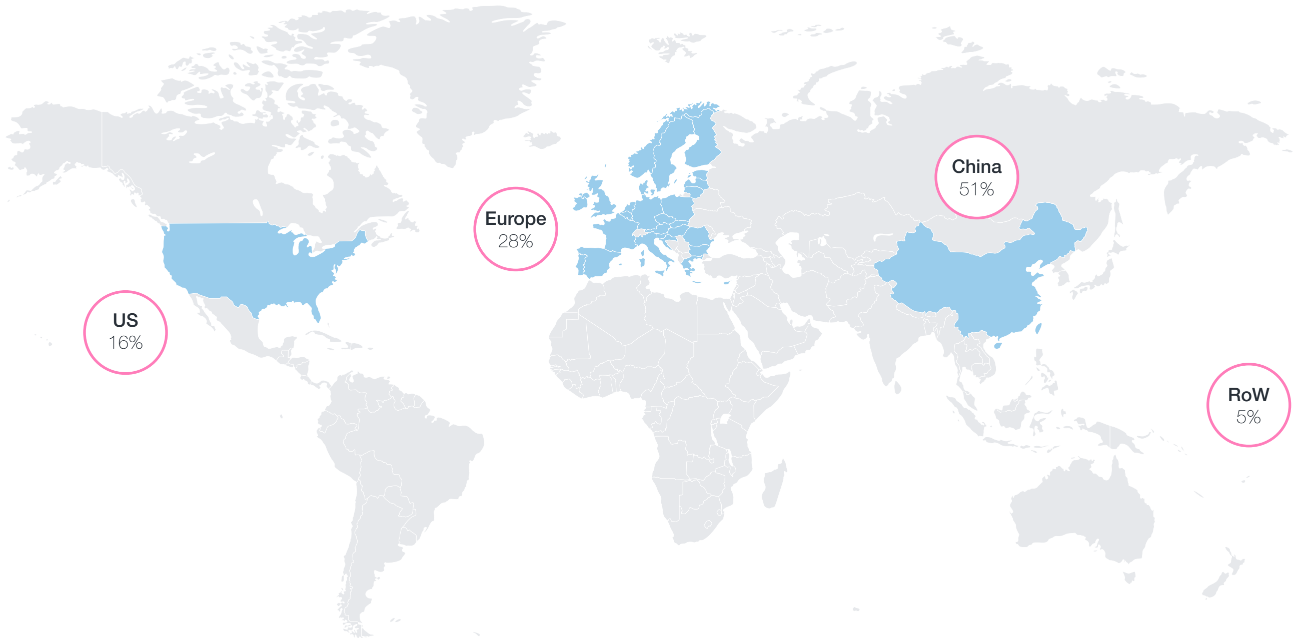
In fully-electric cars, Europe edged past China



Source: PwC, Strategy&, Bloomberg

According to the study by PwC and Strategy&, Europe overtook China in number of EV registrations in Q1 2020. Where Germany, France, the UK, Italy, and Spain receiving 79,300 EV registrations compared to 77,256 in China.

SHARE OF GLOBAL EV SALES



BloombergNEF predicts that there will be 500 million passenger EVs on the road by 2040, out of a total passenger vehicle fleet of 1.6 billion. Thus, EVs will represent about 31% of the global passenger cars, of which over 50% will be in China and parts of Europe.

THE EV TIPPING POINT

According to Deloitte, McKinsey and Bloomberg, the EVs price parity tipping point is expected to be reached between 2022 and 2025. Some market experts predict that sales of electric vehicles will surpass the number of ICE-powered counterparts by 2040. The graph in the next page outlines the time frame and its key drivers.

EV market opportunity: Forecasts of EV adoption and demand vary between studies. Some examples include:

- The Organization of Petroleum Exporting Countries predicts that electric vehicles will represent 11.6% of global fleet of passenger cars by 2040[40].
- PitchBook predicts a PHEV and BEV market to expand significantly by the mid-2020, from $95B in 2019 to $398B in 2025. The market penetration of EVs is also forecasted to grow from 2.4% in 2019 to 11.7% in 2025[41].
- The International Energy Agency "Global EV Outlook 2020" expects EVs to account for about 7% of the global vehicle fleet by 2030 and EV sales to represent 10% in 2025 and 16% in 2030 of all road vehicle sales. It also forecasts the electric two/three-wheeler fleet to increase from about 300M in 2019 to 400M globally in 2030[42].
- BP's "Evolving Transition" scenario predicts EVs to represent 15% of vehicles by 2040, with 30% of miles being traveled by electric cars[43].

Source: International Energy Agency. (2020). Global EV Outlook 2020. BloombergNEF. (2020). Electric Vehicle Outlook 2020.

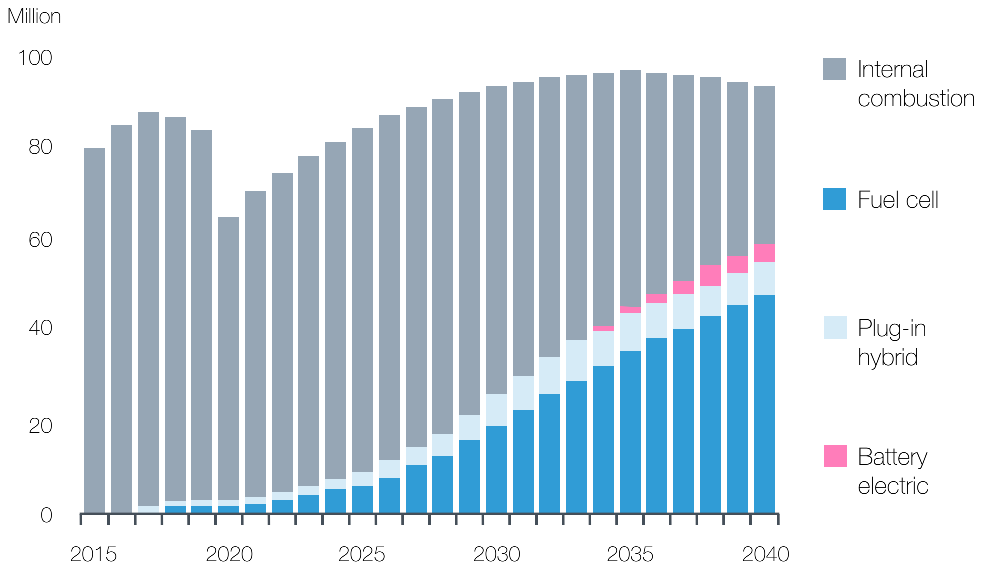
- Morgan Stanley states that electric vehicles will account for around 25% of global vehicle fleet by 2040, and over 55% by 2050[44].
- BloombergNEF EV Outlook 2020 projects that EVs will account for 58% of new car sales by 2040, and that 31% of the world's vehicle fleet will be electrified. BloombergNEF also anticipates the electric two-wheeler sales share to reach 77% and e-buses to represent 67% of the global bus fleet in 2040[45].
- RethinkX forecasts that mobility-as-a-service and driverless vehicles will allow electric vehicles to substitute the majority of passenger and commercial vehicles by 2030[46]. Contrary, a 2016 McKinsey report predicts autonomous vehicles to account for 15% and shared vehicles for less than 10% by 2030[47].

PEAK YEARS FOR VEHICLE SALES AND FLEETS, BY TYPE AND DRIVETRAM

Metric	Drivetrain	Passenger vehicles	Two-wheelers	Commercial vehicles
Sales	ICEs	2017	2026	2037
	EVs	After 2040	After 2040	After 2040
	Total	2036	2035	After 2040
Fleet	Nissan Leaf	2030	2029	2036
	BMW i3	After 2040	After 2040	After 2040
	Chevy Volt	After 2040	After 2040	After 2040

Source: BloombergNEF

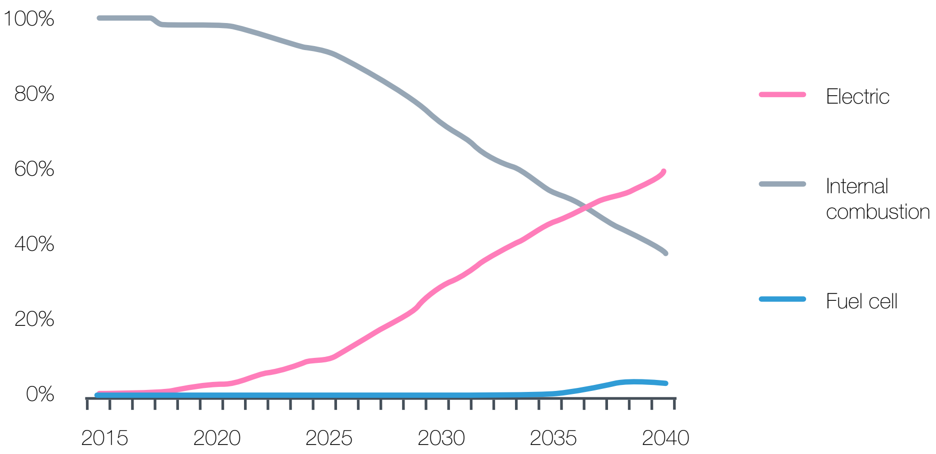
GLOBAL ANUAL PASSENGER VEHICLE SALES BY DRIVETRAIN



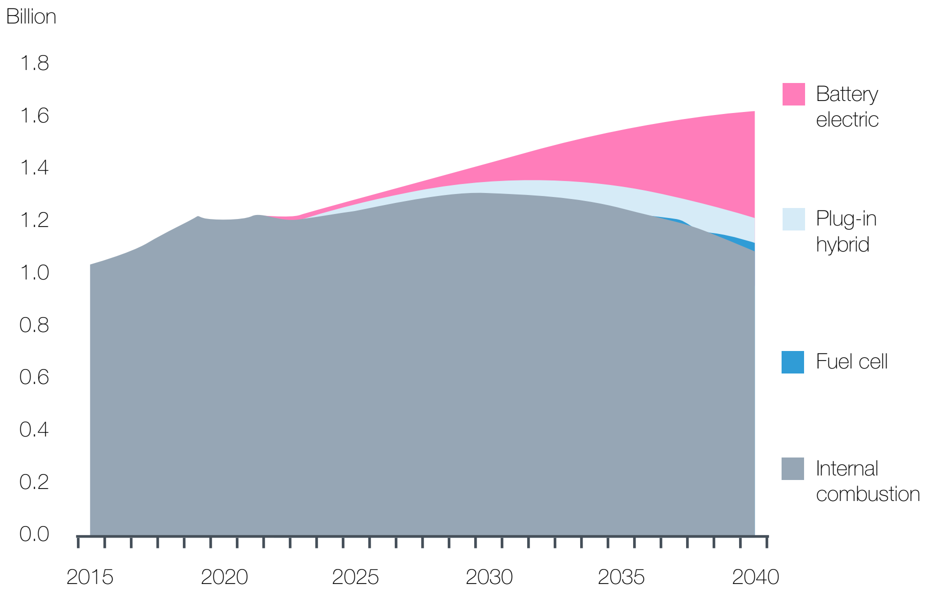
Source: BloombergNEF

Source: [40] [41] [42] [43] [44] [45] [46] [47]

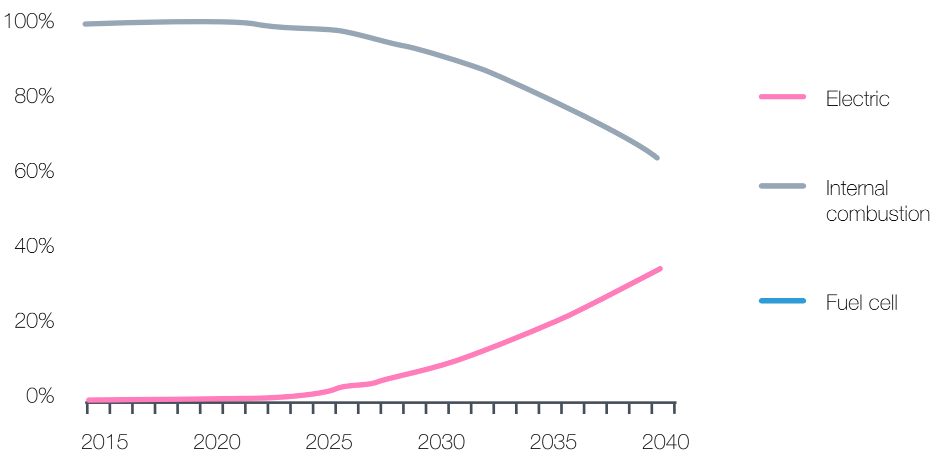
GLOBAL SHARE OF TOTAL ANNUAL PASSENGER VEHICLE SALES BY DRIVETRAIN



GLOBAL PASSENGER VEHICLE FLEET BY DRIVETRAIN



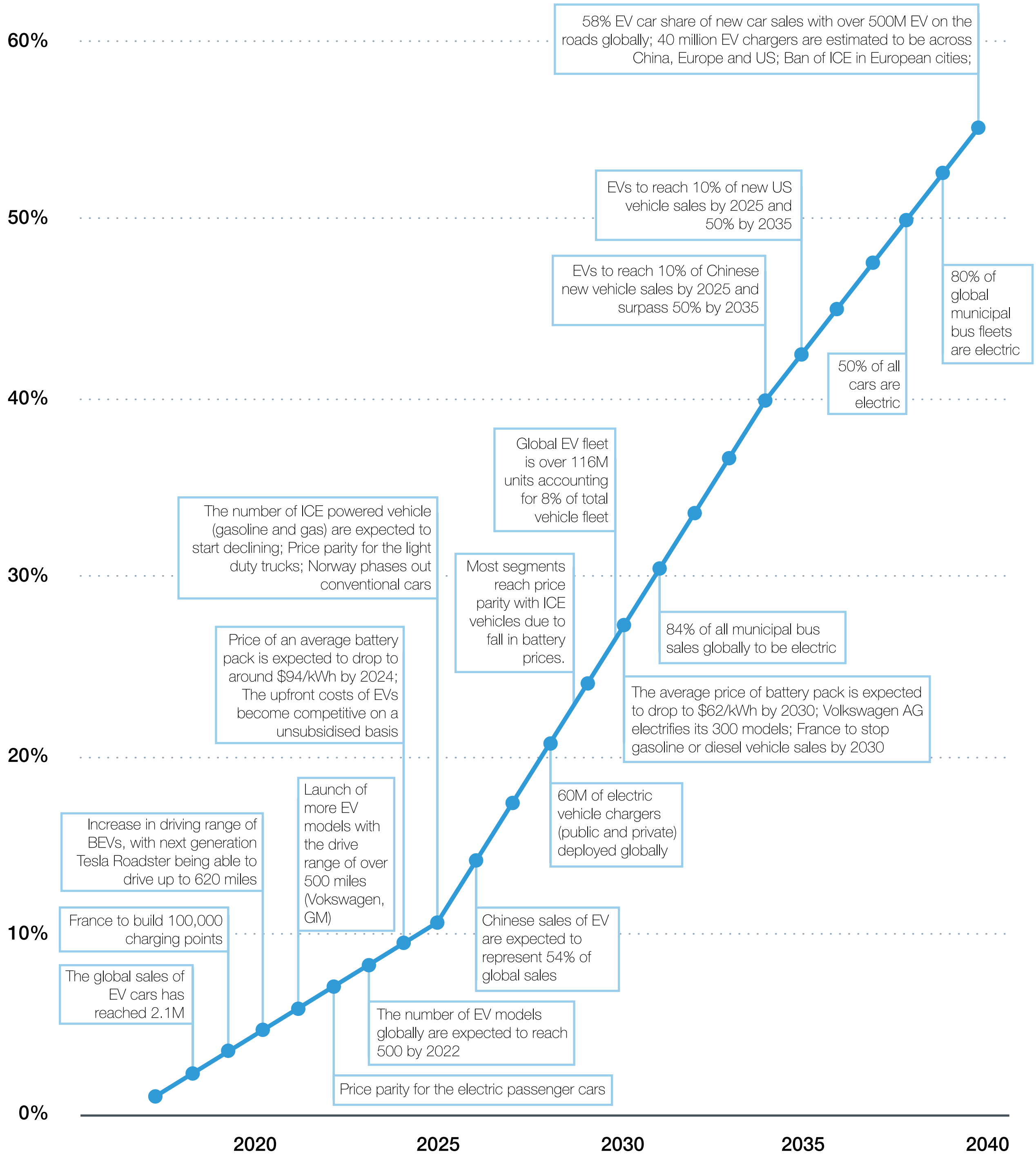
GLOBAL SHARE OF ANNUAL PASSENGER VEHICLE DISTANCE TRAVELED BY DRIVETRAIN



Source: BloombergNEF

Source: PwC, Strategy&, Bloomberg

EV ADOPTION AND THE MAIN DRIVERS



APPLICATIONS

Passenger cars

YOUXIA MOTORS, 车和家 CHJ AUTOMOTIVE, RIMAC AUTOMOBILI, LEAPMOTOR, LUCID, NIO, Faraday Future, SINGULATO 奇点汽车, HOZON, RIVIAN, ICONIQ, 小鹏汽车

Car –Sharing

enjoy, Caocao Zhuanche, ponycar, Clem', OLA, UCAR 神州优车, CleverShuttle, GoFun 首汽共享汽车, MOVE ABOUT

Commercial Vehicles

tropos technologies, inc., ARRIVAL, TEVVA, HYLIION, E/NRIDE, chanje, FIREFLY ESV, EINRIDE, udelv, THOR, NIKOLA, ORANGE EV, emoss Hybrid & Electric drive systems, VIA

Electric Motorcycles

ALTA MOTORS, ENERGICA, LIGHTNING, ZERO MOTORCYCLES, ARC, ELMOTO, LITO Green Motion, BRAMMO, FENRIS, damon

E-Bikes and E-Scooter Sharing

grin, skip, voi., TIER, scoot, grow, BIRD, LimeBike Your ride anytime

Mass transit – Electric Buses and Shuttles

GreenPower MOTOR COMPANY, EASY MILE, AURO, Linkker Intelligent eMobility, ADOMANI, PROTERRA, navya, chanje, eMotiondrive by vectia, DANCER

New Market development – Hyperloop

EuroLoop The Calibration Company, HYPERLOOP TRANSPORTATION TECHNOLOGIES, HARDT HYPERLOOP, TRANSPOD, hyperloop one, ZELEROS, HYPER POLAND, ARRIVO

New Market development- Passenger Electric Aircrafts

EHANG, AMPAIRE, LILIUM, VOLOCOPTER, EHANG, KH, OPENER, LIFT AIRCRAFT, JOBY AVIATION, EVIATION, HOPFLY BREWING CO.

COMPONENTS

EV Powertrains

MAGTEC, EDI Efficient Drivetrains, Rivian, Wrightspeed, Protean, AshWoods, Vantage Power, AVID, elaphe Propulsion Technologies, Silicon Mobility

Battery – Solid-state

ionic materials, QuantumScape, SolidPower, SAKTI3, KeraCel Inc

Battery – Lithium-ion

Enevate, Liotech, Amprius, K2 Energy, StoreDot, 24M, Phylion, Dynami, Cadenza Innovation, LithiumWerks, Farasis, Nugen Systems, Northvolt, Microvast, Sila Nanotechnologies

Battery – Super capacitors

inmatech, NAWA Technologies, Skeleton Technologies, Nesscap, IOXUS

CHARGING TECHNOLOGY

Charging Infrastructure

Chargefox, Plugless, Volta, engenie, opconnect, chargepoint, Fastned, HEVO, Tritium, Wirelane, pod POINT, Freewire, EverCharge, EVgo Fast Charging

Vehicle to grid (V2G)

Fermata Energy, ovo energy, Nuvve, The Mobility House

Charging management

Freemens, 덕우전자 Derkwoo Electronics, Idle Smart, evconnect, driivz, DUKOSI, Hubject, GBatteries, Connected Energy, upside, Eaton, greenlots, ION Energy, ChargeHub, eMotorWerks, PowerShare, 海博思创 Hyper Strong, TWAICE, ViriCiti, GreenFlux, last mile solutions

THE FUTURE OF THE EV TECHNOLOGY STACK

APPLICATIONS

PASSENGER CARS

Timeline

Emission regulations, gas prices and concerns about climate change are driving the appeal of electric cars worldwide. The biggest market now is China, but electric vehicles are also gaining popularity in Europe and the United States. According to BloombergNEF, EV sales will exceed conventional car sales globally by 2038.

Current Market

Electric cars are important to society for a number of reasons, such as low operation and maintenance costs, low environmental impact, improved safety and health benefits, as well as protection of energy security. Government incentives have been introduced by several national governments and local authorities worldwide to support the adoption of electric vehicles and their benefits to society.

It was not until the early 2000s that electric car started to gain attention of car buyers. In 2008, Tesla manufactured the first Roadster powered by a lithium-ion battery; it had the most extended drive range at that time. Since 2012 the sales of passenger electric vehicles have started to pick up, and in 2019 the global sales of EVs have reached 2M units. In 2018, Tesla was the leading seller of electric vehicles with 233,760 new registered units. In China, BYD was the second global seller with 215,800 units.

The same year, Renault-Nissan experienced significant growth but lost its third place to BAIC. In 2019, the top three EV makers in terms of sales were Tesla, BYD, and BAIC.

Chinese government has been leading the shift to new energy vehicles. While 254,000 EVs were sold in China in Q1 2019, less than 50,000 were sold in the US over the same period.

Why It Matters

According to Market Study Report, the global electric vehicles market is expected to reach $912B by 2026.

Incumbents: All established OEMs, Tesla, BYD, BAIC

Key startups: WM Motors ($5B), NIO ($5.2B), Faraday Future ($4.36B), Rivian ($6B), CHJ Automotive ($1.2B), Lucid Motors ($1.1B)

Other startups: Xpeng Motors ($4.4B), Youxia Motors ($1.3B), Leapmotor ($402M), Hozon ($636M), Lucid Motors ($1.1B), Singulato Motors ($1.18B), Byton ($1.2B), Iconiq Motors ($182M), Rimac Automobili ($159M), GLM (Acquired for $113M), Ather ($102.2M), Dubuc Motors ($2.5M), SF Motors ($13.5M), Sono Motors ($72.5M), Fisker ($66M), Terra Motors ($22.9M), Uniti ($4.5M), Mullen Technologies ($3M), ECOmove (acquired by Jiangte Motor)

NOTABLE ACQUISITIONS

2020	Fisker did reverse merger with Spartan Energy Acquisition, SPAC of Apollo Global Management, undisclosed amount
2019	NEVS acquired by Evergrande Health Industry Group, $930M
2017	Hozon acquired by Lhasa Zhixing, $50.5M
2017	GLM (Electric Vehicle) acquired by O Luxe Holdings, $113M
2016	ECOmove acquired by Jiangte Motor, undisclosed amount
2016	New Long Ma acquired by NEVS, undisclosed amount

CAR SHARING

Timeline

Car sharing is not a new concept. In fact, the first experiment program began in 1948 in Europe, and the concept was introduced in the US in the 1980s. In 2001, a US-based car-sharing company, Zipcar first added electric vehicles to its fleet. Today, the point in time in which electric cars are expected to overpass ICE counterparts in car sharing has not yet been estimated.

Current Market

As part of a bigger trend of shared mobility, car sharing is a model where people rent cars for a short period of time as an alternative to car ownership and car rental. Car-sharing companies had some electric vehicles in their fleet for the longest time. However, US demand for electric vehicles and electric car-sharing started to grow substantially only in the last few years following the decline in battery cost and government policies to cut greenhouse gas emissions. With lower maintenance, electric cars are easier to maintain for car-sharing fleets. According to the CEO of Zipcar, electric car-sharing companies can contribute to EV adoption. However, in order to scale, these same companies need accessible charging networks, affordable prices, and the support of city or transit authorities.

A survey published by Volvo and the Harris polling organization shows that 32% of respondents said a manufacturer-sponsored car-sharing program would increase the likelihood of them buying an electric car. Car-sharing also allows to collect data on consumer trends and expose users to the latest car models and features. This explains why auto companies create partnerships with car-sharing companies or launch their car-sharing platforms: Mercedes-Benz with Car2Go, BMW with ReachNow (US), DriveNow (Europe), and GM with Maven, among others.

Why It Matters

According to PitchBook global net revenue from car-sharing was approximately $3B in 2019 and expect this to grow to $10.3B by 2025, a CAGR of 23%. Increasing government incentives are expected to be one of the major factors driving the electric car-sharing market growth. According to Gartner, in some cities, the market is challenged by ride-hailing companies such as Uber and Lyft. The $42 billion-per-year rental car industry is also fighting back and shouldn't be overlooked.

Incumbents: Hertz, Enterprise Holdings, Daimler (Car2Go), BMW (ReachNow, DriveNow), GM (Maven), Audi (Audi-on-Demand), Bollore (BlueIndy), Toyota (Cité Lib), Avis Budget (ZipCar), Group PSA (Emov), Renault, Hyundai, Bosch (SPLT)

Key startups: Caocao Zhuanche ($820M), Getaround ($609.8M), Turo ($496M), OLA Electric ($322M), Zoomcar ($132.3M), Socar ($75.9M), Ponycar ($59M)

Other startups: Shouqi Zhixing (GoFun) ($32M), Envoy Technologies ($6.5M), CleverShuttle (€5M), Clem ($4.46M), Move About ($2.59M), Zen Car (€1.9M), FOMM, Tesloop ($2.2M), WaiveCar ($3.5M), EkoRent, White Car ($1.6M), Yidu Yongche, Ur Car, MyDadao (not only EV but mainly EV)

NOTABLE ACQUISITIONS

2019	Drivy bought by Getaround for $300M
2019	DriveNow acquired by BMW Group, Undisclosed amount
2019	Beijing Yiwei New Energy Technology Development Company acquired by SPI Energy, $4.57M
2016	Emov acquired by Group PSA, $14M
2016	E-Car Club acquired by Europcar, undisclosed amount
2012	Zipcar acquired by Avis Budget, $500M

Source: https://interestingengineering.com/a-brief-history-and-evolution-of-electric-cars; https://apnews.com/Business%20Wire/22912b0992924ddca1757eea6795bc1f; https://qz.com/1618775/by-2038-sales-of-electric-cars-to-overtake-fossil-fuel-ones/; https://www.electrive.com/2019/02/11/the-number-of-evs-climbs-to-5-6-million-worldwide/; https://www.greencarreports.com/news/1118838_electric-car-sharing-programs-expanding-in-u-s; https://climateprotection.org/can-car-sharing-culture-help-fuel-electric-vehicle-revolution/; https://www.marketwatch.com/press-release/car-sharing-market-size-is-expected-to-surpass-usd-11-billion-by-2024-2019-03-19; https://documentcloud.adobe.com/link/track?uri=urn:aaid:scds:US:fe41c6df-c128-4a77-ac95-46e090852dd1

COMMERCIAL VEHICLES

Timeline

On both sides of the Atlantic, government agencies are pushing towards the elimination of gasoline trucks by 2050. According to McKinsey, the e-trucks could reach between 15% and 34% sales penetration by 2030.

Current Market

In 2018, the global sales of battery electric trucks reached 155,000 units. Although there was a small decline in Chinese sales in 2018 due to a reduction in state-sponsored subsidies, there was an increase of over 60% in the rest of the world. The Interactive Analysis predicted e-truck sales to reach 180,000 units in 2019, with 90% representing light-duty e-trucks, 7% medium-duty, and nearly 2% heavy-duty models. The research firm also believes that global sales of fully electric trucks will reach $1.2M by 2025.

At the moment, smaller electric manufacturers like Nikola and Chanje are leading the trend. However, established automakers are following fast and are expected to significantly contribute to the future growth of the e-trucks adoption. Daimler and Volkswagen announced their plans to spend $3.2B and $1.7B, respectively, on electric truck R&D.

Why It Matters

According to P&S Intelligence, the commercial electric vehicle market is projected to reach $362.7B by 2025.

Incumbents: Volvo, Groupe Renault, Daimler, Scania, UPS

Key startups: Nikola ($561M), Via Motors ($57M), Hyliion ($49.35M)

Other startups: EV Transportation Services, Udelv ($19.5M), Tevva Motors ($13.5M), Einride ($35M), Inventev, Thor Trucks, ARRIVAL ($111M), Orange EV, Emoss Mobile Systems (acquired by Plastisol UK), Tropos Technologies ($1.2M), Chanje Energy

NOTABLE ACQUISITIONS

2020	Lordstown Motors did reverse merge with DiamondPeak Holdings, undisclosed amount
2020	Nikola Motor did reverse merger with VectolQ, undisclosed amount
2020	Hyliion Inc. did reverse merger Tortoise Acquisition Corp., $1.1B
2018	Wuhu Kaiyi Motors Company acquired by Push Group, $387.5M
2018	Emoss Mobile Systems acquired by Precision Camshafts, $8.2M
2017	Power Vehicle Innovation acquired by Groupe Renault
2016	Electric Vehicles International acquired by GreenFleet First Priority, undisclosed amount

ELECTRIC MOTORCYCLES

Timeline

2018 was a big year for electric motorcycle announcements. A chance for the motorcycle market to start shifting as the demand for conventional vehicles has been in decline for several years. The adoption of electric motorcycles is estimated to grow in the next few years steadily.

Current Market

The U.S. motorcycle industry has been declining since the recession. New sales dropped by roughly 50% since 2008, with a sharp fall in motorcycle ownership in the under 40 demographic. On the other hand, the global market is expected to grow 4.4% per year through 2022, due to a stronger global economy and the increasing availability of more affordable models.

The motorcycle industry has been much slower in transitioning to fully-electric vehicles. Big brands like Harley, Yamaha, and Ducati have announced but not yet launched electric models. The biggest limitation of electric motorcycles is the restricted range, namely the number of miles that can be traveled on a single charge before the vehicle needs to be recharged. There have been some modest success by industry newcomers that been able to attract new riders and close gaps with conventional motorcycles in performance and cost.

Why It Matters

According to Technavio, the global high-performance electric motorcycle market is expected to grow at 41.8% CAGR during 2017-2021. ID Tech Ex predicts that the market for smaller electric vehicles, including motorcycles, will account for about 5% of overall EV sales, generating $35B per annum by 2027.

Incumbents: Harley Davidson, Yamaha, Ducati (owned by VW group)

Key startups: Zero Motorcycles ($275M), Damon ($41M), Energica Motor ($3M)

Other startups: Damon ($4.3M), Lightning Motorcycle ($4M), ARC Vehicles ($5M), Brammo (acquired by Polaris Industries), Lito Green Motion, Elmoto (acquired by GOVECS Group), VanguardSpark, Fenris Motorcycles, SUR-RON

Source: https://interestingengineering.com/a-brief-history-and-evolution-of-electric-cars; https://apnews.com/Business%20Wire/22912b0992924ddca1757eea6795bc1f; https://qz.com/1618775/by-2038-sales-of-electric-cars-to-overtake-fossil-fuel-ones/; https://www.electrive.com/2019/02/11/the-number-of-evs-climbs-to-5-6-million-worldwide/

NOTABLE ACQUISITIONS

2019	Alta Motors acquired by Zero Motorcycles, undisclosed amount
2019	Stacyc acquired by Harley Davidson, undisclosed amount
2018	Ampere Vehicles acquired by Greaves Cotton, $101M
2018	Elmoto acquired by GOVECS Group, undisclosed amount
2017	Brammo acquired by Cummins, $168M
2016	Torrot Electric Europe acquired by Gas Gas, $25.7M
2016	Taizhou Taiying Electric Vehicle acquired by Dynavolt Renewable Power Technology, undisclosed amount

E-BIKES AND E-SCOOTERS SHARING

Timeline

The earliest well-known bicycle program started in 1965 in Amsterdam. In 2010, JUMP Bikes launched Social Bicycles, the first smart-bikes with integrated GPS, payment systems, and locks that kicked off the dock less revolution. A few years later, in 2017, the first dock less electric kick scooter sharing services started in the US.

Current Market

Micromobility is a brand-new category of vehicles used for short-distance trips and is thought to become an alternative to traditional modes of transportation. Regarding personal transportation solutions, two main types of vehicles prevail: e-bikes and e-scooters.

With increasing urbanization, daily distances have shrunk with over a half of all the trips in the US and Europe being under 5 miles. For example, 60% of the trips in the US are 5 miles or less. This means that the majority of the daily trips fall under the micromobility category. This has surged the development of docking or dock less bike and scooter companies as well as e-scooter and e-bikes manufacturers. Easy-to-ride bicycles still come with major issues, such as sidewalk litter, rampant theft, and mass bicycle graves filled with broken and abandoned bikes.

Source: https://blog.marketresearch.com/key-global-motorcycle-industry-statistics-growth-regions; https://techcrunch.com/2017/03/23/zero-motorcycles-cto-abe-askenazi-on-the-future-of-two-wheeled-evs/; https://www.prnewswire.com/news-releases/the-global-high-performance-electric-motorcycle-market-is-forecasted-to-grow-at-a-cagr-of-4180-during-the-period-2017-2021-300546695.html; https://www.360marketupdates.com/global-high-performance-electric-motorcycle-market-2017-2021-11170956

Why It Matters

According to Markets and Markets, the global e-bike market is projected to reach $38.6B by 2025, growing at a CAGR of 9.01%. In the meantime, Boston Consulting Group estimates that the global market for e-scooters, overlapping e-bikes, is expected to reach between $40B and $50B by 2025. Given that shared e-scooters are generally used for short trips, they will likely expand rather than erode the existing market of on-demand mobility. PitchBook forecasts the global micromobility industry to represent a $105B total addressable market by 2030.

Incumbents: Uber (JUMP Bike), Lyft, Ford (Spin), General Motors, Alibaba (acquired Ofo), Meituan Dianping (Mobike), Didi Chuxing, Grab (GrabCycle), Taxify (Bolt), RazorUSA

Key startups: hellobike ($3.5B), Lime ($947M), Bird ($776M), gogoro ($480M), Tier Mobility ($159M), Skip Scooters ($131M), Grow Mobility (Yellow & Grin) ($150M)

Other startups: VOI Technologies ($168M), Cityscoot (€78.5M), Wheels ($89.7M), Wind Mobility ($72M), felyx (€4.1M), Swiftmile ($11.1M), COUP, Telepod, Yulu Bikes, Zhaodianlv, U-Bicycle, Scuter, Scoot Networks (acquired by Bird), Circ (acquired by Bird)

NOTABLE ACQUISITIONS

2020	Circ acquired by Bird, undisclosed amount
2020	Pushme acquired by TIER, undisclosed amount
2019	Scoot acquired by Bird, $25M
2019	Grin and Yellow jointly raised $150M and merged to form Grow Mobility
2018	Mobike acquired by Meituan Dianping, $2.7B
2018	Jump Bikes acquired by Uber, $200M
2018	Motivate acquired by Lyft, $250M
2018	Spin acquired by Ford, $100M
2018	Poleis Consulting acquired by Europcar, undisclosed amount
2018	Ride acquired by Grin scooter, undisclosed amount
2018	Grin merged with Ride
2016	Wattmobile acquired by Indigo Infra

Source: https://www.bcg.com/publications/2019/promise-pitfalls-e-scooter-sharing.aspx; https://www.prnewswire.com/news-releases/the-global-e-bike-market-is-estimated-to-be-usd-21-1-billion-in-2018-and-is-projected-to-reach-usd-38-6-billion-by-2025--at-a-cagr-of-9-01-300818779.htm; https://www.marketsandmarkets.com/Market-Reports/electric-bike-market-110827400.html; https://documentcloud.adobe.com/link/track?uri=urn:aaid:scds:US:fe41c6df-c128-4a77-ac95-46e090852dd1

MASS TRANSIT – ELECTRIC BUSES AND SHUTTLES

Timeline

Bloomberg predicts that by 2030, 84% of all municipal bus sales in the US will be electric. Europe is expected to transition to electric power by 2030. On the other hand, China is already far ahead, with Shenzhen being the first city in the world to switch to all-electric buses.

Current Market

Urban electric buses represent the fastest-growing part of the electric vehicle market with a CAGR of over 100% since 2013, compared with a 60% CAGR of fully electric passenger cars. In 2019, the global electric bus fleet was about 513,000 units, up 17% from 2018. Although, China has experienced the YoY registrations drop by about 20% in 2019 - due to a decrease in purchase subsidies - it is still accounted for 98% of total eBus fleet. However, Europe and the United States saw an increase in the number of eBuses.

Public demand and government subsidies are pushing the market towards full electrification. However, the vehicles will not provide a total-cost-of-ownership advantage until 2025-2030. This is explained by the high up-front costs of the electric buses and the necessary infrastructure and battery swaps during the vehicle's lifespan. Although this creates a challenge to the mass adoption of electric buses, it also leads to new business models, such as Energy-as-a-Service, joint procurement and bus sharing.

Why It Matters

According to Renub Research, the Electric Bus Market is expected to surpass $400B by 2024. While Bloomberg predicts eBuses to comprise over 67% of the global bus fleet in 2040.

Incumbents: Yutong, BYD, Volvo, Solaris, VDL, Renault, Alstom

Key players: Proterra ($570M), Navya ($70M in funding and $41M at IPO), EasyMile (€22M)

Other startups: Dancerbus, Vectia Mobility, Linkker, Auro Robotics (acquired by Ridecell), Wuhu Kaiyi Motors Company (acquired by Push Group), GreenPower Motor Company (Public), Adomani (Public), Chanje Energy

NOTABLE ACQUISITIONS

2018	FDG Electric Vehicles Limited acquired by CAR Inc, $81M
2018	Solaris Bus & Coach acquired by CAF, undisclosed amount
2017	Auro acquired by Ridecell, $20M
2017	Suzhou E Motors Electric Bus Company acquired by Tantech Holdings, $15.2M
2017	Power Vehicle Innovation acquired by Groupe Renault, undisclosed amount
2016	Chariot acquired by Ford Motor Company, undisclosed amount
2016	Granton Bus acquired by ZTE, undisclosed amount

NEW MARKET DEVELOPMENT – HYPERLOOP

Timeline

The increasing global demand for the fastest and most economical modes of transportation is powering the R&D behind new technologies, such as Hyperloop. At present, hyperloop is in the development stage. However, the technology could be commercialized as early as 2022, according to Markets and Markets.

Current Market

Despite being an early technology adopter, rail has been overlooked by market incumbents. Driven by rising demand for a cheap and fast mass transportation system, Hyperloop has been under active development since 2013.

The system is based on transport containers or pods that are shot point-to-point at speeds above 1,000 kph through a quasi-evacuated tube. For instance, a hyperloop trip from Los Angeles to San Francisco will take 30 minutes compared to a 6-hour road journey. The technology requires less expensive infrastructure and is less vulnerable to earthquakes and other natural disasters.

Currently, Virgin Hyperloop One Systems and Hyperloop Transportation Technologies (HTT) are two of the most established hyperloop companies. To study and demonstrate the benefits of maglev and vacuum tubes, Virgin Hyperloop One built a 500M 'DevLoop' test ring in Nevada. HTT has developed a mass-transit solution that can transfer vast numbers of freight and passengers (approximately 164,000 a day) at a maximum speed of 1,223 km/h. One of the company's technologies breakthroughs is a passive magnetic levitation system or maglev. It allows the capsules to go through a low air-pressure tube using a minimal amount of energy. HTT runs on electricity, in many places, entirely generated by the photovoltaic panels that cover its above ground tracks. Most routes would be two to three times more energy efficient than air travel per passenger mile.

The first commercial hyperloop is expected to be launched in the UAE. It will be operated by HTT and is backed by the support from local government and capital investors. In 2019, HTT was the first company to reach full-scale testing stage in Toulouse and has completed the first feasibility in the USA. It has also received approval from the governments of Slovakia and the Czech Republic to run route feasibility studies. If successful, HTT will start route construction, which is expected to be built as early as 2024. In addition, HTT has signed agreements in twelve countries, including the United States, France, Germany, China, and South Korea.

Why It Matters

Hyperloop is expected to be the fifth mode of transportation in the future. According to Markets and Markets, the hyperloop technology market is projected to be worth $1.35B in 2022 and is expected to reach $6.34B by 2026, with a CAGR of 47.20% during that period.

Incumbents: Dinclix GroundWorks

Key startups: Virgin Hyperloop One ($368.4M), Hyperloop Transportation Technologies ($245M), The Boring Company ($233M)

Other startups: TransPod ($36.7M), Hardt Global Mobility ($7M), Zeleros ($8.1M), Arrivo, euroLoop, Hyper Poland

NEW MARKET DEVELOPMENT – AIRCRAFTS

Timeline

Norway is optimistic enough to announce that the country wants all domestic flights to be electric by 2040. It is probably not so far-fetched given that a company has already announced a full-electric passenger fleet by 2022.

Current Market

One of the key challenges in building electric aircraft is the weight to power ratio of batteries. Although the best batteries are capable of storing approximately 40 times less energy per unit of weight compared to aviation turbine fuel (ATF), a larger share of their energy can be deployed to drive motion. Eventually, ATF still contains 14 more usable energy than the lithium-ion battery for a given weight. This is why short hauls are the most immediate market for electric passenger aircraft.

Harbour Air, North America's largest seaplane airline, and the startup magniX announced their partnership to build the world's first all-electric operating airline by 2020s. They plan to develop new vehicles by equipping an existing fleet with electric motors and lithium-ion battery packs. Indeed, their target market is vast: 45 million flights completed worldwide in 2018, roughly 5% were under 100 miles. In December 2019, the first fully-electric commercial passenger aircraft flight took place, when a retrofitted seaplane took a 15-minute flight from Vancouver, British Columbia.

The idea of flying cabs that carry passengers' short distances over urban areas is also increasingly attracting attention. Dozens of companies, including Boeing, Airbus (CityAirbus) and Uber (UberAir), are working on eVTOL (electric vertical take-off and landing). In 2019, several pilot flights of small battery-electric aircraft had been completed.

Source: https://www.eta.co.uk/2017/02/24/our-friends-electric-how-europe-is-cleaning-up-its-rail-ways/; https://www.mordorintelligence.com/industry-reports/hyperloop-technology-market; https://www.marketsandmarkets.com/PressReleases/hyperloop-technology.asp; https://www.prnewswire.com/news-releases/hyperloop-transportation-technologies-moves-forward-with-first-commercial-hyperloop-system-in-the-uae-300632281.html

Why It Matters

According to BIS Research, the eVTOL aircraft market is projected to reach a $524.0M valuation by 2025. It is projected to grow at a CAGR of 13.75% from 2025 to 2035, reaching a total value of $1.9B by 2035.

Incumbents: Boeing, Airbus, Bell, Honeywell, Geely

Key startups: Joby Aviation ($728.3M), Lilium Aviation ($391.5M), Eviation Aircraft ($200M), Volocopter ($136.4M) , Ehang ($92M)

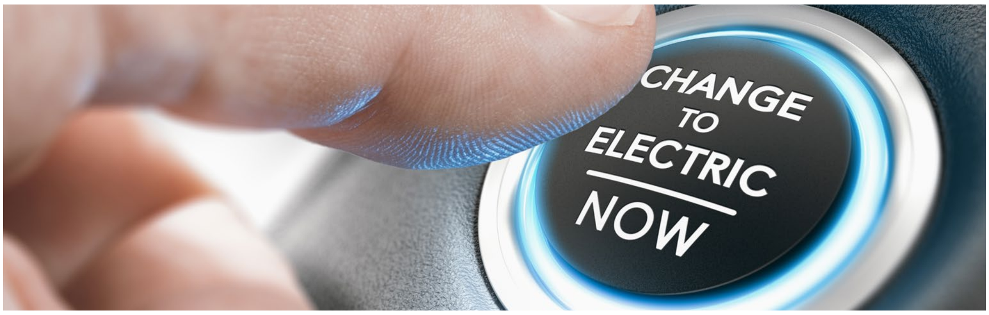
Other startups: Kitty Hawk ($75M), Skyryse ($40M), XTI Aircraft ($30M), AeroMobil ($23.8M), Ampaire ($2.7M), ZEVA AERO ($1.7M), HopFlyt, Lift Aircraft, Wright Electric

NOTABLE ACQUISITIONS

2019	Siemens' electric aircraft business acquired by Rolls-Royce
2018	WestWind Technologies acquired by Strata-G Solutions, undisclosed amount
2017	Aurora Flight Sciences acquired by Boeing, undisclosed amount
2017	Terrafugia acquired by Geely, undisclosed amount

COMPONENTS

EV POWERTRAINS



Timeline

Electric cars, and therefore electric powertrains, are as old as cars themselves. The first practical electric car was developed in 1884 and in 1900, over a third of all vehicles on the road were electrictrified. By the 1930s, the low cost of crude oil, the cheaper Ford assembly line, and the introduction of the highway system drove the electric cars away. Today, the inevitable trend towards electrification supports the recent developments in the powertrain.

Source: https://www.prnewswire.com/news-releases/global-electric-vtol-evtol-aircraft-market-to-reach-1-9-billion-by-2035--300984170.html; https://www.greentechmedia.com/articles/read/another-route-to-all-electric-flight-convert-existing-planes#gs.fac1tc; https://www.prnewswire.com/news-releases/evtol-aircraft-market-worth-411-million-by-2030---exclusive-report-by-marketsandmarkets-300813795.html

Current Market

A powertrain is a mechanism that transmits the drive from the engine of a vehicle to its axle.

In the present industry scenario, the battery electric vehicle powertrain is expected to be one of the most widely used product types while value creation from conventional powertrains is projected to fall. Therefore, the largest manufacturers are massively investing in the development of new electric models in order to compensate for their future losses.

However, at this point in time battery electric powertrains have significantly higher material costs. In addition, even if manufacturing process efforts are substantially lower, they still demand highly different processes. Investments into R&D and manufacturing are significant on top of requiring considerable lead time.

As a consequence, business transformation in the industry has already started to respond to future demand and billions have been invested.

Current Market

According to Market Study Report, the global electric powertrain market is projected to be worth $568.6B by 2026.

Incumbents: AVL, Federal Mogul (Controlled Power Technologies), Mitsubishi Electric, Magna, Valeo, Continental, Automation Tooling Systems, Jayem Automotive, AllCell Technologies

Key startups: Rivian ($6B), Rimac Automobili ($159.5M), Wrightspeed Powertrains ($58.2M), QM Power ($17M)

Other startups: XL Hybrids ($45.7M), Avid Technology ($12.5M), Silicon Mobility ($10M), Vantage Power (hybrid) ($7.2M), Toroidion, Ashwoods Automotive, Efficient Drivetrains (acquired by Cummins), Elaphe Propulsion Technologies, Magnetic Systems Technology, QEV Technologies

NOTABLE ACQUISITIONS

2019	Vantage Power acquired by Allison Transmission, $22.3M
2019	SMRE Spa acquired by SolarEdge, $85M
2019	EM-Motive acquired by Robert Bosch, undisclosed amount
2018	Federal Mogul acquired by Tenneco, $5.4B
2018	TM4 acquired by Dana, $122M
2018	Efficient Drivetrains acquired by Cummins, undisclosed amount
2017	Sevcon acquired by BorgWarner, $193.7M
2017	UQM Technologies acquired by Danfoss, $100M
2017	Controlled Power Technologies acquired by Federal Mogul, undisclosed amount
2017	Visedo acquired by Danfoss, undisclosed amount
2016	Punch Powertrain acquired by Yinyi Group, $1.1B
2016	AC Propulsion acquired by SF Motors, $100M
2016	Brusa Elektronik acquired by AB Motion Technologies, undisclosed amount
2016	Electric Power Conversion acquired by Visedo, undisclosed amount
2016	Mission Motors acquired by Vayon Holdings

BATTERY - LITHIUM-ION

Timeline

Rechargeable lithium-ion technology has existed for decades. It was invented by an Exxon Mobil Corp. researcher in the 1970s and eventually commercialized by Sony in 1991. It is now the most commercially popular rechargeable battery across many of industries including the auto market.

What it is

A lithium-ion battery is the most adopted battery technology among EV manufacturers. As compared to traditional battery technology, lithium-ion batteries have faster charging speed, longer lifespan, and higher power density in a lighter package. In addition, its price continues to decline: $1,160 per kWh in 2010, $176 per kWh in 2018 and BloombergNEF forecasts $100 per kWh by 2024.

However, lithium-ion batteries have disadvantages such as low power densities, long charging times, and poor cycle stability. The auto industry needs to develop a state-of-the-art battery technology to develop an electric vehicle that is more cost-efficient, safer, and capable of traveling long distances on a single charge.

Why It Matters

According to UBS, the electric vehicle battery market will be worth $84B by 2025, compared to $23B today.

The falling battery prices, coupled with rising global automakers commitments, are expected to bring price-competitive electric vehicles. For instance, Daimler is planning to buy $23B worth of battery cells by 2030. The further increase demand for EVs will result in increased demand for lithium-ion batteries. And this will remain valid until a new battery can outperform lithium-ion technology in production.

Incumbents: Contemporary Amperex Technology, Panasonic, LG Chem, BYD, Tesla

Key startups: Northvolt ($2.7B), Farasis Energy ($815M), Liotech ($453.72), Microvast ($450M), Sila Nanotechnologies ($343.5M), Amprius ($141.9M)

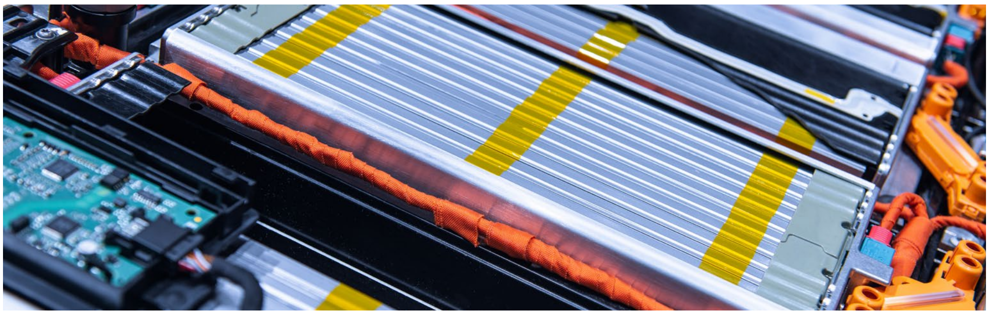
Other startups: StoreDot ($146M), Enevate ($106.2M), Phyllion Battery, 24M ($65M), Dynami, Cadenza Innovation ($8.8M), Hyperdrive Innovation ($6.7M), K2 Energy Solutions ($1.3M), Lithium Werks, Nugen Systems

---

Source: https://interestingengineering.com/a-brief-history-and-evolution-of-electric-cars; https://apnews.com/Business%20Wire/22912b0992924ddca1757eea6795bc1f; https://qz.com/1618775/by-2038-sales-of-electric-cars-to-overtake-fossil-fuel-ones/; https://www.marketwatch.com/press-release/electric-powertrain-market-size-is-expected-to-exhibit-usd-5686-billion-by-2026-2019-03-08

2019	Shanghai CENAT New Energy acquired by Evergrande Real Estate Group, $154.7M
2019	XALT Energy acquired by Freudenberg Sealing Technologies, undisclosed amount
2019	Sonnen acquired by Royal Dutch Shell, undisclosed amount
2019	Kokam acquired by SolarEdge, $88M
2018	ElectRoad (wireless) acquired by Biomedix Incubator, undisclosed amount
2018	Accurate Smart Battery Systems acquired by Voltabox, $5.7M
2017	Automotive Energy Supply acquired by Envision Energy, undisclosed amount
2017	Shenzhen BAK Battery acquired by Wuhu Token Science Company, $851M
2017	Sony (Battery Business) acquired by Murata Manufacturing Company, $166M
2017	GS Yuasa (Industrial Batteries & Power Sources Business) acquired by Maxell, undisclosed amount
2017	EAS Germany acquired by Monbat, undisclosed
2017	The Energain of Dupont acquired by Solvay, undisclosed amount
2016	Pride New Energy Battery Technology acquired by Guangdong Dongfang, $434M
2016	Guangdong Dongfang, $434M
2016	SAFT acquired by Total, $1.1B

BATTERY – SOLID-STATE



Timeline

No one manufacturer or supplier has succeeded in manufacturing the technology in production yet. However, many automakers have already announced that they are planning to utilize solid-state batteries in their vehicles. Toyota plans to showcase its prototype in 2021 and to commence limited manufacturing in 2025. Panasonic says solid-state batteries should be ready for production by 2030.

Source: https://www.sciencedirect.com/topics/materials-science/lithium-ion-battery; https://www.ttnews.com/articles/race-next-generation-battery-supremacy-has-early-leader; https://www.autonews.com/automakers-suppliers/theres-nothing-better-lithium-ion-battery-coming-soon; https://techcrunch.com/2018/12/11/daimler-is-buying-nearly-23-billion-of-battery-cells-to-power-its-electric-vehicle-offensive/

What it is

Solid-state batteries have cells that are made of solid and "dry" conductive material. They prove to be a solution to the intrinsic problems of the existing lithium-ion counterparts being smaller, cheaper, and safer while offering higher-capacity. There is a development race between the industry players, and the winner stands to gain a massive advantage.

Today, durability is a definite concern, and the batteries have been known to lose a considerable amount of their charge capacity in extremely cold weather. Also, the cost is one of the biggest hurdles. A solid-state battery is very expensive to manufacture. It is also cost-preventative for production cars and economies of scale cannot solve this issue yet. In December 2020, Toyota introduced its solid-state battery and is expecting to unveil the prototype in 2021.

Why It Matters

According to Research and Markets, the global automotive solid-state battery market is expected to reach $1.94B by 2030. The study also shows that complicated manufacturing process and high cost of solid-state battery will be the main hurdles of market growth.

Nevertheless, there is a high two digits billion market scenario if some of the drawbacks are solved. This is why many OEMs, suppliers and newcomers are investing in this technology. They include Ford, Toyota, BMW, Honda, Hyundai, and Nissan, and LG Chem.

Incumbents: Toyota, BMW, Honda, Hyundai, Nissan, Bollore Group (subsidiary Blue Solutions)

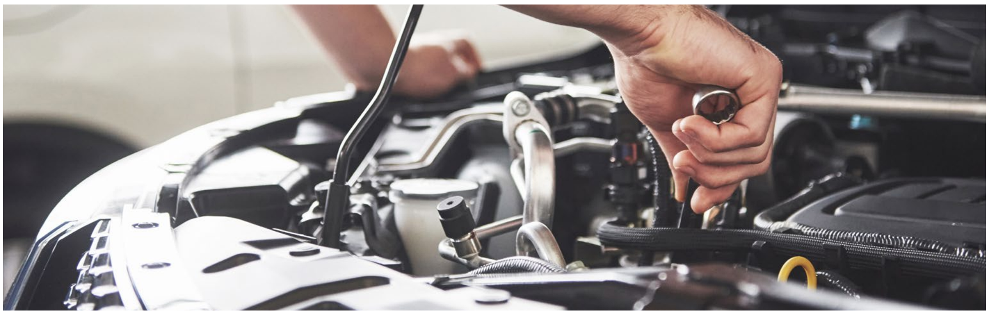
Key startups: QuantumScape ($496M), Ionic Materials ($85.1M), Solid Power ($28M)

Other startups: KeraCel, Sakti3 (acquired by Dyson)

NOTABLE ACQUISITIONS

2015	Sakti3 acquired by Dyson, $90M
2015	Seeo acquired by Robert Bosch, undisclosed amount

BATTERY – SUPER CAPACITORS



Timeline

Back in 2013, Toyota revealed a concept car with a supercapacitor. A promising technology on many aspects, though not yet a replacement to the conventional battery pack. In the meantime, the technology key characteristics already enable many applications in automotive systems, such as start-stop, ignition, kinetic energy recovery, among others.

What it is

Super capacitors or ultracapacitors are the energy storage system that stores energy electrostatically, rather than chemically like a battery. They also show significant benefits over batteries as they are much lighter, safer, and non-toxic. More importantly, super capacitors have a much higher power density, which means they are ideal for high-drain applications like charging a car or powering an acceleration.

China is already using super capacitors to power electric busses. Super capacitors are then charged at the bus stop with a pantograph - like a tram. Super capacitors are capable of charging 50% of a bus battery in 30 seconds.

But can they replace batteries? At the moment, batteries have a much higher energy density, which means they allow for a device to run longer. However, market players expect big progress in super capacitors with a next-generation supercapacitor being able to store more energy than a lithium-ion battery, while still releasing its energy up to 10x faster. A scenario would be one full charge in minutes for more than double the current driving limit of an electric car. This is why manufacturers are stepping into the space. For example, Tesla acquired an ultracapacitor and battery component manufacturer, Maxwell Technologies.

Why It Matters

According to Research and Markets, the global automotive supercapacitor market is expected to reach $6.91B by 2028. Given that the auto industry is currently developing a supercapacitor solution that can be used as a standard electric power option, a higher market scenario is also to be considered.

Incumbents: Maxwell Technologies, Eaton Corporation, Panasonic

Key startups: Ioxus ($163.5M), Skeleton Technologies (€46.4M)

Other startups: Nesscap Energy (acquired by Maxwell), NAWATechnologies (€24.5M), Inmatech ($1.8M)

NOTABLE ACQUISITIONS

2019	Maxwell Technologies acquired by Tesla, $218M
2017	Nesscap Energy acquired by Maxwell Technologies, $25.3M

Source: https://www.china-certification.com/en/china-announces-the-mass-production-of-solid-state-batteries/; https://www.inc.com/magazine/201808/steve-goldberg/fisker-automotive-solid-state-battery.html; https://www.alliedmarketresearch.com/solid-state-batteries-market; https://www.globenewswire.com/news-release/2019/02/11/1716375/0/en/Global-Automotive-Solid-State-Battery-Market-2019-2030-The-Market-is-Driven-by-the-Electric-Vehicle-Demand-for-Safe-and-Efficient-Battery-Technology.html; https://www.supercaptech.com/the-supercapacitor-electric-bus-is-adopted-in-china; https://interestingengineering.com/could-ultracapacitors-replace-batteries-in-future-electric-vehicles; https://www.prnewswire.com/news-releases/global-automotive-supercapacitor-market-to-reach-6-91-billion-by-2028--300754766.html

CHARGING TECHNOLOGY

CHARGING INFRASTRUCTURE

Timeline

As of the end of 2019, there were about 7.3 million chargers worldwide, of which about 6.5 million were private, light-duty vehicle slow chargers. Publicly accessible chargers accounted for 12% of global chargers in 2019, 60% higher than in 2018. Lack of charging infrastructure could become an obstacle to EV adoption.

What it is

Overnight household charging can be limiting in the time and the distances that can be covered from home. This has been a discouraging factor for EV adoption. The answer has been the increasing deployment of fast chargers at public places.

Why It Matters

According to Grand View Research, the global electric vehicle charging infrastructure (EVCI) market size is expected to reach $63.9B by 2025 growing at a CAGR of 32.6% from 2019.

Incumbents: ABB, AeroVironment, Schneider Electric, BP (Chargemaster), Eaton, Siemens, General Electric, Total (G2Mobility), Royal Dutch Shell (NewMotion), ENGIE (EVBox, Chargepoint), EDF (POD Point)

Key startups: Romeo Power ($1.3B), Volta Charging ($176.4M), FreeWire Technologies ($42M), QuantumScape

Other startups: EVgo, Fastned (€60.5M), Tritium ($48M), ChargeFox ($15M), Engenie ($9.4M), EverCharge ($9.6M), ElectRoad, Wirelane, HEVO Power, OpConnect, Plugless, QPower

NOTABLE ACQUISITIONS

2020	POD Point acquired by EDF, undisclosed amount
2019	Chargepoint Services acquired by ENGIE, undisclosed amount
2019	Qualcomm Halo acquired by WiTricity, Announced
2019	Flow Charging acquired by Eneco eMobility, undisclosed amount
2018	Chargermaster acquired by BP, $170M
2018	Garage Juice Bar acquired by Oasis Charger, $2.5M
2018	EVTronic acquired by EVBox, undisclosed amount

2018	Otera acquired by Roadworks, undisclosed amount
2018	eeMobility acquired by Statkraft, undisclosed amount
2018	G2Mobility acquired by Total, undisclosed amount
2018	Esarj acquired by Enerjisa Energy, undisclosed amount
2018	StoreDot acquired by BP, undisclosed amount
2018	Allego (Electric Vehicle charging solutions) acquired by Meridiam Infrastructure, undisclosed amount
2017	Meridiam Infrastructure, undisclosed amount
2017	Nanjing Nengrui Automation Equipment Company acquired by Jilin Jinguan Electric Company, $220.8M
2017	Elektromotive Chargemaster, $10.48M
2017	Estar Investments acquired by Ziwo Holdings, $0.42M
2017	EVBox ENGIE, undisclosed amount
2017	eMotorWerks acquired by EnerNOC, undisclosed amount
2017	NewMotion acquired by Royal Dutch Shell, undisclosed amount
2017	Salto Ladestasjoner acquired by Defa-Norway, undisclosed amount
2017	ElectRoad (wireless) acquired by Biomedix Incubator, undisclosed amount

CHARGING MANAGEMENT

Timeline

According to Mohammed Beshir, a professor at USC's Viterbi School of Engineering, EVs will impact the power grid when 15% or more of the vehicles become electric. As of 2019, in the US, 0.3% of the cars are electric. Norway is leading with 6.5% and China, who leads in a number of EVs sold, has reached 0.5%.

Source: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/charging-ahead-electric-vehicle-infrastructure-demand; https://www.theverge.com/2018/10/3/17933134/ev-charging-station-network-infrastrcuture-tesla; https://cleantechnica.com/2018/03/07/stop-comparing-number-gas-stations-ev-charging-stations/

What it is

Despite the apparent advantages of electric motors over the internal combustion engine, they do present an interesting problem: as EV adoption increases, the utility sector might face disruption. If all cars in the US switch to electricity, the national grid will fail. However, the situation might not be as critical as it appears. According to a number of experts, the investment to accommodate this new demand may be smaller than one could expect. Additionally, many states already have sufficient generation capacity if vehicles are charged during off-peak hours. In the future, there must be the focus on effective grid management.

Charging management platforms connect the EV driver, power grid operator, and charging park operator. They provide the flexibility in charging times and provide an efficient solution to the grid operators to manage electricity supply and demand. It is worth noting that some startups, such as GreenFlux, also target the drivers.

One of their key features is the option to request priority when a driver needs their battery to be charged as fast as possible. The algorithm ensures the vehicle is charged quickly, while complying to the local electrical network's limits. The driver will be notified of their current charge rate and whether the network temporarily limits their charging window.

Why It Matters

McKinsey's base-case scenario for EV adoption predicts that around 120 million electric vehicles will be on the road by 2030 in China, the European Union, and the United States. An impressive fleet of new cars to be managed by each national grid.

Incumbents: Fortum (PlugSurfing), Geotab (FleetCarma), Royal Dutch Shell (Greenlots)

Key startups: HyperStrong ($69M), EVConnect ($25.6M), Driivz ($23M), GreenFlux ($13M), Upside Energy ($8M)

Other startups: Hubject, Connected Energy, Derkwoo Electronics, Dukosi ($9.6M), Eatron Technologies, eMotorWerks (acquired by Enel), Freemens, Gbatteries, Idle Smart, Ion Energy, TWAICE Technologies, Last Mile Solutions, PowerShare, ViriCity, ChargeHub

NOTABLE ACQUISITIONS

2019	Greenlots acquired by Royal Dutch Shell, undisclosed amount
2018	Recargo acquired by Innogy, undisclosed amount
2017	EnerNor acquired by Enel, $250M
2017	Gridcars acquired by Solareff, $0.23M
2017	PlugSurfing acquired by Fortum, undisclosed amount
2017	FleetCarma acquired by Geotab, undisclosed amount
2017	Kisensum acquired by ChargePoint, undisclosed amount
2017	eeMobility acquired by Statkraft, undisclosed amount

Source: https://www.wired.com/story/electric-cars-impact-electric-grid/; https://www.greencarreports.com/news/1121186_us-has-worlds-second-highest-electric-car-population; https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/charging-ahead-electric-vehicle-infrastructure-demand

VEHICLE-TO-GRID (V2G)

Timeline

The industry is divided between believers and sceptics of V2G as a mainstream technology. EDF Energy and Nissan believe that V2G will boom. Nevertheless, most think it has significant potential within the fleet and B2B markets, and some players have already announced roll-outs. Nuvve plans to deploy 4,000 V2G chargers over the next three years in Europe.

What it is

Vehicle-to-grid (V2G) allows electric vehicles to transmit the energy they stored back into the national electricity network providing more energy at peak demand times. Although it is still in the early stages of development, vehicle to grid is gaining attention because of the growing amount of lithium-ion battery capacity stored in electric vehicles, and the fact that this capacity is not being used approximately 95% of the time.

One of the challenges in this market is the high cost of infrastructure, as vehicle to grid requires major facilities for the battery to be exploited to its full capacity. Considering the increasing number of electric vehicles to be managed, V2G is an expensive process for providing a significant vehicle to grid supply.

Why It Matters

Nissan states that an integrated electrical grid in the UK could generate up to £2.4 billion savings in electricity costs by 2030. As of today, extensive research has not been completed to explore the economic impact of smart charging technology. A recent study by The Lawrence Berkeley National Laboratory investigates the potential of smart charging in California. Assuming that a number of battery-electric vehicles and hybrid-electric vehicles are reaching 500,000 and 1 million, respectively, by 2025, it concludes that deploying the smart charging technology would be worth around $15.4B in stationary storage investment.

Incumbents: Nissan, FCA, EDF Energy, Enel

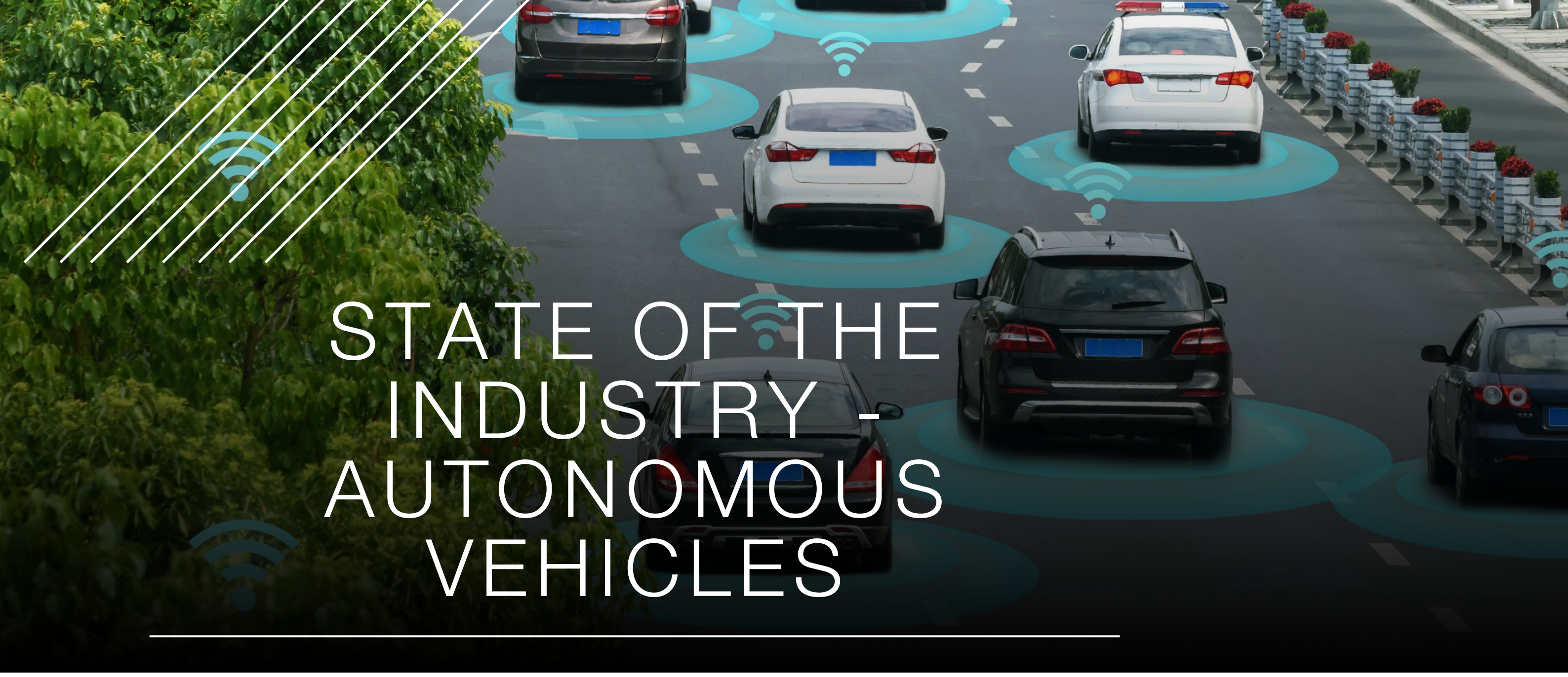
Key startups: Fermata Energy ($16.5M), Nuvve

Other startups: The Mobility House, Ovo Energy, DriveElectric

NOTABLE ACQUISITIONS

2019	Ovo Energy acquired by Mitsubishi Corporation, 20% stake for $216M
2018	EVTronic acquired by EVBox, undisclosed amount
2017	eMotorWerks acquired by EnerNOC, undisclosed amount
2015	Ovo Energy acquired by Mayfair Equity Partners, undisclosed amount

Source: https://theenergyst.com/evs-v2g-vehicle-to-grid-battery-storage-smartgrid/; https://electrek.co/2018/05/24/electric-vehicle-battery-capacity-controllable-load-vehicle-to-grid-feature/; https://www.prnewswire.com/news-releases/global-vehicle-to-grid-chargers-market-2018-2022-with-driveelectric-enel-hyundai-mobis-ovo-energy--shell-dominating-300656502.html



STATE OF THE INDUSTRY - AUTONOMOUS VEHICLES

ARE WE READY FOR SELF-DRIVING CARS?

We tend to forget that the first self-driving trials happened in the early 1980s when Carnegie Mellon launched Navlab[48]. Subsequently, in 1987, Eureka Prometheus Project received over $750M in funding[49] in Europe.

By 2017, over $80B has been invested in self-driving vehicles worldwide[50], and by the end of 2018, there were 24 pilot projects in the US and 50 more in Europe, Asia, and beyond[51]. The resulting impact is expected to be substantial. In 2014, Morgan Stanley estimated that productivity gains from autonomous vehicles could save $5.6T annually to the global economy[52].

Both the transportation industry and the way we live will be redesigned. Urban centers will evolve, more will live independently, and many will rethink their commutes. The secondary effects will be substantial as well. CB Insights counts 33 related industries that will be disrupted by self-driving[53].

Despite the rise in the development of autonomous vehicles, substantial technical, regulatory, and customer perception challenges to mass adoption still exist today. UBS predicts that demand for self-driving cars will take off around 2026[54]. However, the obstacles won't disappear overnight and could delay the widespread AV adoption to well after 2040. A prime example is how every reported accident involving a self-driving vehicle increases consumer skepticism and litigation risk.

Nevertheless, market experts predict an increasing adoption of autonomy in the coming years and expect the global autonomous car market to reach $220.4B by the end of 2025[55]. This suggests a 36.5% CAGR from 2020. More specifically, Boston Consulting Group research forecasts that 25% of all traveled miles in the US will be in shared, electrified, and self-driving vehicles by 2030[56].

So are we ready for fully autonomous passenger vehicles and robotaxi fleets? Not yet. However, there are a number of smaller markets where self-driving vehicles are about to be commercialized or already exist. Given the amount of capital and scientific research being invested in this space, we expect to see significant innovations and market consolidation at all levels of the automotive value chain over the next five years.

Source: [48] [49] [50] [51] [52] [53] [54] [55] [56]

AN OVERVIEW OF THE AUTONOMOUS VEHICLE MARKET

Basic autonomous functions have already been introduced to passenger vehicles over the last few years. Namely, adaptive cruise control and lane-centering assistance. However, high or full levels of automation are still confined to the testing ground. Consistent with the past, luxury automakers are the first to introduce new technology. According to Reportlinker, the global (partially) autonomous market was estimated at 6.6 million vehicles in 2017. Allied Market Research predicts the market will reach $54.23B by the end of 2019 and $556.67B by 2026[57].

The main challenge to bringing autonomous technology is the unavoidable tens of thousands of dollars in additional cost per vehicle. In the near term, ride-hailing business will be the first to have a financially-viable reason to replace human drivers. For this reason, robotaxis are expected to come before mainstream autonomous passenger vehicles. With the support of self-driving, Goldman Sachs estimates that the global ride-sharing market could increase eight-fold by 2030, reaching $285B annually[58].

There are other markets where initial adoption and acceleration to mass-market are expected to come much sooner. There is substantial complexity to driving in busy urban environments and managing fleets of autonomous vehicles. Self-driving on highways or in limited environments is relatively easier and will surely come first.

According to Navigant Research, the first and last mile passenger and deliveries will be the predominant autonomous vehicle markets for the next five to ten years. Self-driving offers immediate benefits on private roads in use cases ranging from airports to corporate campuses, to pedestrian living campuses, such as universities and senior living facilities. Some companies are already tackling the $28B last mile public transportation market where self-driving is expected to provide significant savings while expanding public networks' possibilities. In the logistics sector, the last mile represents 53% of all shipping costs. According to McKinsey, autonomous vehicles are expected to cut this number in half[59].

The trucking industry is expected to be the first to commercialize autonomous driving in a substantial way. Contrary to popular belief, the US trucking industry is currently growing and is in dire need of an additional 60,000 drivers to meet demand. Even partial autonomy will provide the industry the much-needed ROI in driver job satisfaction and retention, efficiency and safety improvements, and fuel savings. Assistive, Level 2+ technologies for driving on highways are already here, including Pronto, TuSimple, Embark Trucks.

McKinsey estimates that full autonomy will reduce trucking industry operating costs by 45%. In the US, this equates from $85B to $125B annually[60].

Though autonomous passenger vehicles' developments get most of the news coverage today, we see a rapidly growing business case for commercial vehicles in the immediate future.

Source: [57] [58] [59] [60]

SELF-DRIVING TECHNOLOGY EXPLAINED

SELF-DRIVING CARS IN A NUTSHELL

Autonomous vehicles sense their environment and navigate without human input. The vehicles use an internal map and a constant analysis of the surrounding obstacles, such as, structures, pedestrians and other vehicles to determine the optimal path to their destination. They accomplish with inertial navigation systems ranging from GPS to HD maps, and a number of "seeing" sensors ranging from camera to LiDAR. Software intelligence has been the primary recent breakthrough that allows analysis of impressive amounts of sensor data necessary to navigate dynamic physical environments in real time.

There are three essential technology areas that enable vehicles to drive themselves: sensors, software intelligence, and connectivity.

Sensors

Many different sensors are used in today's autonomous driving platforms. For instance, Cruise vehicles are equipped with 5 LiDAR sensors, 21 radar sensors, and 16 video cameras[61]. Each has strengths and weaknesses, but the combination of sensors and their redundancy significantly improves the whole system's reliability.

Each sensor has different capabilities and use cases:

- Radar sensors sense the position and speed of vehicles nearby.
- Video cameras identify traffic lights, read road signs, monitor other vehicles, and keep track of other obstacles on the road, such as pedestrians.
- Lidar sensors detect road edges, identify lane markings, and ultimately create a digital twin of the physical environment.
- Ultrasonic sensors detect obstacles during parking.

The table below outlines the advantages and limitations of each sensor employed.

	Radar sensors	Video cameras	LIDAR	Ultrasonic Sensors
Advantages	Short distance accuracy Long range - 98ft - 650ft Low cost - $50 to $150 Operate under bad weather conditions Determines traffic speed	Detect colors Interpret signs and traffic light Long range - 300ft to 820ft Compact design	Accurate to an inch with 980ft of range 3D reconstitution of the environment 360° view Operate in worst weather Provides object detection	Short distance accuracy - up to 25ft Low price - $10 to $20 Easy and fast data processing Operates in the worst weather
Limitations	No object identification Less effective at long distances Works only on metal surfaces	Does not operate well in bad weather High data volumes to be processed - 20 to 60Mbps Very low level of object detection Does not measure distance Does not provide speed	Expensive - $4K to $100K Bulky size and form factor - 1.8 lbs to 28 lbs Not easily integrated into the vehicle design	Few relevant use cases - mainly parking assist

Source: [61]

Software Intelligence

Self-driving vehicles collect data through sensors and analyze it to determine the best course of action for each real world driving scenario. This is the central function of control algorithms and software. These are the most complex components because the decision-making process must be nearly flawless to be commercially viable. Uber's first self-driving pedestrian fatality on March 18th, 2018, has demonstrated the public intolerance of flaws in autonomous systems.

Autonomous vehicle navigation systems and algorithms work in repeated cycles:

1. Localization: determine the location of the car on the map.

2. Perception: receive pictures from the sensors to update the 3D database with objects ahead of the car.

3. Navigation: actuate steering, accelerator, and brakes to the chosen direction of movement while accounting for the path and real-time objects.

Connectivity

Autonomous vehicles rely heavily on cloud computing to process traffic data, weather signals, adjacent car indications, surface conditions, and more. With this added intelligence, vehicles can precisely monitor their surroundings and make informed decisions. Although edge computing hardware can tackle small tasks locally, self-driving cars rely heavily on their Internet connections.

The current 4G LTE network is not an entirely adequate solution for AVs with its high latency being a significant factor. In 2019 and 2020, many major cities started launching 5G services, but the use cases are mainly focused on consumer-based services. However, as countries install the required infrastructure and increase coverage, 5G Networks will expand to enterprise-focused use cases including autonomous driving through 202562. The development and broad coverage of 5G will allow autonomous cars to reliably depend on the cloud due to low latency (1-5 milliseconds compared to 20 milliseconds of 4G), high speed (100x faster than 4G) and increased reliability. Additionally, 5G-based autonomous cars and ADAS will lower the risk of collision and accidents and become more reliable and safer.

Source: [62]

DIFFERENT SCHOOLS OF THOUGHT

Camera-only approach

There are two schools of thought in autonomous driving: camera only or with the support of LIDAR. Most companies working on AV development believe that LIDAR is an essential part of their sensor array. For instance, Ford, GM Cruise, Uber, and Waymo, all rely on different sets of sensors comprised of LIDAR, cameras, and radar. These AV manufacturers claim that LIDAR's enhanced capabilities are critical to safety and provide an important failover.

However, Tesla and other established market players argue that LIDAR is unnecessary and expensive. Their sensory sets include cameras, radar, GPS, maps, among other sensors. There is a heated debate amongst autonomous vehicle experts on the subject. Pronto, the first-to-market autonomous trucking company, combines cameras with neural networks for improved prediction. The company's position is that while LiDAR and HD Maps provide valuable sensing and localization for the vehicle in real time these technologies have. Notably, Pronto is the first to complete a zero disengagement coast-to-coast autonomous drive. Similarly, Mobileye and Aurora Innovation believe that autonomous vehicles can operate with cameras alone.

High-Definition (HD) mapping

Autonomous vehicles cannot only rely on GPS as it doesn't have nearly the level of accuracy needed for Level 2 autonomy and above. On the other hand, the sensor-based approach is critical, but not yet sufficient. For this reason, HD mapping has become one of the key technologies in self-driving. HD maps are very high resolution with centimeter-level accuracy. They allow AVs to sense their physical location with extremely high precision and enable vehicles to see beyond the line of sight. Satellite links allow for fast communication and real-time map updates. However, there is limited coverage of low use roads, high use of data, and expensive processing. Experts are not yet sold on the viability of this approach due to the costly high-speed connections and massive cloud environment needed to support fleets of self-driving vehicles.

AUTONOMY LEVELS DEFINED

In January 2014 the Society of Automotive Engineers published SAE Automation Levels. The US National Highway Traffic Safety Administration accepted it as the standard classification tool.

There are currently six levels of automation: Level 0 being no autonomy and Level 5 being fully autonomous. The Table below describes the SAE Automation Levels, explaining their features and ability to drive autonomously.

	Level 0 No Automation	**Level 1** Driver Assistance	**Level 2** Partial Automation	**Level 3** Conditional Automation	**Level 4** High Automation	**Level 5** Full Automation
	A human being controls all major systems and is fully engaged in driving	Some systems are automated, for example, cruise control and assisted braking, with the car controlling these systems one at a time	The vehicle can perform at least two automated functions together, including acceleration and steering. The vehicle still requires attention of humans for safe operation.	The vehicle can perform all safety-critical functions but under restricted conditions. However, the driver must take over control when alerted	The vehicle is fully-autonomous in some driving scenarios	The vehicle is fully-autonomous in every situation
Driver	performs all driving	in charge of controlling the steering wheel, acceleration and braking	changing lanes, overtaking other vehicles, respect traffic rules, driver is responsible of all	must be alert and ready to take control at all times upon notice	does not need to be alert	the human occupants are passengers and they are not involved in driving
Vehicle	no driving assistance	may have some active driving assistance	can steer, accelerate, brake, under limited conditions	can perform all aspects of the driving task under limited conditions	can entirely manage itself under limited conditions	capable of self driving under all environmental conditions
Features	none	cruise control, automatic emergency braking and lane keeping	self-parking, stop-and-go	self-parking, stop-and-go, traffic assist	complete driving with driver controls (accelerator, brakes, steering) optional	same as Level 4, but not limited by conditions
Preferred area	everywhere	highways	highways	highways	highway / urban	everywhere
Example		Many new cars are equipped with Level 1 automation features, which includes adaptive cruise control and lane-keeping assistance. As early as the late 1990s, Mercedes-Benz presented its pioneering radar-managed cruise control, and in 2008 Honda launched lane-centering assist on its Legend model	There are a few vehicles now with Level 2 automation. For example, Tesla's Autopilot, a driverless car technology which deploys eight cameras to offer 360-degree visibility, twelve ultrasonic sensors and a front-facing radar that analyzes the surroundings of the vehicle and detects potential threats	Audi A8'sTraffic Jam Pilot, which controls the car at speeds below 37 MPH, without the need for driver intervention	Current Waymo and Cruise test vehicles are equipped with LiDAR and radar sensors, video cameras, and safety drivers and fall into the Level 4 category	The Level 5 automation has not yet been achieved; however, market players are in a race to develop a fully-autonomous vehicle, and some studies estimate the launch of test vehicles by mid-2020

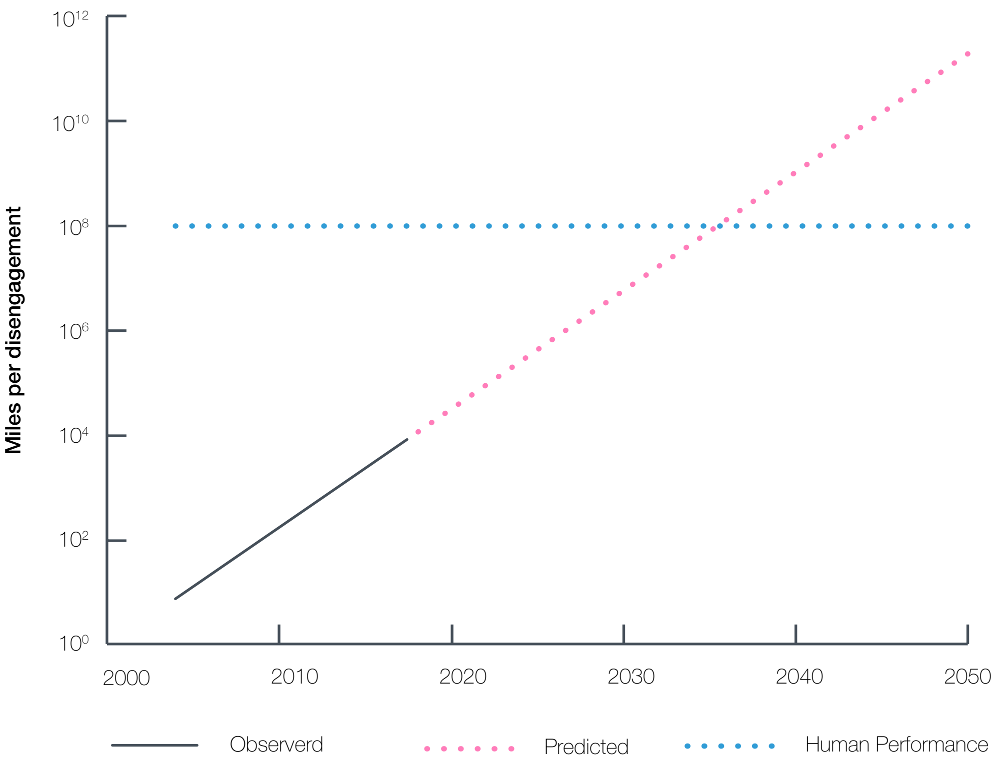
MOORE'S LAW FOR SELF-DRIVING CARS

Edwin Olson, CEO of May Mobility, implied Moore's law, the empirical observation that the number of transistors in a computer grew exponentially doubling every 18 months, to the self-driving cars. He found that Moore's law for AVs is roughly the same as Moore's law for computers, with AVs doubling their performance every 16 months.

Edwin uses the number of miles per disengagement to measure the vehicles' performance, a measure used by the Department of Motor Vehicles of California to show the number of a technology failure when a safety driver has to take control. For instance, in 2004, the best driverless vehicle, CMU's Sandstorm, had a failure rate is approximately 10 miles per hour (driving 7.4 miles of a 150-mile route). In 2019, Waymo reported 1.45 million miles driven in California with disengagement rate of 0.076 per 1,000 self-driven miles, or one disengagement per 13,219 miles. Cruise recorded 831,040 miles of driving and 68 disengagements in 2019, which is about one disengagement per 12,221 miles driven (disengagement rate is 0.082 per 1,000 miles driven)[63].

Given that the driverless cars are about 0.01% as good as humans and with the performance doubling every 16 months, Edwin argues that self-driving cars will perform equally as good as human only in 16 years. Taking into consideration that AVs will rarely result in a fatality, the number of years it will take AVs to achieve human levels of performance can be reduced to 12. Thus we should not expect to see robotaxis on the roads sooner than 2032/2035.

However, this model depends a lot on the data available and the technology. The accuracy of data could either overstate the performance pushing the AV adoption even farther in time or understate, which will allow implementing robotaxis sooner. This model could also be affected significantly by the development rate of new technology as well as if companies decide to focus on different technologies that cover a smaller subset of the overall driving tasks.



Source: Edwin Olson, Medium

Source: [63]
Edwin Olson, Medium. (2019). The Moore's Law for Self-Driving Vehicles.

WHERE WE ARE TODAY - MARKET READINESS AND LEGAL FRAMEWORK

PASSED LEVEL 2, NOT YET LEVEL 3

Today the most advanced vehicles on the roads provide Level 2 autonomy. The vehicles can take over several functions from the driver and provide advanced assistance such as steering, lane centering, and adaptive cruise control. The driver is still responsible at all times.

However, at least in the US, the current legal framework allows for a superior automated driving experience called Level 2+. Essentially a level of autonomy classified between Level 2 and Level 3 that some notable players are already beginning to commercialize. Vehicles with Level 2+ automation and above require highly computerized systems, such as surround sensors for 360-degree visibility and deep neural networks operating together for better object detection and identification.

An example of this is Pronto's Advanced Driver Assistance Systems (ADAS) for trucks, Co-Pilot, a Level 2 system that improves operational and occupational safety, boosts efficiency, and reduces commercial trucks' emission. Another example is NVIDIA. Early 2019, the company introduced its DRIVE AutoPilot, a Level 2+ solution that provides autonomous driving perception and an intelligent cockpit. It is now part of the open NVIDIA DRIVE platform and the technology is already being used by Continental, ZF, and Volvo for the development of their Level 2+ autonomous systems.

Beginning at Level 3, vehicles will start alleviating the need for a human driver and will be autonomously driven under limited conditions, such as highway traffic. The driver will still be required to take over control on short notice. To date, the only platform taking passengers in fully driverless vehicles is Waymo, a Google spin off and sector's presumed front-runner.

Leaders	Posses	Rogues
Waymo	Baidu	Nissan
Cruise	BMW	Pony.AI
Argo	Daimler	Tesla
Aurora	Nuro	Zoox
Aptiv	Toyota	
	Uber	
	Volvo	

THE ECONOMIC IMPACT OF AUTONOMOUS CARS

The potential economic impact of autonomy can be massive. In 2014, Morgan Stanley estimated that autonomous cars could save the US economy $1.3 trillion annually. This is nearly 8% of the US GDP[64]. Utilizing the same methodology, we estimate that autonomous cars could save up to $792 billion in fuel, congestion and accident reduction, and provide up to $134 billion gains in additional hours worked.

FUEL SAVINGS: $291 BILLION

Better traffic management, reduced congestion, and smoother driving autonomous cars will consume significantly less fuel (both gasoline or electric). In 2018, a research funded by the National Science Foundation found that the controlled pace of each autonomous car could reduce traffic for an additional 20 vehicles. Reducing human reaction times and the subsequent traffic waves, can reduce total fuel consumption by up as much as 40 percent[65]. A 2014 study released by the Texas A&M Transportation Institute (TTI) and INRIX calculated that the average US commuter spends an extra 19 gallons of fuel every year due to traffic jams. From these two findings, we can extrapolate that an annual fuel savings of $291 billion can be achieved

FUEL SAVINGS BY IMPROVEMENT IN EFFICIENCY ADJUSTED FOR CONGESTION

- Average 13,476 miles traveled per driver annually in the US[66]
- Average 24.7 miles traveled per gallon[67]
- 546 gallons consumed by an average driver annually
- At $2.66 per gallon[68] and 225 million drivers[69], $327 billion is spent on fuel annually
- Self-driving cars could reduce fuel consumption by as much as 40%
- $131 billion could be saved every year by reducing fuel consumption
- $160 billion wasted time and fuel caused by congestion per year[70]
- A total of $291 billion in potential annual fuel savings at current usage rates and costs

Source: [64] [65] [66] [67] [68] [69] [70]

ACCIDENT REDUCTION: $501 BILLION

The cost of car accidents in the US is substantial – especially when considering the broader economic impact. Beyond auto repair, car accidents carry costs in emergency services, healthcare, loss of earnings, and household productivity.

Approximately 94% of motor vehicle accidents are caused by human error. This is an obvious area where autonomous vehicles–that see better and are always alert–can make a major difference. In 2015, the US racked-up over 4.5 million crashed with property-damage-only, 1.7 million that caused injuries, and 32,538 that caused fatalities. The US Department of Transportation tracks and reports accident data[71]. Building on this, we estimate that eliminating accidents can save up to $501 billion annually.

SAVINGS BY ELIMINATING CRASHES

- 4.5 million property-damage-only crashes
- 1.7 million of crashes causing an injury or a possible injury
- 32,538 fatal crashes
- $10,000 average spent on a property-damage-only crash[72]
- $157,000 average spent on a crash causing an injury[73]
- $5.7 million average spent in the case of a fatal crash[74]
- A total of $501 billion could be saved every year

ADDITIONAL WAGES EARNED: $134 BILLION

Autonomous driving can free-up billions of additional work hours for commuters. In 2014, 29.6 billion hours were spent by approximately 139 million US commuters[75]. In 2015, a report released by the Texas Transportation Institute (TTI) estimated that the average driver logged an additional commute 42 hours annually due to traffic jams[76]. These figures show us that a possible $134 billion of additional earnings could be reclaimed annually.

Gains from working while commuting adjusted for congestion:

- Average 29.6 billion hours spent commuting annually in the US
- 139 million commuters
- Average of 42 hours stuck in traffic per commuter
- A total of 5.8 billion hours spent stuck in traffic annually
- A total of 23.7 billion hours spent commuting adjusted for traffic jam
- At a US-average $25 hourly wage[77]
- With an assumption that 25% of commute time can be spent working at a 10% reduce productivity compared to working at a desk
- A total of $134 billion could be saved every year

Source: [71] [72] [73] [74] [75] [76] [77]

WHY YOU CAN'T BUY A SELF-DRIVING CAR IN 2021

In addition to managing public perception, there are several technical, regulatory, and business model obstacles that need to be overcome before mass commercialization of autonomy becomes realistic.

TECHNICAL HURDLES

Self-driving technologies have to be proven statistically safer compared to human drivers. Measured by the number of disengagements (instances where a test driver had to take over controls), today's best autonomous systems are substantially less reliable than human drivers. Waymo has what's considered to be one of the most reliable systems and drives an average of 11,154 miles without driver intervention[78]. To put that into perspective, the average US driver has one accident every 165,000 miles[79]. Additionally, until 5G and inter-car communication systems are functional, unreliable Internet infrastructure limits autonomous vehicles' safety and operations. Moreover, governments should support digital infrastructure development for AVs, including sensor networks, roadside equipment such as smart traffic lights and high-quality digital mapping. As Level 4 AVs operation relies on external this infrastructure. In contrast, Level 5 AVs can operate independently, but they still need vehicle-to-infrastructure (V2I) communication to deliver safety and efficiency.

LEGAL HURDLES

The US has been one of the most active countries in introducing and updating its legislation on autonomous vehicles each year. Local governments are in the early stages of defining regulations and standards for self-driving vehicles. In 2017, 33 US states introduced legislations of which 15 enacted 18 autonomous driving-related bills in 2018[80]. In 2017, the Self Drive Act was passed by the House of Representatives but has since languished awaiting Senate approval.

Liability will become more complex and affect the insurance aspect of autonomous driving. Traditional auto insurance will be forced to shift focus from driver to manufacturer coverage, bringing new limits and exclusions along the way. Civil liability and criminal culpability are expected to change as well. Accidents involving self-driving vehicles make it far more difficult to determine responsibility and legal liability.

Additional legal issues will present themselves, as well:

E-DISCOVERY

Autonomous technologies generate high volumes of data from raw sensor data and vehicle operation. Mass volumes of data obtained from autonomous vehicles may include proprietary information which may require interpretation of an expert in case of an accident.

DATA SECURITY

Autonomous cars generate a lot of sensitive data that can become vulnerable to theft and malicious use. Current cybersecurity laws are yet to be updated to address this growing need. Countries already diverge over the extent to which they protect the privacy of road users. The EU has strict privacy standards as a result of the General Data Protection Regulation (GDPR). The United States provides less protection at a federal level, although states including California have recently tightened their rules. Some countries, including China, place less importance on privacy due to a more communal approach.

INTELLECTUAL PROPERTY

With the ongoing development of autonomous technology, knowledgeable engineers are highly sought after. Steering clear of trade secrets and registered IP infringement is becoming increasingly more difficult. For instance, Toyota already has 1,400 patents on autonomous technology.

EMPLOYMENT

Autonomous driving will free up commute time, and employers will start expecting productivity on the way to and from the office. This will inevitably bring up issues related to pay and labor laws.

PUBLIC PERCEPTION

Mass adoption of autonomous vehicles will require consumer acceptance. The 2019 KPMG AV Readiness Index report shows that people living in the countries where AV pilots and testing are underway feel more comfortable about the AVs and are more likely to use them as they become available. Including, Singapore, Netherlands and Denmark. American Automobile Association's (AAA) survey confirms that 7 out of 10 Americans feel anxious about self-driving cars[81]. The public is currently more accepting of autonomous vehicles in delivery (44%) or low-speed passenger systems (53%). The recent high-profile accidents involving Uber and Tesla autonomous or semi-autonomous cars have amplified uncertainty among the public.

TRAVELING ACROSS BORDERS

Although countries may differ in how much digital infrastructure they deploy for AVs, they should ensure that AVs can operate borders. Thus, international standardization and some degree of consistency in legislative approach for AVs are required. Including standardized levels of automation, infrastructure, V2I, and insurance. Within the EU, some basic automation will become mandatory in all new vehicles under the ADAS from 2022.

Source: [78] [79] [80] [81]
KPMG. (2020). 2020 Autonomous Vehicles Readiness Index.

THE ROAD TO AV UBIQUITY

To date, many countries have already introduced some of the legislation and regulations to enable AVs, however, a lot of the work on national implementation remains — including putting infrastructure in place, establishing data policies and protocols and setting policies on licensing and insurance.

KEY INSIGHTS FOR NATIONAL AND LOCAL GOVERNMENTS

Many governments now start deploying AVs in shared public transport, as shared AV vans and buses may be as important as private driverless cars. Operators in Singapore, Spain and the UK testing full-length autonomous buses. The technology is maturing with a range of suppliers at all value chain levels, meaning that local governments can bring them into use more quickly.

AVS CAN BE USED TO HELP TRANSFORM AN AREA'S TRANSPORT

The pandemic and shift towards green vehicles changed the way people travel. This provides an opportunity for the city and municipal governments to stimulate the adoption of AVs, either encouraging people to use more driverless buses or private vehicles or to use AVs for freight and in closed environments such as industrial, port and mining areas.

THE SAFETY CASE FOR AVS IS GETTING STRONGER

The reputation of driverless cars was extensively damaged when a test vehicle operated by Uber killed a pedestrian in Tempe in Arizona in March 2018. However, as 95% of road accidents are caused by human error, AVs can potentially reduce these casualties. In February 2020, at a global ministerial conference on road safety, participants recognized that "advanced vehicle safety technologies are among the most effective of all automotive safety devices".[82] Moreover, there is a risk that setting the safety bar too high for AVs will slow their introduction and lead more casualties from human error in the meantime.

AVS WILL NEED BOTH LOCAL & NATIONAL GOVERNMENT FOCUS AND SUPPORT

Cities, municipalities and states have been active in introducing AV related regulations and developing infrastructure in their area. Many of the top countries of the KPMG AV readiness index are urban-dominated countries, such as Singapore and the Netherlands. However, for AV to become ubiquitous both national and city governments have to focus on and support AVs, with national governments providing the enabling policies and cities increasing public acceptance by providing useful, and innovative new services.

Source: [82]

COUNTRIES MOST READY FOR AUTONOMOUS VEHICLES

The KPMG annual Autonomous Vehicles Readiness Index report shows that countries worldwide are rapidly progressing towards the future of transportation. Governments are playing an essential role in AV adoption, supporting the modernization of transport infrastructure and ensuring that autonomy brings real advantages to their communities. Over 2019 countries have been grappling with the critical policy and investment decisions needed to enable the AV revolution, including safety, privacy, digital infrastructure, impact on transport systems and cross-border travel. This year Singapore has been recognized as the most prepared country for AV adoption. Singapore overtook the Netherlands for the top-ranked position and led on consumer acceptance and policy and legislation assessments. They are followed by Norway, the United States, and Finland.

The top-ranked countries are building the necessary regulations and infrastructure to ensure rapid adoption of AVs. For instance, Singapore has extended the AV testing to all public roads in western Singapore and plans to have driverless buses operating in some areas from 2022. Also, it is aiming to expand the charging infrastructure from 1,600 to 28,000 stations by 2030. The Netherlands stays in the top position on the infrastructure pillar in terms of EV charging stations per capita and road quality. From 2019, the country extensively implemented the smart road furniture, including traffic lights that send their statuses wirelessly to AVs in 60 new areas of the country. Denmark has been ranked the highest-rated of the five countries joining the AV readiness index ranking in 2020. In Denmark, the AV tests are now allowed on any public road, and its first driverless bus service started running in March 2020 in Aalborg.

According to the KPMG 2020 AVRI report, there are ten countries most prepared for the future of autonomous transportation:

Country	2020 Rank (#)	2019 Rank (#)
Singapore	1	2
The Netherlands	2	1
Norway	3	3
United States	4	4
Finland	5	6
Sweden	6	5
South Korea	7	13
United Arab Emirates	8	9
United Kingdom	9	7
Denmark	10	New

Source: KPMG.

Source: KPMG. (2020). 2020 Autonomous Vehicles Readiness Index.

MILESTONES - COUNTRIES MOST READY FOR AUTONOMOUS VEHICLES

January 2019
The Consumer Electronics Show in Las Vegas sees Daimler Trucks unveil its Freightliner Cascadia, the first truck in North America to include automated assistance.[8]

February 2019
President Tsai Ing-wen opens the Taiwan CAR (connected, autonomous and road-test). Lab in Tainan, its first closed testing ground for AVs.[9]

March 2019
Australia allows users to take their hands off the steering wheel when drivin within one lane on a highway and operate self-parking systems when outside the vehicle.[10]

April 2019
The City of Espoo in Finland begins public operation of the all-weather Gacha driverless bus, designed by local company Sensible 4 and Japanese retailer Muji.[11]

May 2019
A driverless electric truck built by Swedish AV startup Einride takes its first drive on a public road between a warehouse and a terminal in Jönköping.[12]

June 2019
Apple buys Drive.ai, a Silicon Valley-based startup that has piloted AV technology that can be fitted to existing vehicles.[13]

July 2019
Residents of a retirement village in Coffs Harbour, New South Wales, get access to an on-demand AV minibus services called BusBot, summoned using a smartphone app.[14]

August 2019
UK testing organization Zenzic, which is funded by industry and government, opens a funding competition for the studies on the cybersecurity of AVs.[15]

September 2019
Shanghai becaomes the first Chinese city to issue permits making it easier to test AVs on public roads, to vehicle-makers SAIC and BMW and ride-hailing company Didi Chuxing.[16]

October 2019
Singapore's government opens one-tenth of its total road network for AV testing and starts retraining 100 bus drivers as safety operators.[17]

November 2019
Russian technology company Yandex said it has started road-testing small autonomous robots known as Rovers that are designed to make local deliveries in cities.[18]

December 2019
Waymo buys Latent Logic, a machine learning-focused company that had been spun-out from Oxford University's Department of Computer Science.[19]

January 2020
General Motors' Cruise AV division unveils the Origin, a purpose-built self-driving car designed for ride-sharing with no physical driving controls and room for six passengers.[20]

February 2020
The Spanish government announces a new mobility law that will cover AVs as well as more EV charging points, although details have since been delayed by the coronavirus crisis.[21]

March 2020
US ride-hailing company Uber resumes testing of AVs in its home city San Francisco, two years after one of its vehicles was involved in a fatal accident in Arizona.[22]

April 2020
Japan's Road Transport Vehicle law comes into force, including legal recognition of AVs, an inspection regime and a permit system.[23]

May 2020
US technology company Intel buys Moovit, an Israeli startup which provides an urban mobility app, for around US$900 million, to support its Israeli-based AV unit Mobileye.[24]

June 2020
Germany vehicle makers BMW and Mercedes-Benz put on hold a partnership involving around 1,200 people that was developing shared technology for level 4 AVs.[25]

Source: KPMG. (2020). 2020 Autonomous Vehicles Readiness Index.

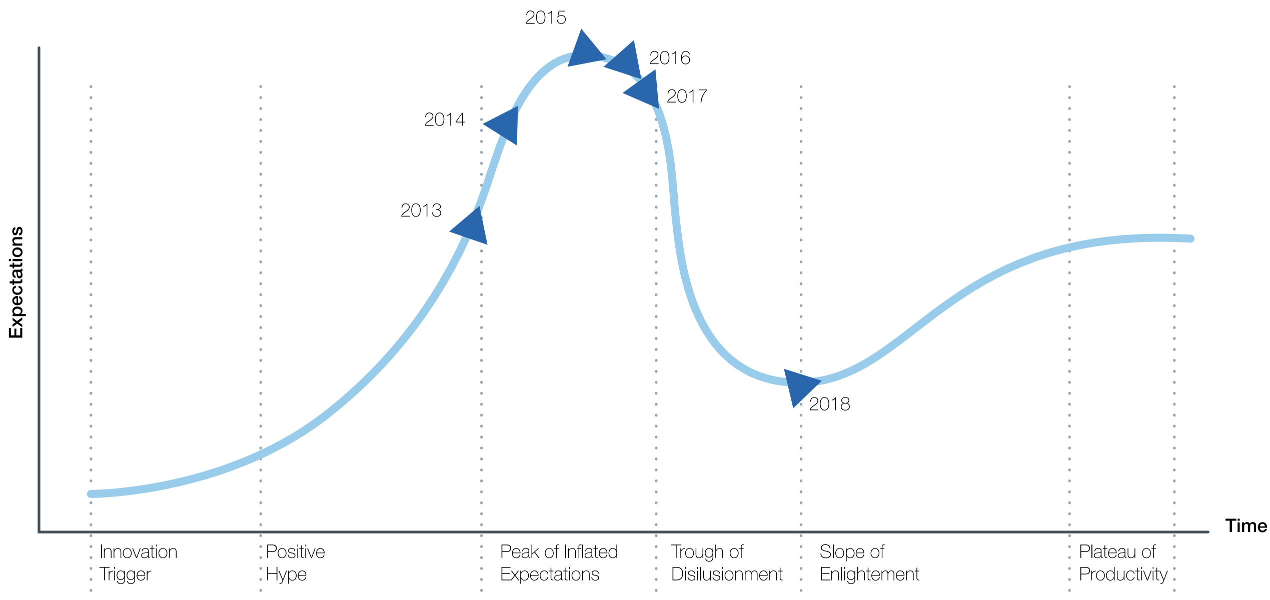
FROM INNOVATION TO MAINSTREAM COMMERCIALIZATION

THE INNOVATION PATH TO AUTONOMOUS DRIVING

The Gartner Hype Cycle organizes developing technologies in the framework of five phases[83]. The cycle helps separate hype, usually appearing first, from technologies that drive real impact in a category. As the technology matures, hype decreases and adoption accelerates.

According to Mike Ramsey, Research Director at Gartner, autonomous technology reached its highest level of hype, a.k.a. "Peak of Inflated Expectations", in 2015. At this stage, a number of well-marketed success stories purported the sentiment that commercialization is about to happen. Mid-2018, AV reached the "Trough of Disillusionment" phase. Hype remained but faltered as implementations failed to deliver. Ramsey forecasted it would take a few more years to reach the "Slope of Enlightenment" and more than ten years to attain the "Plateau of Productivity". At "Slope of Enlightenment", the benefits of the technology will become more widely understood. It is only at "Plateau of Productivity" that mainstream adoption will start accelerating and technology will finally deliver on its long-made promises.

THE GARTNER HYPE CYCLE



Source: KPMG.

Source: [83]
Gartner. (2017). Gartner Hyper Cycle for Emerging Technologies, 2017.

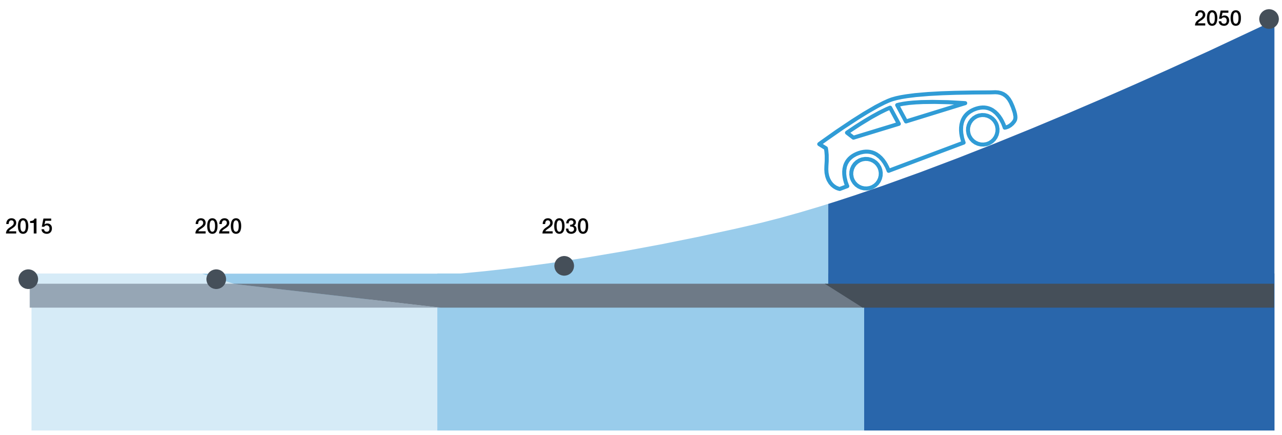
AV ERAS

McKinsey has identified three-time horizons of AV diffusion: the development of vehicles, the early stages of adoption and finally, commercialization.

In the first era, McKinsey expects three main phases. The technology will be first deployed in restricted environments and on private roads. Traditional automakers and new players will follow. Finally, emerging business models, such as mobility-as-a-service, vehicle sharing models, and micromobility will propagate the shift.

In the second era, McKinsey predicts traditional business models to reorient towards AV and mass adoption to scale. Given the technology's safety-critical nature, owners may strongly prefer to use car maker services for maintenance and repair. This may result in higher after-sales revenue for OEMs, as independent providers will face difficulties offering the same service level. The car insurance model is also expected to be disrupted, as liability will shift from millions of consumers to a few OEMs and infrastructure operators. Last but not least, logistics and supply chains will increase in efficiency, as labor costs diminish and productivity increases.

In the third era, McKinsey forecasts autonomous vehicles to reach mainstream adoption and finally produce significant savings and productivity gains. Commuters will save billions of unproductive hours each year. Need for parking will be reduced since autonomous vehicles can occupy 15% tighter spaces than human-driven vehicles. Removing the error-prone human factor accidents and consequent fatalities will be significantly reduced. The development and adoption of autonomous vehicles will also stimulate and accelerate the development of robotics in consumer applications, such as advanced remote sensing, GPS, image recognition, and advanced AI.



1. AVs go mainstream
2. Car OEMs face a decision
3. New mobility models begint to transform
4. The car-service landscape changes
5. Car insurers begin to shift their business models
6. Companies begin to reshape their supply chains
7. Drivers have more time for everything
8. Parking becomes easier
9. Accident rates drop
10. AVs accelerate robotics development for consumer applications

Source: McKinsey. (2015). Ten ways autonomous driving could redefine the automotive world.

AV MARKET OPPORTUNITY

Market forecasts vary widely. Some recent examples include:

- HTF Market Intelligence forecasts the global self-driving car market to grow at 36.2% CAGR from 2018, and reach $173.15B by 2023.[84]
- Research Cosmos report predicts the global self-driving car market to reach $155.69B by 2024, which implies a 50.9% CAGR from 2018.[85]
- A report released by Allied Market Research finds that the global market for autonomous vehicles will be worth $54.2B in 2019. From this date, the market will grow at 39.5% CAGR and attain $556.7B by 2026.[86]
- A study by Intel Strategy Analytics forecasts autonomous vehicles to expand dramatically from $800B in 2035 to $7T by 2050. Consumer use will represent $3.7T by 2050, while mobility-as-a-service will account for an another $3T. In the meantime, autonomous vehicle services will drive new applications, which will account for an additional $200B in revenue.[87]
- PitchBook forecasts the AV market to expand to $41.4B by 2030 through sales of global AV software, sensors, and other hardware. This estimate implies unit sales of approximately 600,000 autonomous and semi-autonomous vehicle platforms in 2025, rising to 8 million units sold in 2030. This also predicts a fall in the price of hardware units as automotive sensor and processor manufacturing costs rapidly decline.[88]

Source: [84] [85] [86] [87] [88]

THE FUTURE OF THE AV TECHNOLOGY STACK

THE AV TECHNOLOGY STACK

APPLICATIONS

Passenger cars and Robotaxis

- APTIV
- AImotive
- OXBOTICA
- LeSEE
- Waymo
- Cruise
- ZOOX
- Lyft
- Uber
- pony.ai
- voyage
- ROBORACE
- DiDi

2-Wheelers

- Honda
- Bosch
- Yamaha
- BMW
- RideVision
- AB Dynamics
- damon

First-Last mile Commercial

- robomart
- autox
- udelv
- OTTO Motors
- dispatch
- 踏歌智行 TAGE IDRIVER
- marble
- nuro
- Starship
- Wing
- boxbot
- BUILT Robotics
- ZMP
- ELIPORT
- GATIK AI

Trucking

- Daimler
- Kodiak
- Waymo
- Embark
- 图森 TuSimple
- CiDi 长沙智能驾驶研究院 CHANGSHA INTELLIGENT DRIVING INSTITUTE
- Ike
- Tesla

First-Last-mile Passenger

- AURO by Ridecell
- Waymo
- The Hi-Tech Robotic Systemz Ltd.
- Perrone Robotics
- Perceptin
- Optimus Ride
- Next Trucking
- EasyMile
- local motors
- navya
- MOOV
- COAST Autonomous
- 清智科技 TSINTEL TECHNOLOGY
- may mobility
- 2getthere

Agricultural Applications

- DOT
- pyka
- Iron Ox
- naïo Technologies

Unmanned Aerial Systems

- zipline
- Skydio
- FORTEM Technologies
- PrecisionHawk
- dji

SYSTEMS

Computer Vision

Mighty Ai, SENSESIM, Humanising Autonomy, Apostera, Seoul Robotics, Calmcar, algolux, JIMU, VAYAVISION, Kodiak, Perceptive Automata, Phantom AI

Localization & Mapping

Jrop, Albora Technologies, rideOS, swift navigation, Accerion, point one

Development Tools

TENSYR, foretellix, Latent Logic, robby, Merantix, Apex.AI, Roadstar, Intempora, realtime robotics, Deepscale, COMSA, Holomatic, isee, caruma, Base Lab, Preteckt, Preferred Networks, Helm.ai, RobotWits, TTTech, Autonomous Fusion

HD mapping

mapbox, DEEPMAP, Artisense, Momenta, Civil Maps, Carmera

Simulation

cognata, foretellix, Applied Intuition, A, metamoto, parallel domain, Righthook, rFpro, AVSimulation, Fleetonomy, monoDrive

Cybersecurity

Mocana, Trillium, Argus Cyber Security, Arxan, dellfer, Centri, Karamba Security, Arilou

V2X

Notraffic, CiDi, Connected Signals, excelfore, Autotalks, Savari, Cohda Wireless, DERQ, Luxoft, aiPod, Valerann, tts, Veniam, commsignia

COMPONENTS

LiDAR

Innovusion	Cepton	Baraja	sense photonics
mirada Technologies, Inc.	Andela	Blickfeld	NewSight Imaging
Nodar	Tetravue	Luminar	Hesai
oryx	XenomatiX Automotive LiDAR Solutions	LeddarTech	Ouster
Quanergy	Lumotive	TriLumina	Innoviz Technologies

Camera

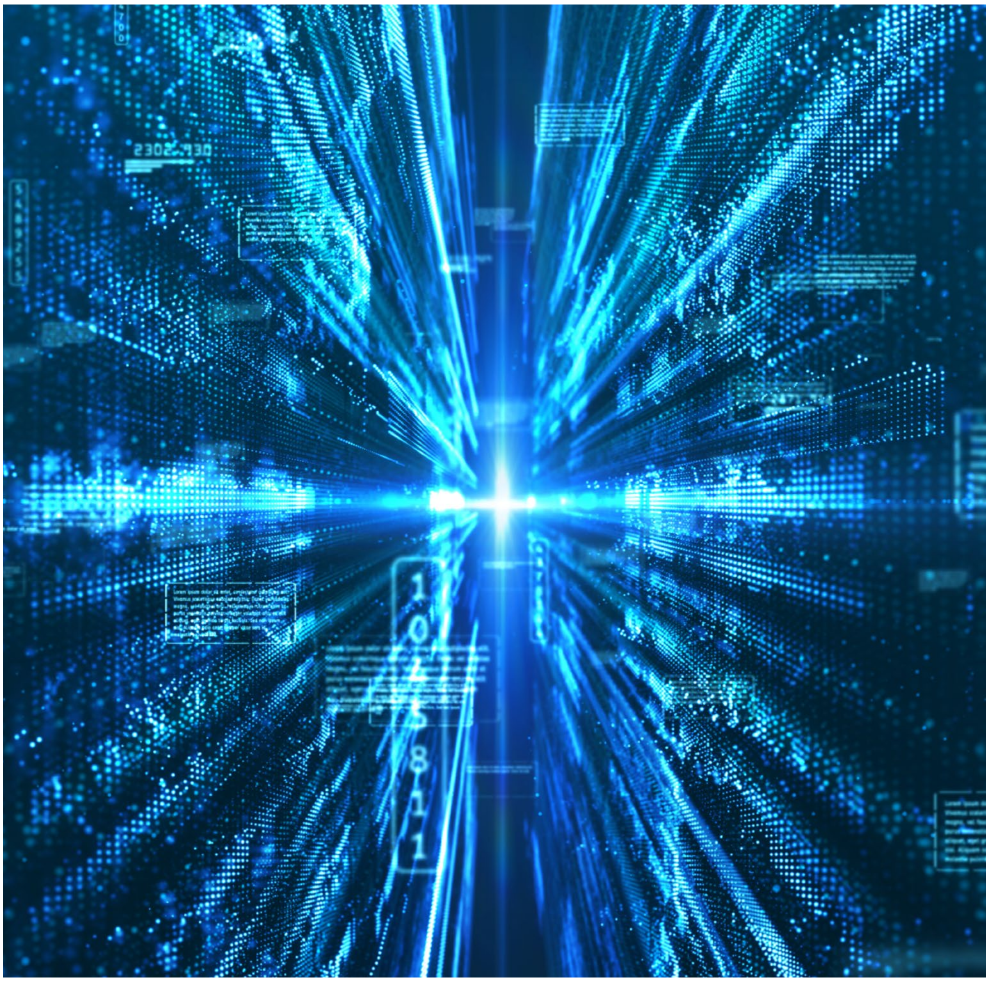
TriEye	Eatron Technologies	epilog	AEVA

RADAR

Uhnder	Metawave	RFISEE	arbe Robotics
Echodyne	Lunewave	Tusk IC	Hertzwell

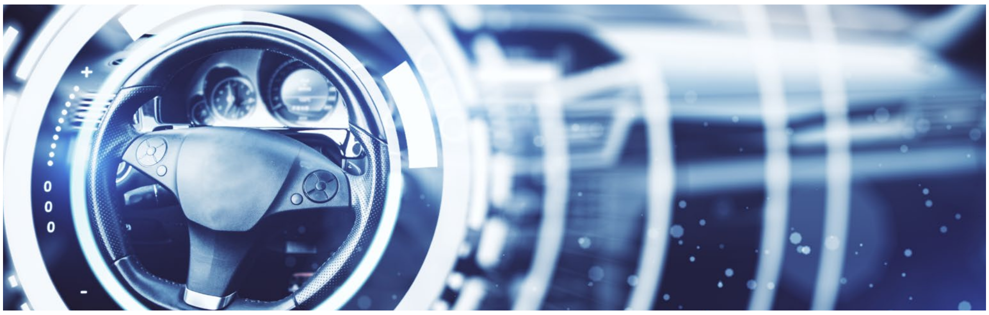
Onboard Communication and Safety Devices

PolySync	Smart Autolabs	Radiomize	excelfore
Predina	Smart wheel	Zobie	OnBoardSecurity
SaverOne	eyeris	Foresight	LyfeLens
carvi	splitsecnd	ALMA care	Tourmaline Labs
Nebula Systems	engie	Soniclue	



APPLICATION

PASSENGER CARS AND ROBOTAXIS



Timeline

The first truly autonomous cars were named Navlab and were launched in the early 1980s by Carnegie Mellon in the US. In 1987, Eureka Prometheus Project received over $750M in funding in Europe and became by far the largest self-driving R&D project up to that point. Daimler and Mercedes-Benz were already involved. However, it is not until the recent advancements in sensory systems, computer vision, and machine learning did we see a path to commercially-viable autonomy. UBS predicts that demand for self-driving cars will take off around 2026.

Current Market

Self-driving cars are inevitable. It is only a question of time. Morgan Stanley estimates that autonomous vehicles can save just the US economy a total of $1.3 trillion per year. The technology will disrupt the transportation industry from passenger car to mass transit. Any industry related will likely see massive secondary effects. As a self-driving car is a digital car and autonomy will naturally go hand in hand with electric drivetrains creating a significant impact on the energy and fossil fuel sector. The way we live will be redesigned. Urban centers will evolve, more will live independently, and many will rethink their commutes. According to Bloomberg, in 2019, over 50 major cities globally were piloting self-driving vehicles already. Passenger cars and robotaxis closely related. The main challenge to bringing autonomous technology is the unavoidable tens of thousands of dollars in additional cost per vehicle. In the near term, ride-hailing business will be the first to have a financially-viable reason to replace human drivers. For this reason, robotaxis are expected to come before mainstream autonomous passenger vehicles. As we transition to an access economy, urban consumers will increasingly favor a driverless-car booking over car ownership. Automakers, OEMs, and other legacy players will need a larger share of new mobility services and data revenue to sustain a growing topline and relevancy in the market.

Why It Matters

According to PitchBook, the autonomous vehicle industry to reach $41.4B by 2030 through sales of global autonomous vehicle software, sensors, and other hardware revenue. Implying unit sales of about 600,000 autonomous and semi-autonomous vehicle platforms in 2025, rising to 8 million units sold in 2030.

In addition, a recent Goldman Sachs projections show that global ride-sharing market (with the support of self-driving) could increase eight-fold by 2030, reaching $285B annually. Today, Goldman Sachs values the global taxi market at $108B, which is triple the size of the $36B ride-hailing market.

Incumbents: Tesla, General Motors, Ford, Alphabet, Uber, Amazon, Baidu, Intel

Key startups: Waymo (Alphabet) ($3B), Cruise (GM), Aurora ($763M)

Other startups: Zoox (Amazon), Pony.ai ($726M), DiDi ($500M), Ghost Locomotion ($64.5M). nuTonomy (acquired by Aptiv)

NOTABLE ACQUISITIONS

2020	Zoox acquired by Amazon, $1.2B
2019	Drive.ai acquired by Apple, undisclosed amount
2019	ZF acquired 60% of 2getthere, undisclosed amount
2017	nuTonomy acquired by Aptiv, $450M
2016	Cruise acquired by GM, $1B

TRUCKING

Timeline

Since 2014, Daimler (the parent company of Freightliner Trucks and Mercedes-Benz) has been testing self-driving trucks. However, it was Uber's Otto that made the first autonomous truck delivery in 2016. The trucking industry is on the cusp of disruption. It will be one of the first applications because the simpler autonomous application to highway vs cities provides a tangible return on investment in this category today.

Current Market

The industry will be substantially altered as soon as trucks can drive semi-autonomously on highways or specific routes. It will benefit from safety improvements, as well as fuel and labor savings long before full Level 5 autonomy is achieved.

Another overlooked catalyst accelerating the need for self-driving in trucking is the critical driver shortage. The workforce is ageing, has over 90% turnover, and is grappling with reduced capacity due to regulatory changes all while experiencing progressively increasing demand. Today, approximately 60,000 truck drivers are needed to meet demand in the US alone. According to industry experts, this will likely triple by 2026.

Since semi-autonomous technology will be first commercially deployed in highway trucking, it is likely to be the segment to go fully-autonomous. Prototypes are being tested to enable driving in all conditions while semi-autonomous will be on customer trucks in the second half of 2019. These Level 2+ assistive technologies are already road-legal under today's regulations. In the fall of 2018, Pronto used a demonstration of the first coast-to-coast autonomous drive with zero disengagements to show the technology's viability.

Why It Matters

Trucking is a $700B business that moves 71% of all goods in the US. In 2017, there were 3.5 million Class 8 trucks, 5.7 million commercial drivers and 210,000 trucking companies in the US alone. According to McKinsey, full autonomy will reduce the carriers' operating costs by about 45%. This would save the US for-hire trucking industry between $85B and $125B annually.

Incumbents: Daimler, Volvo

Key attackers: Alphabet (Waymo), Tesla, Uber

Key startups: Pronto, TuSimple ($288M), Inceptio Technology ($100M), Changsha Intelligent Driving Institute ($54M), Ike ($54.5M), Embark ($177.1M), Kodiak Robotics ($40M)

NOTABLE ACQUISITIONS

2019	TorcRobotic acquired by Daimler, undisclosed amount
2016	Otto acquired by Uber, $680M

2-WHEELERS

Timeline

Although experiments go back a couple of decades, established players haven't announced plans to build self-driving two-wheelers at this point. Instead, many see the benefits of autonomous being applied as assistive technologies to create a safer riding experience.

Current Market

Startups and established players are developing safer motorcycles equipped with some level of "smart" technology in critical riding situations. While some sensors and software algorithms are similar to those being applied in autonomous vehicles, they are markedly different products. This shows again that self-driving technology will bring an array of benefits well before reaching full autonomy.

Yamaha and Honda have been developing robotic motorcycles in their labs for several years. The Yamaha Motoroid concept and Honda's Riding Assist-e are proof-of-concept models that use self-balancing technology. In the meantime, BMW has released a video of its new BMW R 1200 GS, showing the motorcycle maneuvering around a test track without a rider.

Source: https://www.ft.com/content/3355f5b0-539d-11e8-b24e-cad6aa67e23e; https://www.nextbigfuture.com/2017/10/worldwide-ridesharing-at-285-billion-per-year-by-2030-will-be-profitable-when-self-driving.html; https://www.prnewswire.com/news-releases/global-autonomous-vehicle-market-was-valued-at-6-6-million-units-in-2017-and-is-expected-to-reach-67-5-million-units-by-2028--registering-a-cagr-of-20-78-between-2018-and-2028--300806007.html; https://www.alliedmarketresearch.com/autonomous-vehicle-market; https://emerj.com/ai-adoption-timelines/self-driving-trucks-timelines/; https://www.mckinsey.com/industries/travel-transport-and-logistics/our-insights/distraction-or-disruption-autonomous-trucks-gain-ground-in-us-logistics; https://medium.com/s/story/the-long-road-to-self-driving-trucks-d142229832d6; https://www.thestreet.com/markets/truck-driver-shortage-may-triple-by-2026-analysts-say-14650452; https://www.marketwatch.com/press-release/semi-autonomous-and-autonomous-trucks-market-2018-global-growth-size-trends-share-opportunities-competitive-analysis-opportunities-regional-and-industry-forecast-to-2023-2018-12-05

Why It Matters

Safety is one of the most critical factors in this large market. According to the US National Highway Traffic Safety Administration fatal motorcycle accidents have surpassed car fatalities and occurred 28 times more frequently per mile traveled in 2016. The market is large and growing, especially in emerging countries and China. While the motorcycle market is relatively small in the US when compared to passenger cars (500,000 units annually), in China, sales reached 1.35 million units in April 2018 alone.

Incumbents: BMW, Bosch, Honda, Yamaha, AB Dynamics, Uber

Key startups: Damon Motor, Ride Vision

FIRST-LAST-MILE PASSENGER

Timeline

Running self-driving vehicles on predefined routes or in geofenced locations offers relative simplicity. It is one of the first segments, where companies focused solely on selling self-driving vehicles have already reached over $10M in revenue. According to a senior analyst of Navigant Research, this market, alongside first-last mile delivery, will be the predominant opportunities for highly-automated vehicles for the next five to ten years.

Current Market

Communities looking to reduce the cost of commutes, road congestion, and greenhouse gas emissions are creating a growing demand for autonomous shuttles. Fenced environments present a better scenario compared to open-world driving. Facilities, such as corporate campuses, universities, residential neighborhoods, and senior living facilities offer the opportunity to operate on private roads where routes are typically no longer than 1-2 miles.

In 2018, the autonomous and electric shuttles startup, Navya reported an 85% year-over-year revenue increase to over $20M. The company has developed a 15-person bus that is already running in many geofenced sites in France.

Other companies, such as May Mobility, are tackling a portion of the $28B last mile public transportation problem many commuters face. Self-driving shuttles with safety drivers are already being launched in busy downtown areas. They aim to provide convenient and reliable transportation while solving the current parking, traffic, and land management issues.

Why It Matters

Source: https://www.vox.com/2018/6/14/17450826/motorcycle-self-driving-safety-adas-system; https://theweek.com/articles/763907/autonomous-motorcycles-want-share-road-selfdriving-cars; https://interestingengineering.com/bmw-unveils-autonomous-motorcycle-that-aims-to-make-riding-safer

According to IBIS World, the scheduled and chartered bus service segment generated $5B revenue in 2017. The market is projected to grow steadily through 2024. The immediate benefits of self-driving technologies here are expected to provide significant savings while expanding the possibilities of public transportation networks.

Incumbents: Bosh, Continental, ZF, Transdev, Meridian Autonomous

Key attackers: Alphabet (Waymo)

Key startups: Navya (€64.1M), May Mobility ($87.1M), EasyMile ($25.1M), Optimus Ride ($84.3M)

Other startups: Tsintel Technology ($15.2M), Next ($5.1M), Auro Robotics ($2.2M), Coast Autonomous, The Hi-Tech Robotic Systemz, Local Motors, Perrone Robotics, 2Getthere

NOTABLE ACQUISITIONS

2019	2Getthere acquired by ZF, undisclosed amount
2016	Auro Robotics acquired by Ridecell, undisclosed amount

FIRST-LAST MILE COMMERCIAL

Timeline

According to the Senior Vice President of the Renault-Nissan-Mitsubishi Alliance LCV Business, commercial vehicles will be the first to undergo the autonomy revolution. Self-driving technologies could solve the last mile delivery problem within the next few years. Similar to trucking, it is relatively easier to develop reliable self-driving vehicles in operating in predefined spaces versus driving in complex cities. According to McKinsey, self-driving vehicles on predefined routes will deliver 80% of all items in less than a decade.

Current Market

Consumers on all continents are increasingly relying on e-commerce. According to Business Insider Intelligence, the last delivery mile represents an estimated 53% of shipping's total costs. The market opportunity here is significant and according to McKinsey, automation would cut these costs in half.

Delivery companies will use small electric autonomous vehicles to navigate short distances to deliver groceries, meals, and packages directly to the customers' doorsteps. Their commercial fleets will eventually likely include autonomous drones. Many tests are already underway.

Source: https://www.vox.com/2018/6/14/17450826/motorcycle-self-driving-safety-adas-system; https://theweek.com/articles/763907/autonomous-motorcycles-want-share-road-selfdriving-cars; https://interestingengineering.com/bmw-unveils-autonomous-motorcycle-that-aims-to-make-riding-safer

Why It Matters

According to The Market Reports, the Global Last-Mile Delivery market was worth $30B in 2018 and is projected to be valued at $55B by 2025 – a 9% CAGR. According to ResearchandMarkets, the drone logistics and transportation market is expected to be worth $11.20B in 2022 and $29.06B by 2027 – a 21.01% CAGR.

Incumbents: Amazon (Prime Air), Airbus, UPS, DHL, Rakuten, FedEx

Key attackers: Alphabet (Wing X), 7-eleven

Key startups: Nuro ($1B), Robomart, AutoX ($160M), Starship Technologies ($160.1M), Otto motors ($70.1M), Udelv ($19.5M), Marble ($10M) Boxbot ($25M), Gatik ($24.6M), Dispatch ($21M), Eliport ($126.6K), ZMP

AGRICULTURAL APPLICATIONS

Timeline

In the 1990s, John Deere was already building its first autonomous navigation system. Many industry insiders, consider agriculture as one of the greatest near-term opportunities for self-driving vehicles for the same reasons as trucking and first-last mile transportation. Additionally, safety rules in wide-open fields are significantly lower than on congested city streets. Companies, such as Driscoll, will have fully autonomous agricultural vehicles operating by the end of 2019.

Current Market

By 2015, the global investment in agricultural technology, including corporate R&D, partnerships, minority investments and acquisitions reached a record of $25B. The industry has changed considerably in the last few years, with 80% of large US farmers using GPS devices to steer their tractors, while 70% to 80% use yield mapping.

An acceleration of precision farming will propel the next great wave of agricultural productivity. According to Euromonitor, autonomous technologies and a critical labor shortage will be key drivers of this opportunity. According to the Farm Bureau, in 2014, an estimated 56% of farmers have turned to automation – more than half said it was labor shortages.

Autonomous tractors will seamlessly integrate into existing fleets, reduce costs, and help farmers get more out of each acre of farmland. Driscoll, who controls a third of the $6B US berry market, has been testing many robots to harvest fruit. Harvest CROO Robotics, expects to deploy its farming robot that can cover eight acres in a single day and replace a team of more than 30 human pickers in the next two years.

Source: https://www.prnewswire.com/news-releases/29-06-billion-drone-logistics-and-transportation-market---global-forecast-to-2027--300667775.html; https://www.itchronicles.com/automation/the-last-mile-to-automation-how-autonomous-vehicles-could-solve-the-last-mile-delivery-problem/; https://www.marketwatch.com/press-release/global-last-mile-delivery-market-forecast-55200-million-us-by-2025-as-per-the-latest-research-report-2019-01-16

Why It Matters

According to Markets and Markets, the farm equipment market is expected to grow from $102.5B in 2018 to $135.2B by 2025. Goldman Sachs forecasts that farm technologies will represent a $240B market opportunity for agricultural suppliers by 2050.

Incumbents: Caterpillar, CNH, John Deere, Volvo, Bosch (Deepfield Robotics)

Key startups: DOT farming, Built Robotics ($48M), Tage I-driver, Iron Ox ($25.3M), Naio Technologies (€19.5M), Pyka ($11.1M)

Other startups: Monarch, Octopus robot, SoftRobotics ($48M), Agrobot, Rabbit Tractors, Bear Flag Robotics ($3.5M), Dynium Robot ($1.1M)

NOTABLE ACQUISITIONS

2017	Argo AI acquired by Ford, $1B
2017	Blue River Technology acquired by John Deere, $305M

UNMANNED AERIAL SYSTEMS

Timeline

Unmanned Aerial Systems, or UAS, were initially viewed as a military tool, however, over the past decade, they have established a presence in the corporate world. Some big tech companies invest in this technology and explore different use cases, from law enforcement and package delivery to construction and agriculture crop surveying, film making, search and rescue, and humanitarian aid efforts. McKinsey estimates that by 2026, commercial drones—both corporate and consumer applications—will have an annual impact of $31-$46 billion on the GDP of the USA.

Current Market

Since 2000, more than 300 start-ups have entered the space, which typically focus on hardware, support services, or operations of the UAS. The latter is a broad category that includes software and services related to navigation, unmanned traffic management (UTM), the mitigation of threats related to unmanned aerial vehicles (UAVs), and the construction and maintenance of UAS-related infrastructure. However, as with any new tech-

Source: https://www.farmprogress.com/node/144104; https://www.marketsandmarkets.com/PressReleases/agriculture-equipment.asp; https://www.cnbc.com/2019/05/01/farmers-turning-to-mechanization-due-to-labor-shortages-says-survey.html; https://mapof.ag/uk/polls/are-you-looking-to-invest-in-automation-and-or-robotic-farming-methods-in-the-next-5-years/; https://www.nanalyze.com/2018/12/autonomous-tractors-self-driving-farm-equipment/

nologies, there are a lot of uncertainties and challenges. For instance, air taxis, which are drawing much press attention, are still in early development, lack regulatory approval and infrastructure and face uncertain public acceptance. It will take years for industry incumbents and start-ups to overcome these hurdles.

Although it may take years to develop and commercialize the most innovative drone applications, stakeholders of the UAS industry have already started to refine their UAS strategies. As the market matures, more value is expected to shift toward software, particularly for solutions that improve UAS operations by enhancing detect-and-avoid systems, enabling analytics, and assisting with navigation in areas where drones cannot rely on a GPS signal. Companies would also value software solutions that support autonomous flight and integrate air-traffic control of drones and planes.

Why It Matters

According to ResearchandMarkets the UAV market is projected to reach $21.8B by 2027, at a 14.1% CAGR between 2020 and 2027. In terms of volume, the market is expected to grow at a CAGR of 16.2% from 2020 to 2027 to reach 13.2 million units by 2027.

Incumbents: Airbus, Boeing, DJI, NVIDIA, Uber, UPS

Key startups: Zipline ($303.3M), Skydio ($168.4M), PrecisionHawk ($138.7M), SZ DJI Technology Company ($155M), Airobotics ($101M), Skycatch ($96.6M), DroneDeploy ($91M), Airmap ($77.5M), Kespry ($61.3M)

Other startups: Yuneec ($60M), Dedrone ($55.4M), Clobotics ($48M), Delair ($37.8M), Fortem Technologies ($36.4M), SkySpecs ($30.7M), Elroy Air ($15.9M), Flytrex ($10.5M)

SYSTEMS

COMPUTER VISION

Timeline

Research on computer vision started in university artificial intelligence labs in the 1960s. Today it is the fundamental "perception" and one of the primary tools used in autonomous driving. Breakthroughs in the basic science of computer vision lead directly to the applied science advancements in self-driving.

Current Market

Under the hood of autonomous driving, on-board processors run computer vision algorithms on images captured by cameras and combine the results with other sensor data, such as radar and LiDAR to identify objects and the surrounding environment.

Source: https://www.globenewswire.com/news-release/2020/06/24/2052576/0/en/Global-Unmanned-Aerial-Vehicle-Market-2020-to-2027-Growing-Defense-Budgets-of-Major-Economies-Present-Opportunities.html; https://www.intermap.com/blog/uavs-today-where-are-they; https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/commercial-drones-are-here-the-future-of-unmanned-aerial-systems

Autonomous driving requires near-instant processing of a mass amount of data. Even at semi-autonomous levels, data is generated at 25 gigabytes for each driving hour. According to AAA, the average American drives over 290 hours annually. This equates to 380 - 5,100 terabytes of data in one year. Processing that amount of data quickly is the main challenge for automakers. This technological challenge and the potential pay-off, explains the substantial investors and strategics attention space has already received. Intel's $15.3B acquisition of Mobileye is one of the leading examples, so far.

Why It Matters

According to Markets and Markets, the artificial intelligence in computer vision market was valued at $3.62B in 2018 and is expected to reach $25.32B by 2023 – a 47.54% CAGR. A significant component of its growth is expected to be driven by the increasing demand for self-driving cars. This is supported by Market Research Engine, who estimates that the automotive artificial intelligence market will exceed $10.50B by 2024.

Incumbents: Alphabet (Waymo), Intel, Ambarella

Key startups: Scale AI ($123.1M), Prophesee ($64.8M), StradVision ($44.2M), Kodiak Robotics ($40M), Recogni ($25M), Mighty AI (acquired by Uber), Phantom AI ($26.9M), Perceptive Automata ($18.9M), DeepScale (acquired by Tesla)

Other startups: Zongmu ($22.9M), Vayavision (acquired by LeddarTech), Calmcar ($18.7M), Algolux ($13.4M), Allegro.AI ($11M), JIMU Intelligent ($15M), Linker Networks ($7.4M), Seoul Robotics ($6.1M), Humanising Autonomy ($6M), Understand.ai ($2.8M), Playment ($2.5M), Apostera ($1M), SenseSim, Nullmax

NOTABLE ACQUISITIONS

2020	Vayavision acquired by LeddarTech, undisclosed amount
2020	Artisense acquired by Kudan, undisclosed amount
2019	Understand.ai acquired by dSpace, undisclosed amount
2019	DeepScale acquired by Tesla, undisclosed amount
2019	Mighty AI acquired by Uber, undisclosed amount
2019	Integrated Device Technology acquired by Renesas, $6.7B
2018	Blue Vision Labs acquired by LYFT, $72M
2018	Mobileye acquired by Intel, $15.3B
2017	Autonomous acquired by TomTom, undisclosed amount
2016	VisLab acquired by Ambarella, $30M
2016	Movidius acquired by Intel, $400M
2015	Elektrobit acquired by Continental, undisclosed amount

HD MAPPING

Timeline

Google's Geo division emerged as the winner in digital maps years ago. Already, many companies are competing to lead the emerging HD Mapping category employed by the autonomous industry though the mass commercial scale is still years away.

Current Market

The high-definition maps come from centimeter-level pre scanning a specific location or route. Vehicles can then navigate by triangulating the distance from known objects while the on-board sensors focus on impermanent objects around the car, such as pedestrians and other vehicles. While a single standardized design has not yet been settled on, most of the existing systems rely on expensive hardware and software to build the maps.

One of the main challenges in this category remains the labor-intensive production and maintenance cost of high-precision HD maps. For instance, a single scanning vehicle from the leading Chinese map maker, AutoNavi Maps, costs over $1M. DeepMap's founders believe that the high manufacturing costs will decline over the next five years, as global demand for HD maps rises.

Why It Matters

According to Goldman Sachs, the HD map category is expected to climb to an estimated market value of $9.4B by 2025.

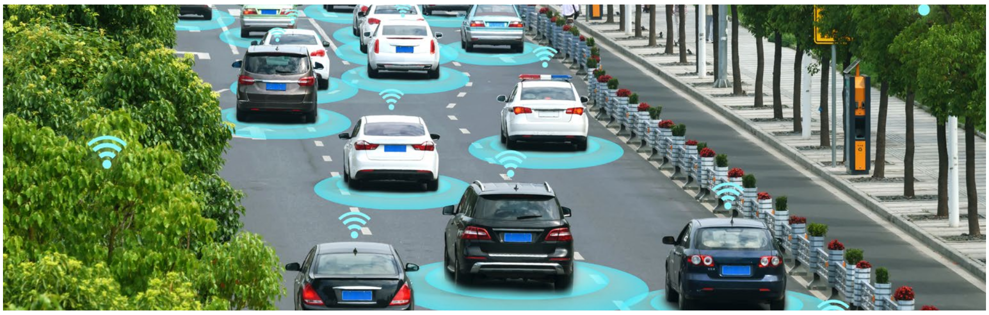
Incumbents: Alphabet, Alibaba

Key startups: Mapbox ($227.2M), Momenta ($203.2M), Deepmap ($92M), Carmera ($27.1M), Civil Maps ($15.9M), Advanced Navigation ($13M), Mapper ($10.5M), Dynamic Map Platform (Acquired Ushr), Artisense ($5.3M)

NOTABLE ACQUISITIONS

2019	Mapper acquired by Velodyne LiDAR, undisclosed amount
2019	M5 acquired by DoorDash, undisclosed amount
2019	Ushr acquired by Dynamic Map Platform, $282M
2018	Mapdata acquired by Mapbox, undisclosed amount
2015	Here acquired by Consortium of BMW, Audi and Daimler, $3B
2015	Autonavi acquired by Alibaba, $1.5B
2015	Elektrobit acquired by Continental, $677.5M

SIMULTANEOUS LOCALIZATION AND MAPPING (SLAM)



Timeline

The Global Positioning System (GPS) with its first launch by the US Airforce in 1973, became available for civilian use in the 1980s. Over the years, we've become reliant on GPS. Automotive navigation systems have primarily pushed the continuous improvements in the systems. Simultaneous Localization and Mapping (SLAM) is the computational approach to using and constantly updating a digital map to navigate in an environment. A natural progression from the basic GPS functionality needed in the autonomous driving world.

Current Market

No matter the sensor school of thought or type of vehicle, autonomous driving needs extremely precise localization. Many approaches have been in simultaneous development from satellite communication to machine learning in the cloud to SLAM. The winner will ultimately be a solution providing the acceptable level of precision at the lowest cost.

The computational approach to making a robot or a device produce a map of its surroundings and navigate itself accurately within the map in real-time is the essence of SLAM. Over the past several years, tech giants Google, Apple and Facebook and startups alike, have made contributions to SLAM technology development. Though it has several applications in navigation, autonomous driving is SLAM's most significant opportunity, by far. As the technology transitions from R&D to commercialization, we will see an increasing number of funded startups, such as Israel's Cortica with its $69.4M raised to date.

Why It Matters

According to BIS Research, the global SLAM technology market is projected to be valued at $8.23B by 2027 – a 66.6% CAGR.

Incumbents: Alphabet, Apple, HERE Global B.V, TomTom NV, MapQuest Inc., Luxoft

Key startups: Swift Navigation ($97.6M), rideOS ($34M), Point One Navigation

Other startups: Accerion (€1.1M), Jrop ($100K), Albora Technologies ($50K)

Source: https://www.globenewswire.com/news-release/2018/05/16/1507077/0/en/25-Billion-AI-in-Computer-Vision-Market-to-Grow-at-a-CAGR-of-47-54-Global-Forecast-to-2023.html; https://www.linkedin.com/pulse/how-computer-vision-works-self-driving-cars-david-silver/; https://www.marketwatch.com/press-release/automotive-artificial-intelligence-market-is-expected-to-touch-a-value-of-us-1050-billion-by-2024-2019-02-21; https://www.zdnet.com/article/intel-buys-mobileye-for-15-3-billion-eyes-autonomous-driving-market-computer-vision/; https://medium.com/syncedreview/the-golden-age-of-hd-mapping-for-autonomous-driving-b2a2ec4c11d; https://syncedreview.com/2018/11/28/the-deepmap-approach-your-data-your-hd-map/; https://www.freightwaves.com/news/technology/freightwaves-features-in-the-breakout-list-of-high-potential-and-growth-startups; https://www.mordorintelligence.com/industry-reports/automotive-digital-mapping-market; https://en.wikipedia.org/wiki/Simultaneous_localization_and_mapping; https://www.prnewswire.com/news-releases/global-slam-technology-market-anticipated-to-reach-823-billion-by-2027-reports-bis-research-684156451.html; https://www.analyticsinsight.net/future-ar-slam-technology-slam/

SIMULATIONS

Timeline

Simulations have been an essential part of autonomous driving system development from the early days. Collected sensor data from real-world driving is used to verify and train the software to handle challenging situations and edge cases.

Current Market

Collision models require extensive simulation in addition to on-road testing. This is because collecting large datasets of edge cases via driving is incredibly time-consuming and expensive. Advanced simulators, such as Waymo's Carcraft, can to build entire virtual road networks with other vehicles, bicyclists, and pedestrians to train and test algorithms.

The number of simulators has sprouted to meet the growing market of autonomous vehicle projects and increasingly sophisticated safety regulations. Variations on autonomous driving, such as truck platooning, and growing complexity, such as vehicle-to-everything (V2X) communication, will increasingly create new opportunities. The relatively early stage of benchmark data and the complexities of real-time vehicle control will continue to serve as the speed limit on how fast simulation technology can develop in the near term.

Why It Matters

According to Reportlinker, the global automotive simulation market is estimated to grow from $1.4B in 2018 to $2.9B in 2025 – an 11.1% CAGR.

Incumbents: Mechanical Simulation Corporation, Moog, Cruden, ECA Group, Ansys

Key attackers: Alphabet (Waymo)

Key startups: Cognata ($23.5M), Foretellix ($15.5M), Edge Case Research ($15M), Applied Intuition ($51.5M)

Other Startups: Fleetonomy ($3M), Parallel Domain ($2.9M), Metamoto ($2M), RightHook ($1.9M), MonoDrive ($95K), AV simulation, Alpha Drive, rFpro

NOTABLE ACQUISITIONS

2019	LatentLogic acquired by Waymo, undisclosed amount
2019	Quantum Signal AI acquired by Ford, undisclosed amount
2019	rFpro acquired by AB Dynamics, $22.9M
2018	Optis acquired by Ansys, $300M
2017	Tass International acquired by Siemens, undisclosed amount
2017	VIRES Simulations Technology acquired by MSC Software, undisclosed amount

2017	MSC Software acquired by Hexagon, $834M
2017	Tass acquired by Siemens, undisclosed amount
2017	Vires simulation acquired by MSC Software, undisclosed amount
2015	Elektrobit acquired by Continental, $600M

DEVELOPMENT TOOLS

Timeline

The tremendous market opportunity and recent acceleration in demand for autonomous vehicle technology have created an ever-expanding value creation window for developers of platforms and tools in this sector.

Current Market

Tools in this industry are off-the-shelf technologies for organizing input data, in-depth learning analysis, and sensor data exchange. The breadth and depth of technological challenges that have to be solved to reach full autonomy make it highly unlikely that one company will be able to develop the entire solution on its own.

While major automakers, such as BMW, Audi, Ford, Google, GM, Tesla, Volkswagen, and Volvo are focusing on developing their software, they rely on a number of others to provide software and hardware component technologies to plug into the mix.

Why It Matters

The overall automotive software market is poised to grow from $18B in 2018 to $52B by 2025.

Key startups: TTTech ($169M), Preferred Networks ($147.2M), HoloMatic ($30M), Foretellix ($15.5M), Edge Case Research ($15M), Apex.AI ($15.5M)

Other startups: Merantix ($37.5M), Helm.ai ($13M), Robby Technologies ($5.5M), Autonomous Fusion ($5M), Deepen AI, Preteckt ($6.4M), Caruma ($2M), Realtime Robotics ($13.7M), ISEE ($17.7M), NextNomy, Robot-Wits, Prome, BlinkAI Technologies, OURS Technology, Comsa Computer and Software, Latent Logic, Xotar, Base Labs, Edge case, Intempora, Tensyr

NOTABLE ACQUISITIONS

2020	CMORE Automotive acquired by Luxoft, undisclosed amount
2019	Figure Eight acquired by Appen, $300M
2016	Symtavision acquired by Luxoft Holding, undisclosed amount

CYBERSECURITY

Timeline

With mass amounts of data being generated by autonomous vehicles, privacy and safety issues are front and center. These new vehicles will be susceptible to hacking and cybersecurity will become an increasing priority.

Current Market

Though still early, hacking demonstrations and actual incidents have made automakers more vigilant about cybersecurity. In 2015, security researchers hacked into a Jeep AV using its Internet connectivity. Modern cars have been rolling computer open to hacking for many of years but self-driving brings with it much higher stakes in security. With increasing adoption and ultimate reliance on autonomous vehicles, cybersecurity tools and experts will be critical to ensure fleets' safety and reliability.

Why It Matters

According to Markets and Markets, the automotive cybersecurity market is projected to grow from $1.34B in 2018 to $5.77B by 2025 – a CAGR of 23.16%.

Incumbents: Green Hills Software, NHTSA, Honeywell, Check Point, Cymotive

Key startups: Mocana ($95.7M), Karamba Security ($27M), Trillium Secure ($15M), Centri Technology ($12.8M), Regulus Cyber ($11.6M), VisualThreat ($8.5M), Dellfer ($2M), Olympus Sky ($1.9M)

NOTABLE ACQUISITIONS

2020	Arxan Technologies acquired by Digital.ai, undisclosed amount
2017	Argus Cyber Security acquired by Continental, $400M
2016	Arilou Tech acquired by NNG, undisclosed amount

Source: https://www.apnews.com/Business%20Wire/6d8a712523444f2da59525f6c75e93da; https://www.forbes.com/sites/davidsilver/2018/11/01/simulation-becomes-increasingly-important-for-self-driving-cars/#3c36fc3d5583; https://www.apnews.com/3af5a970fc004751867f5bd1b9183257; https://www.globenewswire.com/news-release/2019/04/04/1796848/0/en/Automotive-Software-Market-to-surpass-52bn-by-2025-Global-Market-Insights-Inc.html; https://www.wgu.edu/blog/how-cybersecurity-drives-self-driving-car-adoption1812.html; https://letstalkselfdriving.com/safety/cybersecurity.html; https://www.freightwaves.com/news/insurance-and-risk-management/auto-cybersecurity-importance; https://www.marketsandmarkets.com/PressReleases/cyber-security-automotive-industry.asp

VEHICLE-TO-EVERYTHING (V2X) COMMUNICATION

Timeline

In 2016, Toyota was the first automaker to equip a vehicle with V2X communication. GM followed in 2017. The rise of semi-autonomous driver assistance systems is already growing the communication segment. The demand will explode as autonomous, connected vehicles begin rolling out in the next few years.

Current Market

V2X is defined as a vehicle (V) to any external (X) communication; vehicle-to-vehicle (V2V); vehicle-to-infrastructure (V2I); vehicle-to-cloud (V2C); vehicle-to-pedestrian (V2P); and vehicle-to-network (V2N).

V2X is an important component in the autonomous vehicle technology stack. Each of the sensors: cameras, RADARs, LiDARs, and others complete part of the puzzle. Identification of objects is still the primary challenge in fully autonomous vehicles. V2X allows vehicles to communicate with other objects to enhance further the set of data used in navigation.

Currently, IEEE 802.11p and Cellular V2X are the two leading technologies in play. The need for low latency and high reliability are the main challenges. Ford recently announced that by 2022 all its cars and trucks sold in the US would feature Qualcomm's C-V2X capabilities. The future success of real-time Vehicular-to-Everything (V2X) requires resilient, highly reliable, and secure 5G mobile networks with a high degree of reliability across the entire vehicle network. Though 4G is a step in the right direction, it lacks the speed, bandwidth, and efficiency self-driving connected cars will need.

Why It Matters

According to Reports and Data, the global Automotive Vehicle-to-Everything (V2X) market is expected to grow from $38.2B in 2018 to $110.3B by 2026.

Incumbents: Continental, Qualcomm, NXP Semiconductors, Robert Bosch, Denso and Delphi Automotive, Tima Networks, Torro Electric Europe (Sensefields), Ford, Kapsch Group, Luxoft, Kontron, Marvelle, Keysight, Nordsys, NXP

Key startups: Autotalks ($90M), Veniam ($26.9M), Savari ($20M), Metawave ($17M), Excelfore ($10.6M), Valerann ($5M), NoTraffic ($6.9M)

Other startups: Connected Signals ($2.8M), Cohda Wireless ($1.8M), Derq ($3.1M), ZD, aiPod, CIDI, Commsignia, V2X network, Traffic Technology Services, YoGoKo

NOTABLE ACQUISITIONS

2018	eTrans Systems acquired by Kapsch Group, undisclosed amount
2018	Objective Software acquired by Luxoft, undisclosed amount

COMPONENTS

LIDAR

Timeline

Soon after the birth of the laser in the 1960s, Light Detection and Ranging (LiDAR) was developed. It was used during the Apollo 15 mission in 1971 to map the surface of the moon. In 2005, Stanley Thrun, head of Stanford's artificial intelligence laboratory, first utilized LiDAR in a Grand DARPA Challenge vehicle. Most of the companies working on self-driving vehicles are now using this technology. The cost and size of LiDAR systems are steadily decreasing, and it is currently still too expensive to be commercially viable for passenger vehicles.

Current Market

LiDAR provides a 360° 3D reconstitution of the environment around a vehicle. Its advantages over other sensors are tracking range (up to 200M), predictability, and high-resolution object tracking. This has made LiDAR attractive in the autonomous driving application. Recent advances enable differentiation between a cyclist and a pedestrian. However, the technology is still expensive (as much as $80,000 a unit), large in size and weight, and suffers from limited capabilities in fog, rain, and snow.

A substantial portion of the market believes LiDAR sensors will be the future of autonomous vehicles. According to the research firm Yole, there are currently 85 companies developing automotive-grade LiDAR products. Some are already being used for Advanced Driver Assistance Systems (ADAS) and support semi-autonomous vehicles. Mainstream adoption in autonomous vehicles is expected to drive market growth, economies of scale, and lower manufacturing prices.

Why It Matters

The demand for automotive-grade LiDAR is growing in parallel with the self-driving industry. By March of 2019, Velodyne (one of the market leaders), has shipped a total of 30,000 sensors worth $500 million dollars. Almost all were sold to autonomous vehicle manufacturers for testing. LiDAR sensors absorbed over 20% of the ADAS market in 2017 – a market worth $24.24B in 2018, according to Markets and Markets. BIS Research predicts that the global automotive LiDAR market will reach $8.32B by 2028.

Incumbents: Velodyne ($225.2M), Leica Geosystems AG, Quantum spatial GeoDigital, Riegl USA, Abax Sensing, Ibeo

Key attackers: Alphabet (Waymo)

Key startups: Quanergy ($325.1M), Innoviz Technologies ($264M), Luminar ($250M), Hesai ($231.2M), LeddarTech ($183.7M), Ouster ($120.9M), Cepton Technologies ($100M), AEye ($71.9M)

Other startups: Robosense ($43.7), Trilumina ($38.6M), Baraja ($33.7M), Innovusion ($32.7M), Sense Photonics ($33.7M), SOS Labs ($14.2M), NewSight Imaging ($13.2M), Blickfeld ($10M), TetraVue ($10M), Lumotive ($9M), Voyant Photonics ($4.3M), Mirada Technologies, Nodar, Benewake

NOTABLE ACQUISITIONS

2020	Luminar announced about SPAC merger with Gores Metropoulos Inc., $3.4B
2020	Velodyne LiDAR did a reversed merger with Graf Industrial Corp.
2019	Blackmore acquired by Aurora, undisclosed amount
2018	Advanced Scientific Concepts (LiDAR unit) acquired by Continental, undisclosed amount
2018	SensL acquired by On Semiconductor, undisclosed amount
2018	AutonomouStuff acquired by Hexagon, $160M
2017	Princeton Lightwave acquired by Argo.AI, undisclosed amount
2017	Strobe acquired by GM, $36.5M
2016	Otto acquired Tyto LIDAR, undisclosed amoun
2009	Fotonic acquired Autolive, undisclosed amount

RADAR

Timeline

Radar has been used to measure the range, velocity, and edges of objects on land, water, and the air for many years. The technology was first deployed on production automobiles by supplier Delphi in 1999. Since then, it has become the key input for obstacle detection on driver-assist systems. More recently, the role of Radar is transforming as a component of the autonomous vehicles technology stack.

Current Market

Compared to LiDAR and other sensors, RADAR, or Radio Detection and Ranging, is low cost and mostly insensitive to various light and environmental conditions, such as rain or fog. The technology is also accurate for short distances and highly accurate in determining traffic speed. However, its range is short, Radar cannot contribute to objects identification, and only works on metal surfaces.

This technology plays a key role in semi-autonomous and autonomous vehicles. Advanced Driver Assistance Systems (ADAS) is a crucial stage on the way to full autonomy. The Radar enables two ADAS technologies: the automatic emergency braking system (AEBS) and the adaptive cruise control (ACC).

Increasing automation levels will require systems to analyze complex scenarios. To meet these challenges, the advantages of a variety of sensors are combined. This aggregation is known as a sensor fusion and is the agreed-upon path in autonomous systems development. With its low cost and evident benefits, Radar has a vital role to play. The rising demand for self-driving technologies will drive Radar market growth.

Why It Matters

According to Grand View Research, the global automotive radar market is projected to reach $12.16B by 2025 – a 20.8% CAGR. In addition, Radar sensors are the fastest growing component segment in ADAS. According to Markets and Markets, the overall ADAS market is expected to be worth $91.83B by 2025 – a CAGR of 20.96%.

Incumbents: Bosch Tool Corporation, Continental AG, Denso

Key startups: Vayyar ($188M), Echodyne ($64M), Arbe ($53.5M), Metawave ($48M), Oculii ($17.7M), Zvision ($11.4M), Zendar ($10.7M)

Other startups: Imagry ($6.5M), Lunewave ($5.5M), Hertzwell, RFISee, Tusk IC, Uhnder

NOTABLE ACQUISITIONS

2018	mmWave technology acquired by On Semiconductor, undisclosed amount

CAMERAS

Timeline

First installed in a luxury car as backup cameras, they've become mandated in all cars sold in the US since May of 2018. These small, inexpensive modules have improved performance and started playing a major role in developing self-driving vehicles. Several influential leaders, such as Tesla and Pronto, have promoted that a camera-only, machine learning approach is the only feasible path to immediate driverless future.

Source: https://www.globenewswire.com/news-release/2019/04/18/1806686/0/en/Automotive-Vehicle-to-Everything-V2X-Market-To-Reach-USD-110-3-Billion-By-2026-Reports-And-Data.html; https://www.auto-talks.com/technology/v2x-wiki/; https://www.zdnet.com/article/what-is-v2x-communication-creating-connectivity-for-the-autonomous-car-era/; https://www.smartcitiesdive.com/news/ford-cv2x-tech-new-vehicles-2022/545412/; https://www.wired.com/2006/01/stanley/; https://www.autopilotreview.com/lidar-vs-cameras-self-driving-cars/; https://www.apnews.com/Business%20Wire/d75b9c9da4234624b59820daefef60bf; https://www.electronicdesign.com/automotive/yole-anticipates-6b-market-autonomous-vehicle-lidar-five-years; https://www.prnewswire.com/news-releases/global-automotive-lidar-market-to-reach-8-32-billion-by-2028-822726783.htm

Current Market

The automotive-grade camera market is still primarily driven by the increasing demand for safety and convenience in luxury vehicles. Camera-based Advanced Driver Assistance Systems (ADAS) were previously limited by cost but demonstrated safety improvements led to government safety mandates and subsequent economies of scale.

The deployment of cameras in autonomous vehicles is expected to fuel demand for continuing technology improvement and cost reduction. Cameras are well-suited for autonomous systems because of the relatively low cost, compact size, weight, and a long-range of the modules. Additionally, only cameras can be helpful in perceiving colors, recognizing street signs, and traffic lights. Limitations in cameras are related to low visibility or bad weather environments and the inability to sense distance or speed. A number of leaders in autonomous driving, such as Tesla, Pronto, Comma, and AutoX, have announced that they intend to rely on the camera-only approach. Tesla is pushing to increase autonomous functionality on the 300,000+ cars it already manufactures annually today. For that reason, it is not entirely clear if their CEO, Elon Musk's public pronouncements against the usefulness of LiDAR are to be taken at face value or are motivated by the lack of market-ready components. This underscores the fact that a single technological approach to self-driving has not yet been settled-on by the industry.

Why It Matters

According to ResearchandMarkets, the Global Automotive Camera market will grow from $6.28B in 2017 to $17.94B by 2026 – a 12.4% CAGR.

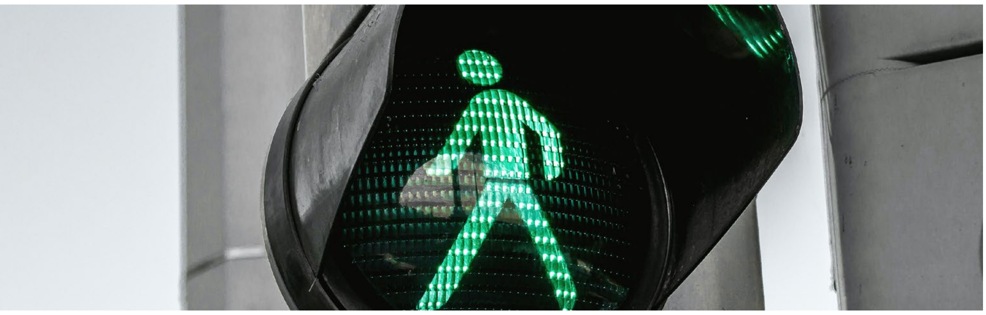
Key startups: Aeva ($108.5M), TriEye ($22.1M), Slightech ($7.6M), Epilog Imaging Systems ($4.1M)

Other startups: Wissen, Eatron Technologies

NOTABLE ACQUISITIONS

2020	Foresight Autonomous Holdings completed PIPE on FRSX, $80M
2016	Point Grey Research acquired by Flir, $253M

ONBOARD COMMUNICATION AND SAFETY DEVICES



Timeline

Electronic fuel injection created the need to carry automotive electronic control units (ECU). By the 1990s, efforts to reduce tailpipe emissions made this technology commonplace. ECU began to become more complex and increasingly more relied upon. With the recent rise of autonomous vehicles, they have become sophisticated on-board computers with artificial intelligence-tuned, application-specific integrated circuits (ASIC).

Current Market

Autonomy will transform the automotive landscape and offer new opportunities in driver assistance, safety, maintenance, security, and infotainment.

As the overall economy transition from ownership to an emphasis on access, vehicle unit sales are projected to plateau. It will become a strategic imperative for automakers, suppliers, and other legacy players to find growth in other products and services. According to McKinsey, car data monetization could become a $450B to $750B global opportunity by 2030.

With autonomy comes the opportunity to provide value in the form of services and entertainment to passengers. Vehicles will become the ultimate Internet of Things (IoT) devices. 4G has given true mobility via access to all of the world's information and media through high-speed wireless streaming; 5G combined with V2X infrastructure, will further unlock a massive potential upside.

Why It Matters

According to Harman International, there will be more than 200 million connected vehicles worldwide by 2020. Allied Market Research projects the global connected car market to grow from $63.03B in 2017 to $225.16B by 2025 – a 17.1% CAGR.

Incumbents: Cortexlabs, Nauto ($173.9M)

Key startups: SambaNova Systems ($460.6M), Horizon Robotics ($700M), Mythic ($86.4M), Zubie ($25.9M), Phantom Auto ($19M), Carvi ($20M), Excelfore ($10.6M), Engie ($9.5M), Formant ($6M)

Other startups: Kneron ($73M), Realtime Robotics ($21.3M), Tactile Mobility ($9M), TourmalineLabs ($3M), Phrame ($2M), Foresight AI ($1.3M), LyfeLens, Smart Autolabs, Eyeris, Alma Care, Saverone, Smart wheel, Radiomize, Braiq, Soniclue, Predict Systems, Predina, OnBoard Security, PolySync

NOTABLE ACQUISITIONS

2019	Scotty Labs acquired by DoorDash, undisclosed amount
2019	Latent Logic acquired by Waymo, undisclosed amount
2019	Journey Holding acquired by Ford Smart Mobility, undisclosed amount
2017	Automatic Lab acquired by Sirius XM, undisclosed amount
2017	Lojack acquired by CalAmp, $134M
2016	Pelagicore AB acquired by Luxoft, undisclosed amount

Source: https://www.wired.com/2006/01/stanley/; https://www.autopilotreview.com/lidar-vs-cameras-self-driving-cars/; https://www.apnews.com/Business%20Wire/d75b9c9da4234624b59820daefef60bf; https://news.voyage.auto/an-introduction-to-lidar-the-key-self-driving-car-sensor-a7e405590cff; https://www.prnewswire.com/news-releases/global-automotive-lidar-market-to-reach-8-32-billion-by-2028-822726783.htm; https://www.prnewswire.com/news-releases/17-94-billion-automotive-camera-market-by-2026-global-outlook-study-2019--300837628.html; https://www.marketwatch.com/press-release/car-camera-modules-market-outlook-to-2023-top-companies-trends-and-growth-forecasts-2019-01-19; https://www.wired.com/story/the-know-it-alls-how-do-self-driving-cars-see/https://www.wired.com/story/the-know-it-alls-how-do-self-driving-cars-see/; https://www.autonews.com/technology/radar-finds-new-place-self-driving-technology; https://www.prnewswire.com/news-releases/connected-car-market-worth-225-16-bn-by-2025-at-17-1-cagr-allied-market-research-822425512.html; https://www.digitaltrends.com/cars/everything-you-need-to-know-about-obd-obdii/; https://www.mckinsey.com/~/media/mckinsey/industries/automotive%20and%20assembly/our%20insights/monetizing%20car%20data/monetizing-car-data.ashx

THE ADVANCED MOBILITY ALMANAC - 50+ CORPORATIONS WORKING ON ELECTRIC AND AUTONOMOUS VEHICLES

AUTOMAKERS

TECH COMPANIES

ENERGY AND INDUSTRY

APTIV

EV

In **2020**, unveiled its new Smart Vehicle Architecture (SVA) at CES
In **2018**, received 20th PACE award-winning Selective Metal Coating (SMC) technology
In **2018**, customer shed 11 kilograms and 400 meters of cabling from its popular 2018 truck, while another customer reduced the mass of the electrical distribution system on its 2018 SUV platform by 15%
In **2017**, helped one leading EV company to reduce wiring mass in its 2017 model by 10% and removed 150 meters of cabling

AV

In **2020**, unveiled its new Smart Vehicle Architecture (SVA) at CES
In **2018**, received 20th PACE award-winning Selective Metal Coating (SMC) technology
In **2018**, customer shed 11 kilograms and 400 meters of cabling from its popular 2018 truck, while another customer reduced the mass of the electrical distribution system on its 2018 SUV platform by 15%
In **2017**, helped one leading EV company to reduce wiring mass in its 2017 model by 10% and removed 150 meters of cabling

BAIC

EV

In **2020**, partnered with State Grid Electric Vehicle Services to expand its EV charging network
In **2018**, its EC Serie model became the second most sold EV in the world
In **2014**, launched its first electric vehicle in China
In **2009**, acquired intellectual property of 9-5 and 9-3 Saab models

AV

In **2020**, announced a JV with Didi Chuxing autofocus division to develop high-level customized self-driving automobiles
In **2019**, set up a joint laboratory with visionICs to research and develop solid-state LiDAR
In **2019**, partnered with Huawei to set up a "1873 Davidson Innovation Laboratory
In **2017**, have formed a strategic partnership with Baidu to collaborate on the advancement of autonomous vehicles in China

BMW

EV

Announced that all new platforms will be built to accommodate electric powertrain by **2021**
Planned to offer 12 electric models by **2025**
Aims to produce 7M EVs by **2030**
In **2020**, signed $2B battery supply contract with Northvolt
In **2019**, combined all its car sharing services in a $1B joint venture with Daimler
In **2018**, announced its self-driving prototype line iNEXT
In **2018**, partnered with Solid State, a solid-state battery developer
In **2018**, signed a $1B battery supply contract with CATL
In **2016**, launched its North Amercia car sharing services ReachNow
In **2016**, completed a 100 DC charging network with Volkswagen and Chargepoint
In **2013**, released its first electric car i3
In **2011**, in a joint venture with Sixt, launched its Europe car sharing services DriveNow

AV

Announced its plans to deploy Level 3 self-driving cars by **2021**
In **2019**, partnered with Daimler to co-develop automated driving technologies, all the way up to SAE Level 4
In **2019**, partnered with Microsoft to launch Open Manufacturing Platform and self-driving systems
In **2018**, opened a second autonomous driving campus in Munich
In **2017**, teamed up with Volkswagen, Nissan, Mobileye and Aptiv on shared mapping platform
In **2016**, an unveiled autonomous car concept at CES Las Vegas
In **2015**, acquired Here with Daimler and Volkswagen
In **2014**, partnered with Baidu to develop an autonomous vehicle

CONTINENTAL

EV

In **2019**, announced that it will put more focus and capital on the electric powertrain
In **2019**, announced its plans to expand production capacity in China
In **2017**, announced an additional $326M investment plan in electric-car technology by 2021
In **2017**, signed strategic cooperation agreement with NIO in the field of electric vehicles
In **2012**, unveiled the world's first dedicated e-car tire, the Conti.eContat

AV

In **2020**, pledged to invest €100M to build a plant for radar sensors in Texas, as part of the "high triple-digit million euros" investment in assisted & automated driving areas over the next 5 years
In **2020**, has set up a new supercomputer specifically for developing advanced driver-assistance technologies
In **2020**, showcased its holistic solution for human-machine interaction for the AVs
In **2019**, started a collaboration with Vodafone to develop 5G, V2X, and mobile edge computing
In **2018**, partnered with Nvidia to build self-driving vehicle systems
In **2017**, opened Silicon Valley R&D lab
In **2016**, acquired the Hi-Res 3D Flash LIDAR unit from ASC

DAIMLER

DAIMLER

EV

In **2020**, Mercedes-Benz announced a partnership with CATL to create cutting-edge battery technology and supply batteries and with Hydro-Québec on future battery technologies
In **2020**, Daimler is trialling eight more purely battery-powered eActros trucks
In **2019**, combined its car sharing services with BMW in a $1B joint venture
In **2018**, announced a $3.2B investment plan in e-trucks
In **2016**, Mercedes-Benz approved a $10B program to develop 130 electric cars
In **2014**, launched the Mercedes B250e
In **2008**, launched Car2go, a car sharing venture with Europcar

AV

In **2020**, Mercedes-Benz and NVIDIA announced its plan to enter into a cooperation to create a revolutionary in-vehicle computing system and AI computing infrastructure
In **2019** Daimler Trucks acquired a majority stake in Torc Robotic
In **2018**, announced a partnership with Bosch to launch self-driving taxi rides
In **2017**, announced a partnership with Uber to supply self driving vehicles
In **2015**, started autonomous truck testing in Nevada
In **2015**, along with BMW and Volkswagen, acquired HERE's Mapping Business

FCA

FCA
FIAT CHRYSLER AUTOMOBILES

EV

Invested over $11B to develop 32 fully or partially electrify models by **2022**; the 2020 model year will bring seven new electric vehicles to the FCA global lineup
In **2020**, FCA plans to launch battery electric versions of the new Fiat 500 and Ducato, and PSA will release the Peugeot e-2008 and Opel Corsa-e EVs
In **2019**, signed agreement with ENGIE and Enel X for new e-mobility solutions in 14 European countries, to enable customers to locate, book and pay for public charging points via an app
In **2019**, Jeep® launched its first-ever plug-in hybrid, the Jeep Commander, in China. In North America, the patented "e-Torque" hybrid technology was introduced
In **2013**, launched the 500e model
In **2013**, partnered with Eni to launch car sharing service "Enjoy" in Italy

AV

In **2020**, announced a merger with PSA Group to work on autonomous, electrified, connected vehicles
In **2020**, announced that it will deepen their partnership with Waymo and build commercial vehicles for transporting cargo
In **2019**, partnered with Aurora to develop self-driving commercial vans
In **2018**, invested an additional $30M in US autonomous driving testing facilities
In **2018**, extended a partnership with Waymo by providing more than 60,000 vehicles
In **2016**, announced a partnership with Waymo by supplying 600 hybrid minivans

FORD

EV

Declared it will have 20 new EVs on the market by **2023,** spending $20B by **2025** on electric and autonomous tech
In **2019**, Ford invested $500M in Rivian in order to use the company's unique battery architecture
In **2019**, expanded its partnership with Volkswagen on autonomous, electric vehicles
In **2018**, announced the development of 16 "electrified" models
In **2017**, created "Team Edison" and developed all-electric cars
In **2017**, pledged to invest $4.5B over five years on new all-electric and hybrid vehicles
In **2016**, launched the Focus electric

AV

Announced its intention to roll out autonomous vehicles by **2021**
In **2020**, expanded partnership with Mobileye on ADAS
In **2019**, acquired Quantum Signal, a company focused on mobile robotics, modeling and simulation
In **2019**, ArgoAI started collaboration with Volkswagen to introduce autonomous vehicle technology in the U.S. and Europe
In **2018**, partnered with Walmart and Postmates on autonomous delivery tests
In **2017**, acquired majority stake in AI startup Argo for $1B
In **2017**, started a partnership with Domino's on autonomous delivery pilots

GM

EV

Unveiled its all-electric Cadillac which is planned for production by **2021**
Announced the introduction of 20 new electric car models and aim for $5M EV sales by **2023**
In **2020**, GM and Honda have agreed to jointly develop two all-new electric vehicles for Honda
In **2020**, partnered with EVgo to add 2,700 new fast chargers in U.S
In **2017**, produced 1,117 of EV1, to be leased, 100 miles range
In **2016**, launched car sharing service, Maven
In **2016**, launched the Chevy Bolt
In **2015**, partnered with LG Electronics to supply batteries to Chevy Bolt
In **2011**, signed a partnership with SAIC to develop electric cars in China

AV

In **2020**, Cruise rolled out a self-driving, all-electric, ride-sharing shuttle developed with Honda
In **2019**, Cruise secured an $1.15B round from investors, including T. Rowe Price Associates
In **2018**, announced an AV partnership with Honda, which should invest $2.8B in Cruise over 12 years
In **2018**, Cruise secured a $2.25B round from SoftBank
In **2018**, launched semi-autonomous Super Cruise Cadillac CT6
In **2018**, filled petition to run a commercial autonomous ride-sharing business
In **2016**, acquired Cruise Automation for over $1B becoming its autonomous unit
In **2016**, invested $500M in Lyft to develop self-driving cars

HONDA

EV

In **2020**, GM and Honda have agreed to jointly develop two all-new electric vehicles for Honda
In **2020**, signed an agreement with CATL to form a "comprehensive strategic alliance" on new energy vehicle (NEV) batteries
In **2019**, presented ePrototype, the EV destined for the European market
In **2019**, partnered with GM and CATL to develop new lithium-ion batteries
In **2018**, partnered with CalTech and NASA researchers who are developing fluoride-ion batteries
In **2018**, unveiled Everus all-electric concept at the 2018 Beijing Motor Show
In **2017**, started producing the Clarity Electric

AV

In **2018**, invested $750M in GM's autonomous unit Cruise, as part of the $2.8B partnership with GM on autonomous vehicles
In **2017**, announced plans to launch Level 3 self driving vehicle on the road in Japan in 2020
In **2017**, launched its R&D Center X
In **2016**, announced a deal with Waymo to build new type of autonomous delivery vehicles
In **2016**, introduced semi-autonomous driver assist on Civic models

HYUNDAI

EV

Announced the launch of a new electric car model built on Hyundai EV platform by **2020**
Announced the development of 38 "green car" in the next 8 years
In **2020**, announced a partnership wit Canoo to develop an EV platform based on Canoo's proprietary skateboard design for upcoming Hyundai and KIA models
In **2019**, invested $300M in Ola as part of a strategic partnership focused on electric vehicle development
In **2019**, invested over $80M in Rimac Automobili with KIA Motors
In **2018**, launched the Kia Niro EV
In **2017**, released the Iconiq Electric

AV

In **2020**, announced a $4B joint venture with Aptiv, Motional, to introduce driverless vehicles for ride-hailing fleets by 2022
In **2019**, partnered with Russian company Yandex to develop autonomous vehicle platform
In **2019**, announced plans to invest $35B over the next 5 years on its self-driving, electric, and connected mobility initiatives
In **2019**, announced its aiming to bring an autonomous vehicle to market by 2025
In **2018**, started focusing on creating affordable driver-assist technology
In **2018**, partnered with Cisco to deliver OTA (over the air) update
In **2017**, invested in Israeli technology firm Autotalks

JAGUAR LAND ROVER

EV

Announced that starting in **2020**, all new Jaguar Land Rover vehicles will have electrified option
In **2020**, announced a milestone of over 1.5 million Ingenium engines produced
In **2018** started to produce the i-Pace
In **2017**, Jaguar launched I-PACE eTROPHY – the world's first single-make electric race series car

AV

Announced the deployment of a fleet of 100 self-driving vehicles on the road in Britain by **2020**
In **2020**, unveiled autonomy ready electric car concept aiming to launch on-road trials in 2021
In **2018**, announced a partnership to supply cars for Waymo's fleet of ride-hailing vehicles
In **2018**, announced it would begin working on off-road self-driving technology
In **2017**, invested $25M in Lyft to autonomous and connected vehicle activities
In **2016**, joined a $7.9M UK program to further autonomous driving R&D, aiming to gather data on driving habits and test vehicle communications technology

MAGNA INTERNATIONAL

EV

First production of electric vehicles planned to be launched in late **2020**
In **2020**, Fisker Inc. entered a memorandum of understanding with Magna to build its Ocean electric SUV
In **2019**, announced a joint venture with BAIC Group and the Zhenjiang government on electric vehicle manufacturing in China

AV

In **2020**, changed focus of its partnership with Lyft to produce hardware and software components for AVs
In **2019**, announced a partnership with Waymo to build a factory to manufacture self-driving cars in southeast Michigan
In **2019**, invested $200M into Lyft to co-develop fully autonomous vehicles
In **2019**, along with Bosch, Continental, ZF, and Valeo, was coined "Tier 1" autonomous vehicle supplier
In **2018**, partnered with May Mobility to build autonomous buses
In **2017**, joined a BMW, INTEL, FCA autonomous platform consortium
In **2016**, partnered with solid-state lidar startup Innoviz to round out the sensor package for its self-driving system

PSA

EV

In **2020**, announced it has developed a new dedicated platform for battery electric vehicles, which will be the foundation for new electric models starting from 2023
In **2020**, spinner off its mobility services into separate company, under the Free2Move label, including fleet management, car-sharing, short- and long-term rentals, parking, and electric vehicle charging points
In **2018**, announced the creation of a new EV platform with 15 new models out a couple of years

AV

Pledged to deliver the "eyes off" mode is slated to arrive by **2021**, and semi-autonomous "hands off" modes by **2020**
In **2020**, announced a merger with FCA to work on autonomous, electrified, connected vehicles
In **2019**, PSA Group's vehicles, equipped with Level 3 autonomy, started operating on open roads in France as part of the European L3Pilot project
In **2018**, launched Emov in Lisbon
In **2017**, partnered with nuTonomy to install self-driving tech in Peugeot vehicles EV
In **2016**, self-driving car traveled 300+ kilometers without supervision between Paris and Amsterdam
In **2016**, launched car sharing service Emov in Madrid

RENAULT-NISSAN

EV

The Renault, Nissan, and Mitsubishi alliance announced to develop 12 all-electric models by **2022**

Nissan

Announced it will offer electrified versions of all its cars in Japan from mid-2020
Announced a $9.52B investment plan in China to introduce over 20 electric car models by **2022**
In **2020**, announced the production version of its 2021 electric crossover based on Ariya Concept
In **2019**, Leaf became the first electric car to exceed 400,000 in sales
In **2018**, launched the 2nd generation Leaf
In **2018**, created EV car sharing «e-share mobi»
In **2017**, launched EV car sharing "Choimobi Yokohama"
In **2010**, launched electric carLeaf

Renault

In **2020**, reduced the battery cost by 30% and the e-motor by 20% on its CMF-EV platform
In **2019**, revealed K-ZE all e-crossover in Shanghai
In **2019**, launched EV Moovin in Nice and Amsterdam
In **2018**, announced $1.2B investment plan to increase production capacity in France
In **2018**, launched car service EV Moovin in Paris
In **2012**, launched the electric car Zoe

AV

Alliance Intelligent Cloud partnership to deliver cloud-connected cars in ~200 markets
Renault and Nissan plan to develop a robotaxi service by **2022**

Nissan

In **2020**, its battery-powered autonomous car Leaf successfully undertook the longest and most complex road journey in the UK, covering a total of 230 miles
In **2018**, began a partnership with DeNA to run self-driving taxi trials in Yokohama
In **2017**, partnered with BMW, Volkswagen, and Mobileye on shared mapping platform
In **2017**, announced a joint effort with Toyota to develop standardized "intelligent" maps

Renault

In **2019**, partnered with Waymo to develop self-driving systems for a range of vehicles
In **2017**, partnered with Oktal to focus on testing in autonomous technologies in virtual environments

SAIC MOTORS

EV

In **2019**, Volkswagen's Shanghai $2.5B EV plant with SAIC has started trial production
In **2018**, announced the launch of an electric crossover by its MG subsidiary
In **2018**, partnered with CATL to cooperate on new battery technologies
In **2017**, unveiled an electric light delivery vehicle, the Maxus EV80
In **2012**, unveiled its first electric car concept, Row e50
In **2011**, partnered with GM to work on EV in China

AV

In **2020**, showcased first autonomous truck at Shanghai port
In **2018**, partnered with Intel and Mobileye to develop next-generation autonomous vehicles
In **2018**, completed two generations of ICV platforms and a 5G telematics platform
In **2018**, partnered with TTTech to push the AI effort and deploy the "Smart Brain" for AVs in China
In **2017**, agreed to cooperate with Wuhan Kotei in HD mapping
In **2015**, unveiled its self-developed intelligent vehicle dubbed iGS

TESLA

EV

In **2020**, the Tesla Model S Long Range Plus became the first EV with 400-mile range EPA rating
In **2020**, announced that it works on next-generation EV batteries, based on lithium iron
In **2019**, Tesla was the world's best selling passenger EV maker, with 367,820 units sold
In **2019**, talked with CATL regarding a battery technology partnership
In **2019**, Allianz reported an electric pick-up truck is expected to be launched within the year
In **2019**, acquired battery manufacturer Maxwell Technologies for $218M
In **2017**, started producing Model 3
In **2014**, partnered with Panasonic to construct the Gigafactory, a large-scale battery plant
In **2012**, released the first Model S
In **2012**, introduced the Tesla Supercharger network of fast-charging stations
In **2009**, launched the Roadster
In **2004**, announced it will manufacture electric cars

AV

In **2020**, announced that it is working on HW4.0 self-driving chip with TSMC with a timeline for mass production in Q4 2021
In **2019**, announced to launch a million autonomous robotaxis by 2020
In **2019**, released Autopilot Hardware 3 and started production of Model X and Model S vehicles equipped with the system
In **2018**, Tesla ended its partnership with NVIDIA
In **2018**, second fatal crash involving Autopilot
In **2016**, first autopilot fatality which hurt Tesla's self-driving reputation
In **2016**, announced all vehicles would be equipped with full self-driving hardware
In **2016**, partnered with NVIDIA to equip cars with its AI system
In **2014**, released "Autopilot" software, a semi-autonomous driver assist technology

TOYOTA MOTOR CORP

EV

Toyota to accelerate the popularization of BEVs with more than 10 models available in world markets by the early 2020s
In **2020**, said that its quick-charging solid-state battery production is on track by 2025
In **2020**, created JV with Panasonic to produce prismatic lithium-ion batteries, solid-state batteries and next-generation batteries for EVs
In **2019**, partnered with Subaru to launch jointly developed electric vehicle as early as 2021
In **2018**, joined the Didi Auto Alliance to bring one million electric vehicles into the market by 2020
In **2018**, agreed with Panasonic to develop high-capacity EV batteries
In **2017**, partnered with Suzuki to produce EVs and compact cars
In **2017**, launched car sharing HA:MO in Japan and Thailand
In **2017**, partnered with Mazda and Denso to develop structural technologies for electric vehicles
In **2014**, launched CitéLib, an EV car sharing pilot in Grenoble, France
In **1997**, launched the Prius, one of the first mass-produced hybrid-electric vehicles

AV

In **2020**, invested $400M in Pony.ai to deploy the autonomous driving tech in Toyota's Lexus RX vehicles in Shanghai and Beijing
In **2020**, announced at CES a plan to build a city to test its self-driving and smart technology as well as robot-assisted living
In **2020**, released innovative dataset to accelerate autonomous driving research
Jointly with MIT
In **2019**, partnered with Suzuki to work on AV tech and took a stake worth $96B yen in Suzuki
In **2019**, announced a plan to invest $100M in autonomous driving and robotic technology start-ups
In **2018**, announced an investment of $2.8B in a new spin-off company, the Toyota Research Institute – Advanced Development
In **2017**, collaborated with NVIDIA to accelerate market introduction of autonomous cars
In **2016**, invested $22M in University of Michigan for robotics and AV research

VALEO

EV

In **2019**, collaborated with Dana Incorporated to develop and supply 48-volt hybrid and electric-vehicle systems
In **2018**, introduced new low-voltage (48V) two-seater car
In **2018**, showcased thermal and comfort solutions for electric vehicles to optimize travel range
In **2016**, teamed up with Siemens to develop electric vehicle powertrains
In **2011**, acquired electric supercharger technology, Variable Torque Enhancement System

AV

In **2019**, signed an agreement with Mobileye to promote a new AV safety standard
In **2019**, entered into a strategic cooperation with Meituan in Autonomous Delivery
In **2019**, announced $49M investment program to develop ADAS and maintain its leader position
In **2018**, entered in strategic cooperation with Baidu's Apollo, the open autonomous driving platform.
In **2018**, partnered with LERO SFI Research center at NUI Galway
In **2018**, partnered with Docomo to offer 5G/V2X, and enhanced controls for on-board equipment
In **2018**, unveiled a new technology to identify and analyze individual passengers within a car
In **2017**, unveiled eCruise4u driving assistance
In **2015**, partnered with Mobileye to work on the development of an affordable self-driving car

VOLKSWAGEN

Volkswagen

EV

By **2022**, plan to bring their MEB EV to the US and produce them there
In **2020**, announced its going to develop battery cells for electric cars in the US
In **2020**, increased its stake in QuantumScape with an investment of up to $200M
In **2019**, announced $90B investment plan to raise annual production of electric cars
In **2019**, partnered with Northvolt, a battery production startup, to advance batteries for electric vehicles
In **2019**, signed startup e.Go Mobile for its modular platform for electric vehicles
In **2019**, announced a collaboration with Ford on electric and autonomous vehicles development
In **2018**, invested $25B in battery supplies and technology
In **2018**, Audi launched the e-tron
In **2017**, announced $12B investment plan to develop a range of new electric vehicles in China
In **2016**, partnered with Chargepoint to complete EV express charging corridors
In **2015**, launched Audi on demand
In **2013**, launched the e-UP

AV

In **2019**, struck a deal with Porsche SE to launch fully-functional autonomous van service in Doha, Qatar, by the end of 2022
In **2019**, spun off its self-driving startup into a subsidiary, Volkswagen Autonomy; announced its plan to set up similar companies in Silicon Valley and China in 2020 and 2021
In **2019**, started a $7B venture with Ford to introduce AV technology in the U.S. and Europe
In **2019**, started testing a fleet of 5 e-Golfs equipped with ADAS technology in Hamburg, Germany
In **2019**, joined PAVE partnership to enhance autonomous vehicle education to public.
In **2019**, hired an executive from Apple to develop self-driving capacities and Mobility as a Service
In **2018**, collaborated with Intel Mobileye and Champion Motors mobility as-a-service AV in Israel
In **2017**, unveiled self-driving shuttle concept car called the "Sedric"
In **2017**, Audi was the first auto company to deploy hands-free driving
In **2017**, A8 model approved for street driving in Europe

VOLVO CARS

VOLVO

EV

Announced that it will introduce five BEVs between 2019 and 2021
In **2019**, introduced the XC40 Recharge, its first electric car under a new EV-focused brand
In **2019**, agreed with CATL and LG Chem to supply of lithium ion batteries to Volvo and Polestar
In **2018**, selected Ricardo as engineering test partner to assess the performance of battery cells
In **2018**, partnered with the utility Vatenfall to launch a joint offer for EV home charging in Sweden
In **2018**, invested in electric car charging company, FreeWire Technologies
In **2018**, announced its goal for 50% of global sales to be electric by 2025
In **2017**, committed to electrify all new Volvo cars starting from 2019
In **2010**, Geely acquired Volvo, and started its conversion to hybrid and electric power

AV

Self-driving technology deployment target date of **2021**
Aims for self-driving cars to make up one-third of its sales by **2025**
In **2020**, announced an "exclusive" partnership to integrate Waymo's self-driving technology onto Volvo's vehicular platform
In **2019**, unveiled a self-driving production car in collaboration with Uber
In **2018**, announced partnership with Luminar to work on both physical, car-mounted sensors and the software designed to process, label, and tag captured data
In **2018**, presented a fully electric robo-taxi
In **2018**, partnered with Baidu to develop self-driving electric cars in China
In **2018**, announced to deliver self-driving vehicles by 2021
In **2017**, received an order for 24,000 self-driving cars from Uber
In **2016**, teamed up with Autoliv to commercialize driver assist technology and ADAS
In **2015**, the company made collaborations with Microsoft to develop HoloLens technology

VOLVO TRUCKS

EV

In **2020**, DB Schenker integrated a new Volvo FL Electric truck into the electric fleet of the 'Oslo City Hub' distribution center, with 23 trucks expected to arrive by the end of 2020
In **2020**, launched their electric heavy duty truck program in California, called "Volvo LIGHTS", unveiling a large program that will put more than 50 electric vehicles in service
In **2019**, delivered its first set of all-electric heavy goods vehicles (HGV) in Europe
In **2019**, announced a 150 passenger electric bus
In **2018**, announced it will sell electric trucks in the United States by 2020

AV

In **2019**, announced a plan to collaborate with NVIDIA on self-driving trucks in multiple commercial truck industries
In **2019**, Volvo Trucks' AV Vera was ready to hit the road; in collaboration with ferry and logistics company DFDS, Vera transports goods between a logistics center and a port terminal in Sweden
In **2018**, introduced Vera, an electronic and autonomous truck
In **2018**, signed a deal with Brønnøy Kalk to develop an autonomous transport truck
In **2017**, partnered with Renova to develop a garbage collecting truck
In **2017**, developed a Brazilian self-steering truck for sugarcane harvesting
In **2016**, announced a $300M joint partnership with Uber to develop self-driving cars

WAYMO

EV

In **2020**, announced its partnership with Volvo Cars to develop electric robotaxis and integrate Waymo's self-driving software into a new electric vehicle designed for ride-hailing

AV

In **2020**, achieved 20 million self-driven miles by autonomous vehicles
In **2020**, raised $2.3B in its first external funding round, with investors including Silver Lake, Andreessen Horowitz, and AutoNation.
In **2020**, teamed up with UPS to test delivery of packages along a pre-set route in its self-driving vans in Arizona
In **2019**, obtained permission to transport passengers in Waymo robotaxis granted in California
In **2019**, announced $13.6M investment plan in dedicated to the production of Level 4 AV
In **2019**, partnered with Lyft to scale robo-taxi in Phoenix
In **2018**, launched Waymo One, self-driving car service
In **2018**, extended partnership with FCA to acquire 62,000 extra vehicles
In **2018**, partnered with Jaguar Land Rover to build a fleet of first fully-electric self-driving car
In **2017**, achieved 4 million self-driven miles by autonomous vehicles
In **2016**, announced a deal with Honda to build new type of autonomous delivery vehicles
In **2016**, announced a partnership with Honda

YUTONG

EV

In **2020**, announced a shipment of 130 electric trolleybuses currently making its way to Mexico City
In **2019**, cumulative production and sales of new energy bus by Yutong Group had exceed 120,000 units
In **2018**, sold 90,000 full electric buses

AV

In **2019**, launched a Level 4 self-driving bus
In **2019**, developed a cloud control platform of autonomous driving
In **2018**, Greyhound Australia started a 6-month trial of Yutong's T12 coach
In **2015**, completed the world's first driverless bus trip over 32.6 kms, without disengagement

ZF GROUP

EV

In **2020**, announced the formation of a new division for electrified drivelines and halting development of ICE drives in favor of BEV/PHEV
In **2018**, announced a $3B investment program to develop electrification of transmission technology
In **2017**, partnered with ZAPI to offer complete electric or hybrid drive systems for commercial use
In **2016**, created the E-Mobility division, focusing on hybrid and electric transmission systems
In **2016**, became the official technology partner of the Venturi Formula E team

AV

In **2020**, acquired Wabco for $7B to increase its expertise in trucks and driver-assistance systems
In **2020**, launched coASSIST Level 2+ automated driving system
In **2019**, partnered with Transdev and e.Go to develop a new shared autonomous mobility solution
In **2019**, partnered with Airbus to develop AV solutions using Airbus satellite derived information
In **2019**, acquired 60% stake of 2getthere, a provider of automated passenger transport systems
In **2018**, partnered with DHL and Nvidia to develop an autonomous delivery fleet
In **2018**, announced a $14B investment plan to develop AV capacities in logistics and delivery sectors
In **2018**, partnered with Baidu and Nvidia to build autonomous vehicles in China
In **2017**, acquired a 45% stake in radar company Astyx Communication & Sensors GmbH
In **2017**, acquired a 40% stake vehicle networking company double-Slash Net-Business GmbH
In **2017**, acquired a 40% stake in lidar company Ibeo Automotive Systems GmbH
In **2015**, acquired TRW for $12.4B

ALIBABA

Alibaba Group

EV

In **2018**, partnered with Bolloré Group to support automotive and battery technology
In **2017**, led an $350M investment round of Xiaopeng Motors

AV

In **2019**, participated in $100M funding round of AutoX
In **2019**, partnered with Changan and Tencent to form a $1.45B Chinese smart mobility joint venture
In **2018**, established a subsidiary focused on developing AI-based microchips and computing systems
In **2018**, launched its first-ever L4-class self-driving logistics vehicle
In **2018**, partnered with Ford to build a transportation cloud
In **2017**, established DAMO Academy, division for Alibaba to research advanced technologies such as AI and machine learning
In **2016**, launched an AI-powered "city brain" system in Hangzhou to crunch data from mapping apps and increase traffic efficiency

AMAZON

amazon.com

EV

In **2020**, announced its largest deployment of electric mobility in Germany to date; the distribution center in Essen has been equipped with 340 charging stations and operates more than 150 electric delivery vehicles every day
In **2019**, said that it planned to put 100,000 Rivian's electric delivery vehicles on the road by 2030, with deliveries starting as soon as 2021
In **2019**, led a $700M investment round of Rivian, an electric car manufacturer
In **2019**, partnered with Kia to sell and install electric car charging stations
In **2018**, announced its plans to start home EV charging installation services

AV

In **2020**, announced acquisition of autonomous vehicle start-up, Zoox, for $1.3B
In **2020**, rolled out its robot delivery trial to more cities
In **2019**, introduced the Amazon Scout, a 6-wheeled electric-powered delivery robot, which is currently making deliveries around Washington and in Southern California's Irvine area
In **2019**, invested in Aurora, a self-driving vehicle startup, as part of a $530M funding round
In **2019**, partnered with Ford to create a universal cloud-based service
In **2018**, partnered with Toyota to develop fully-electric autonomous delivery vans
In **2018**, filed a new patent for "Passenger Profiles for Autonomous Vehicles"
In **2017**, received a highway network patent for AVs
In **2015**, filed patent for autonomous lane-switching technology

APPLE

EV

In **2015**, started working on "Project Titan", which involves the development of an electric car

AV

In **2019**, acquired Drive.ai, a self-driving startup that is backed by more than $77M in funding and was valued at $200M in 2017
In **2018**, registered 70 autonomous test vehicles with California's Department of Motor vehicles
In **2018**, hired former Waymo and NASA engineer to head Project Titan and Tesla lead engineer
By **2018**, test vehicles recorded 80,739 miles in autonomous mode
In **2018**, partnered with Volkswagen to turn existing T6 Transporter vans into self-driving shuttles

BAIDU

EV

In **2019**, partnered with Cherry Automobile to build an electric vehicle using its AI system
In **2019**, led a $450M investment round in WM Motor, one of China's electric car startups
In **2018**, unveiled Apollo 2 and announced more than 90 partners to utilize Apollo's technologies
In **2018**, partnered with Volvo to produce self-driving electric vehicles in China

AV

In **2020**, development of a 3,000m2 intelligent network hub in Yongchuan's Big Data Industrial Park for research on testing AV technologies
In **2020**, partnership with Tesla to use Baidu's mapping data for its vehicles in China
In **2019**, partnership with Zhejiang Geely Holding Group to equip Geely cars with self-driving technology provided by Baidu
In **2019**, announced plans to launch 100 robotaxis that will cover 130 miles in Changsha
In **2019**, had 300 autonomous vehicles on the road and logged about 1.8M miles of urban driving; received license to test its fleet in some areas of Beijing
In **2019**, unveiled Apollo Enterprise, a new line that focuses on use cases including highway driving, valet parking, autonomous mini-buses, and mapping technology
In **2018**, announced plans to mass-produce self-driving cars by 2021
In **2018**, partnered with ZF and Nvidia to build autonomous vehicles in China
In **2018**, received approval from the Chinese government to start testing Apollo on 33 different roads spanning 65 miles around Beijing and first batch of T4 test permits
In **2017**, launched its open-source autonomous driving platform, Apollo
In **2017**, opened AI lab in Silicon Valley

CISCO

EV

In **2019**, led a consortium consisting of six companies using active electric vehicles in real-world fleets

AV

In **2020**, partnered with Oxbotica, a global leader in autonomous vehicle software, to unlock the potential of fully-connected autonomous vehicle fleets, enabling the seamless and secure sharing of high-volume data while on the move
In **2018**, partnered with Hyundai to deliver hyper connected car with the OTA (over the air) update
In **2017**, launched “Cisco Connect Driveway” project with Michigan Transportation department

DIDI CHUXING

EV

In **2019**, partnered with BP to build EV charging network in China
In **2019**, around 967,000 fully electric cars have been registered on Didi’s ride-hailing platforms
In **2019**, established a joint venture with Beijing Electric Vehicle Co. to work on EV projects
In **2019**, teamed up with State Grid in order to allows drivers to use 50,000 charging station
In **2018**, formed an alliance with 31 auto industry players to manufacture 1M electric vehicles by 2020
In **2018**, partnered with Continental AG to develop Internet-connected, electric cars

AV

In **2020**, partnered with a China-based operating system technology company, ThunderSoft, to share technology and expertise on autonomous driving, ADAS, smart assistants, among others
In **2019**, said it would start using self-driving vehicles to offer free rides in AVs to its customers in a district in Shanghai city. Wit plans to expand this service to the rest of Shanghai, Beijing and Shenzen by 2020, and its other global markets by 2021.
In **2019**, created a joint venture with Volkswagen to develop self-driving cars
In **2018**, received permission from the California Department of Motor Vehicles to begin conducting further tests of its self-driving vehicles on public roads in the state
In **2018**, demonstrated a working self-driving car for the first time
In **2017**, opened an autonomous driving tech R&D lab in Silicon Valley
In **2017**, received an $1B investment from Appl
In **2016**, acquired Uber China for $35B

DENSO

EV

In **2019**, announced a $1.6B investment to foster the automotive electrification
In **2019**, led a $20M investment in Bond Mobility, e-bike sharing startup
In **2018**, established a joint venture company with Aisin Seike to sell electrification driving modules
In **2018**, announced to invest $1B in electrification, connectivity and advanced safety products
In **2017**, teamed up with Mazda and Toyota to develop basic electric vehicles structural technologies

AV

In **2019**, announced the launch of the co-developed human machine interface (HMI) digital cockpit system with Blackberry that will be first shipped in vehicles by Subaru
In **2019**, partnered with Toyota to develop next-generation automotive semiconductors
In **2019**, invested $1B in Uber's autonomous vehicle spin-off with Toyota and SoftBank
In **2019**, invested $5M in Airbiquity, a leader in connected vehicle services
In **2019**, entered into a JDA with Dellfer to bring a cyber security product to the automotive industry
In **2018**, formed a new company with AISIN, to develop autonomous car technology
In **2017**, partnered with Ridecell to further the advancement of new mobility services
In **2016**, partnered with NEC to develop self-driving car components

HUAWEI

EV

In **2020**, BYD launched the Han EV, which will be equipped with 5G and run on Huawei's software based on its HarmonyOS operating system
In **2019**, partnered with BYD to promote comprehensive strategic cooperation
In **2018**, partnered with eluminocity to build innovative smart city solutions
In **2018**, partnered with BAIC BJEV to help build its next-generation EVs
In **2017**, partnered with GAC to develop connected electric vehicles

AV

Working with automakers in Europe (Audi) and China (GAC Group, Beijing New Energy Automobile, Changan Automobile) with the goal of launching autonomous cars as early as **2021**
In **2019**, partnered with Chinese mapping company NavInfo to use its mapping data for navigation in its self-driving cars
In **2019**, launched the world's first 5G-ready communications module for autonomous vehicles
In **2019**, partnered with BYD to work on autonomous driving solutions
In **2018**, partnered with Audi to develop Level 4 self-driving technology cars that will be sold in China
In **2018**, partnered with Porsche to equip and operate a Panamara from a mobile phone
In **2018**, its subsidiary, HiSilicon, joined group pushing open-source autonomous driving technolog
In **2017**, partnered with Vodafone and Audi to build AI capabilities for connected cars
In **2017**, partnered with GAC to develop connected cars and self-driving vehicles
In **2017**, partnered with Groupe PSA to showcase a connected vehicle

INTEL

EV

In **2016**, led a $100M investment round in Enovix, a silicon lithium-ion rechargeable battery developer
In **2015**, invested in Prieto Battery, an advanced 3D Lithium Ion battery technology
In **2015**, participated in $8.6M funding round of Qnovo, a battery charging enhancement developer
In **2014**, partnered with WiTricity on wireless energy transfer technology

AV

The company is building a test fleet of 100 cars
In **2020**, Mobileye paired with Ford on ADAS
In **2019**, partnered with Nio to develop AV
In **2018**, partnered with Waymo to provide sensors and connectivity
In **2018**, acquired Eonite Perception, a startup developing LiDAR 3D mapping and tracking
In **2018**, partnered with Mobileye and NavInfo to build and distribute an end-to-end mapping engine
In **2018**, started collaborating with SAIC to develop Level3/ Level4/Level5 AV
In **2018**, started collaborating with Volkswagen and Champion Motors on mobility-as-a-service
In **2017**, acquired Mobileye for $15.3B
In **2017**, partnered with BMW, Delphi to develop an automated driving platform
In **2016**, announced a $250M investment for autonomous driving
In **2016**, established a partnership between Mobileye and Baidu to develop safer AVs

JD.COM

EV

In **2018**, invested in NIO, a Chinese smart electric car company
In **2017**, partnered with NIO to launch a new in-car delivery service

AV

In **2020**, completed first delivery of medical aid via L4 autonomous delivery robots in Wuhan
In **2019**, invested $55M into Jiangsu Xinning Modern Logistics to further automate its logistics network
In **2018**, launched its self-driving delivery vehicles in Tianjin
In **2018**, debuted a L4 self-driving heavy truck which is expected to launch by 2020
In **2017**, launched IDriverPlus, a low speed delivery robot
In **2017**, invested $1.5B in Changsha, an equipment-manufacturing hub in Hunan province

LYFT

EV

In **2020**, announced its commitment to reach 100% EVs on the Lyft platform by 2030
In **2019**, Electrify America partnered with Lyft to supply the company's Express Drive fleet with fast charging, as well as an investment in electric buses for a new route at UC Davis-Sacramento
In **2019**, added an electric vehicle "green mode" option on its platform
In **2018**, acquired bike-sharing company Motivate International for $250M

AV

In **2020**, changed focus of its partnership with Magna to produce hardware and software components for AVs
In **2019**, opened a closed-course track in East Palo Alto with AV infrastructure to test vehicles
In **2019**, had 19 AVs testing on public roads in California which drove nearly 43,000 miles between 2018 and 201
In **2019**, partnered with Waymo to scale Phoenix a robotaxi service
In **2018**, partnered with Aptiv to deploy self-driving taxis on the Lyft app
In **2017**, received investment from JLR to support its autonomous ride-hailing business
In **2017**, collaborated with Ford Motor to deploy Ford self-driving vehicles on the Lyft's network
In **2016**, received a $500M investment from GM to develop an on-demand network of self-driving cars

MICROSOFT

EV

Aims to be carbon-negative by **2030**
In **2020**, Microsoft China announced strategic partnership with Human Horizons to jointly develop an on-board AI assistant, HiPhiGo, for Human Horizons' premium smart all-electric vehicles, HiPhi
In **2018**, partnered with Volkswagen to build the automaker's fleet of connected electric cars
In **2017**, partnered with Allego to improve EV Cloud Service for EV charging
In **2015**, announced a partnership with ABB to launch next-generation electric vehicle charging services

AV

In **2020**, partnered with Upstream and Otonomo to deliver secured connected vehicle solution
In **2019**, launched Microsoft for Startups Autonomous Driving to help improve self-driving cars
In **2019**, partnered with LG to improve autonomous cars using Microsoft Azure cloud
In **2019**, partnered with BMW to launch an open-sourced industrial manufacturing platform
In **2019**, partnered with Ericcson to allow it to build its connected vehicle cloud on top Microsoft's connected vehicle platform
In **2018**, partnered with ICONIQ Motors and AKKA to develop a Level 5 AV by 2020
In **2018**, became the data partner at the 330-acre American Center for Mobility facility in Michigan
In **2017**, partnered with Baidu to provide Azure infrastructure to Baidu's Apollo
In **2017**, partnered with Ola to build a new connected vehicle platform for car manufacturers
In **2016**, partnered with Toyota to support research in AI, AV, Robotics and HoloLens
In **2015**, partnered with Volvo to develop next-generation autonomous technology

NVIDIA

AV

In **2020**, teamed up with Mercedes-Benz to develop a next-generation computing platform for vehicle
In **2019**, announced a collaboration with Toyota to develop, test and validate AVs
In **2019**, introduced the first commercially available Level 2+ automated driving system
In **2018**, partnered with Volkswagen to develop new generation of intelligent vehicles
In **2018**, partnered with Volvo to develop AI-capable computers for the next generation of Volvo cars
In **2018**, created the Networking for AV Alliance with Bosch and Volkswagen
In **2018**, partnered with Continental to create top-to-bottom AI self-driving vehicle system
In **2018**, partnered with Baidu and ZF to build autonomous vehicles in China
In **2018**, signed deals with three Chinese electric vehicle startups
In **2017**, invested TuSimple in Chinese autonomous truck company
In **2017**, partnered with DHL and Zf to develop a fleet of autonomous delivery trucks
In **2017**, created a cloud-to-car mapping system with Here
In **2017**, unveiled plan to build self-driving trucks with Paccar
In **2016**, unveiled 8 teraflop computing platform designed for autonomous cars

SAMSUNG

EV

In **2020**, revealed a solid-state EV battery prototype with 500-mile range and can be recharged more than 1,000 times
In **2019**, entered into a $25B partnership with Volkswagen and LG Chem
In **2018**, announced a partnership with Hyundai to push car batteries and AV effort
In **2016**, developed a new high-energy density battery cell
In **2016**, partnered with electric vehicle startup Lucid Motors to supply Lithium-ion cells
In **2016**, invested $450M in BYD, now Chinese leading EV and battery manufacturer
In **2015**, acquired battery business Magna Steyr

AV

In **2018**, started to develop 5G and V2X network infrastructure with the KOTSA
In **2018**, unveiled a $22B investment plan in self-driving cars and AI
In **2018**, at CES, Samsung unveiled a new technology platform designed to help automobile manufacturers build customized AVs
In **2017**, purchased Harman, a car audio manufacturer, for $8B
In **2017**, partnered with Hyundai to build autonomous cars
In **2017**, established a $300M fund for autonomous vehicle development
In **2017**, invested in LIDAR start-up TetraVue
In **2017**, secured a permit to begin testing self-driving cars on South Korea's public roads

TATA

EV

Aims to establish itself as the leader in the electric vehicle market in India
In **2020**, Tata Nexon EV, the home grown automaker's first mass market electric vehicle for personal buyers, became available via subscription in India
In **2019**, signed a deal to supply 255 electric buses to 6 Indians cities
In **2019**, partnered with Australian Tritium to provide DC chargers in India
In **2018**, set up nearly 1,000 charging stations in the Indian National Capital Region
In **2018**, partnered with Zoomcar to offer Tigor EV, a self driving car

AV

In **2020**, Tata Elxsi unveiled its concept autonomous car Robo-Taxi at CES 2020
In **2018**, partnered with Hyundai to create virtual world to advance AV research
In **2017**, signed a licensing deal with Autonomai
In **2017**, its subsidiaries, Land Rover and Jaguar, started with road tests for its autonomous vehicles
In **2015**, developed Valet, an autonomous parking system

TENCENT

EV

In **2020**, increased its stake in Nio to 16.3%, making Tencent the second-largest holder in terms of voting rights
In **2019**, partnered with Dongfeng Motor, FAW Group and Alibaba to launch ride-hailing venture
In **2017**, invested $1.78B in Tesla
In **2017**, led $1B funding round n Nio, a Chinese electric automobile manufacturer

AV

In **2020**, unveiled plans for an almost entirely car-free "city of the future," equivalent in size to Monaco, in the Chinese metropolis of Shenzhen
In **2020**, released the new generation of its autonomous-driving simulation platform, to improve the development and testing efficiency of AVs
In **2019**, teaming up with BMW to launch a computing center in China that will help develop self-driving cars
In **2019**, have signed a preliminary deal with Hyundai to develop software for driverless vehicles
In **2019**, partnered with GAC group to work on Internet connected car and smart driving
In **2018**, built AV research centers in the Bay Area and New York City
In **2018**, started to test autonomous vehicles in Shenzhen
In **2018**, signed a $31M joint venture with Changan Automobiles to develop a smart vehicle

UBER

Uber

EV

In **2020**, partnered with Hyundai Motor to develop and potentially mass produce air taxis
In **2020**, led an investment round of $170M in scooter-rental company Lime
In **2019**, partnered with Joby Aviation to launch an air taxi service
In **2019**, signed a deal with Nissan to make 2,000 of its Sunderland-made electric Leafs available to Uber drivers
In **2018**, launched "EV Champions" initiative to pilot fleet electrification via a driver-partners program in 7 US cities, and has also committed to helping London Uber drivers to make the transition to zero emissions vehicles by 2025
In **2018**, invested $335M in Lime, an electric scooters company
In **2018**, acquired electric bike sharing startup JUMP
In **2017**, Embraer joined Uber Elevate Network
In **2016**, introduced Elevate Network aiming to launch an air taxi service by 2023 with industry partners

AV

Plans to have 75,000 autonomous vehicles in operation by **2019** and to have driverless taxi services operating in 13 cities by **2022**
In **2020**, received licenses to resume its self-driving trials in California and to launch trials in Washington D.C and Dallas
In **2019**, announced a $1B investment to fuel its autonomous driving efforts: $333M from the SoftBank Vision Fund and $667M from Toyota Motor Corp and Denso Corp
In **2019**, had just 250 AVs on the road
In **2019**, unveiled a new self-driving car model, this time developed in partnership with Volvo
In **2018**, announced a $500M investment from Toyota and a plan to jointly work on autonomous vehicle development
In **2018**, shut down Otto, its self-driving truck subsidiary
In **2018**, a self-driving Uber vehicle was involved in a fatal crash in Arizona, striking and killing a person, it was subsequently banned from testing AVs on public roads in Arizona
In **2017**, bought 24,000 Volvo self-driving cars
In **2017**, partnered with Daimler to supply self driving vehicles
In **2016**, revealed its in-house autonomous prototypes for the first time, and the company acquired self-driving truck startup Ott
In **2015**, acquired deCarta, a mapping company

YANDEX

Yandex

EV

Claimed to have the largest car-sharing organization in the world, with 21,000 cars in Russia
In **2020**, announced that it plans to expand its car-sharing offerings into Europe. Anton Ryazanov, a Yandex executive, said the company will put 1,000 electric vehicles in an unspecified city in the EU

AV

Yandex shared that it has invested $35M in its self-driving program since its inception and is developing custom lidar sensors and a camera for self-driving vehicles
In **2020**, claimed that its 130 autonomous cars have driven 4 million miles to date (Jul 2020), becoming one of the world's top 3 companies for the number of miles driven
In **2020**, started testing self-driving cars in Michigan
In **2019**, its delivery bots, Yandex.Rover, started testing in Moscow in Yandex headquarters
In **2019**, announced partnership with Hyundai to develop an AI-based fully autonomous vehicle platform
In **2018**, started offering robo-taxi rides in Russia and at CES in Las Vegas
In **2017**, completed first successful autonomous test drive in Moscow

ABB

EV

In **2020**, started construction of its new $30M facility to manufacture electric vehicle chargers
In **2020**, announced that it will provide the mobile ultra-fast charging technology for the Gen3 cars in the ABB FIA Formula E World Championship
In **2020**, Terra 184 EVchargers have been selected by Japan's e-Mobility Power Co. to modernize the infrastructure for the country's EV market and accelerate EV adoption
In **2019**, agreed to deliver its market-leading electric vehicle infrastructure for Porsche Japan
In **2019**, ABB's EV charging stations were at 40 public locations across Sweden for Vattenfall
In **2018**, launched the world's fastest e-vehicle charger at Hannover Messe
In **2018**, became a title partner of the ABB FIA Formula E Championship
In **2017**, launched TOSA flash charging electric buses in Geneva
In **2015**, announced a partnership with Microsoft to launch next-generation charging services platform
In **2011**, acquired Epyon B.V. a manufacturer of electric vehicle charging equipment
In **2010**, acquired Baldor Electric Company for $4.2B

AV

In **2019**, won a contract from ST Engineering Land Systems Ltd. to deliver and commission integrated smart charging points for Automated Guided Vehicles (AGV) in the new Tuas port of Singapore
In **2019**, announced $150M investment to build the world's most advanced and automated robotics factory in Shanghai
In **2018**, partnered with Volvo Bus and NTU to develop Singaporean autonomous buses
In **2018**, successfully operated the first trial of a remote controlled ferry in Helsinki

AIRBUS

EV

Airbus' efforts to advance the electrification of commercial aircraft and push towards achieving zero-emission flight over the next 20 years
Established the E-Aircraft System House is Europe's largest test facility dedicated to alternative propulsion systems and fuels
In **2020**, Airbus' new eVTOL, CityAirbus, took its first public flight
In **2020**, Airbus and Rolls Royce ended E-Fan X hybrid-electric aircraft initiative
In **2019**, signed an MOU with SAS to establish the requirements for the next generation of electric aircraft and to develop a framework on how to introduce hybrid-electric aircraft for large-scale commercial use over the next 10 to 15 years
In **2019**, Airbus and Siemens announced the termination of their development cooperation
In **2019** announced a partnership with SAS to push hybrid and electric effort
Became Founding Partner of Air Race E, world's first electric airplane race set to launch in **2020**
In **2016**, started developing the hybrid E-Fan X with Rolls-Royce and Siemens
In **2017**, Airbus has backed GBatteries, a developer of advanced fast charge technology
In **2014**, successfully completed a Channel crossing with its all-electric E-Fan

AV

In **2020**, the prototype of Airbus Helicopters' VSR700 unmanned aerial system has performed its first free flight
In **2020**, achieved autonomous taxiing, take-off and landing of a commercial aircraft through fully automatic vision-based flight tests using on-board image recognition technology
In **2019**, revealed its cooperation with Vodafone on a new unmanned aerial vehicle called ALtAIR
In **2019**, created a new venture to manufacture drones and self-driving cars with Local Motors Industries, a 3D-printing start-up.
In **2019**, Vahana drone air taxi has successfully completed 114 test flights in Pacific Northwest
In **2019**, partnered with ZF to enrich and complement ZF onboard system for AVs
In **2019**, completed the first successful take-off of the unmanned CityAirbus demonstrator
In **2018**, Airbus' Vahana autonomous eVTOL flying taxi flew for the first time
In **2018**, Skyways unmanned parcel delivery drone successfully completed its first flight demonstration
In **2018**, presented a flying taxi concept in partnership with Audi
In **2018**, operated an unmanned helicopter flight
In **2018**, completed the first demonstration flight of "Skyways", an autonomous delivery drone

BELL

AV

Became one of the first Uber Air partners to develop a network of city-based flying taxis for **2022**
In **2020**, Bell Autonomous Pod Transport completes beyond visual line of sight flight
In **2019**, Bell Textron was selected by the NASA to perform flights in 2020, under the Systems Integration and Operationalization (SIO) program
In **2019**, announced that its Autonomous Pod Transport (APT) 70 has successfully completed its first autonomous flight at the company's testing site near Fort Worth, Texas
In **2019**, revealed 6,000-pound unmanned electric flying taxi Nexus
In **2018**, Bell Helicopter rebranded as "Bell" as a technology company redefining flight
In **2018**, became the first helicopter manufacturer to ever present at CES with its electric flying taxi
In **2018**, signed agreement with NASA to demonstrate its APT70, a commercial unmanned air vehicle

BOEING

EV

In **2019**, Boeing HorizonX Ventures and Safran Corporate Ventures made a joint investment in Utah-based Electric Power Systems, whose energy storage products are blazing a trail for electric airplanes
In **2019**, partnered with Porsche to develop flying electric car
In **2019**, partnered with Japan's Ministry of Economy, Trade and Industry (METI) on electric aircraft
In **2018**, invested in Cuberg, developing advanced battery Technologies
In **2017**, backed Zunum Aero, which is bringing hybrid-electric regional airliner to market in 2022

AV

In **2019**, announced a strategic partnership with Kitty Hawk Corporation to collaborate on future efforts to advance safe urban air mobility
In **2019**, successfully completed the first test flight of its autonomous passenger air vehicle (PAV) prototype, Boeing NeXt, in Virginia
In **2018**, completed first indoor flight test of its heavy-duty drone lifting a 500-pound load
In **2018**, invested in Fortem technologies, a startup specializing in micro radars technologies
In **2018**, invested in Matternet, a Californian startup focusing on Urban Aerial Delivery
In **2018**, launched a software platform supporting autonomous delivery applications with SparkCognition
In **2017**, acquired Aurora Flight Sciences, which develops unmanned fully-electric long-range aircrafts
In **2017**, invested in an autonomous flight technology provider called Near Earth Autonomy

BOLLORE GROUP

EV

In **2019**, Bolloré Logistics deployed a fleet of zero-emission electric vans in Singapore
In **2019**, won an estimated $150M contract with RATP as part of EU's largest electric bus tender
In **2018**, Paris terminates Autolib, world's largest electric car sharing contract
In **2018**, partnered with Alibaba Group in clean energy and mobility and logistics
In **2017**, launched an electric car sharing service in Los Angeles and London
In **2017**, won a 10-year tender for Singapore's first large-scale electric car-sharing program
In **2015**, launched an electric car sharing service in Indianapolis (US)
In **2015**, launched a 12 meter electric bus with a 110 mile range
In **2014**, won the tender to manage London public charging stations
In **2013**, launched "BlueCar", an electric car with a 155 mile range
In **2011**, launched a 6 meter electric bus with a 75 mile range

BOSCH

EV

Won €13B in electro mobility orders since 2018
In **2020**, offered over 150,000 recharging points for EV throughout Europe
In **2019**, announced development of new cloud services, Battery in the Cloud, which extends EV battery service life by 20%
In **2019**, took full control of EM-Motive, a former JV with Daimler
In **2018**, rejected previous $22B investment plan in battery cell production capacity
In **2017**, started investing in commercial electric vehicle technologies
In **2015**, acquired Seeo developing a safer lithium-ion battery for EVs

AV

In the process of constructing a $1.1B facility in Dresden that will produce semiconductors for use in AVs, smart home and smart city tech stack
In **2020**, unveiled new, long-range AV sensors
In **2019**, became a part of a consortium working towards commercializing of AV technology
In **2019**, Bosch and partner Daimler started a trial for a self-driving taxi service in California
In **2019**, Bosch and partner Daimler received approval from German regulators to operate its autonomous parking feature without driver
In **2018**, invested in ABAX Sensing a solid-state chip Lidar company
In **2018**, partnered with Daimler and Nvidia to develop a self-driving car platform by 2021
In **2018**, partnered with e.GO to launch automated valet parking lots
In **2018**, presented a self driving shuttle concept
In **2018**, established new division for connected mobility services with 2,000+ engineers
In **2018**, partnered with Veniam to develop seamless Vehicle-to-Vehicle communications
In **2017**, partnered with Mercedes to develop Level 4 and 5 (full automation) vehicles
In **2017**, partnered with TomTom to create HD maps based on radar signals
In **2017**, with Vodafone and Huawei, performed V2X trials using 5G test modules
In **2016**, became Tesla's radar supplier for its Autopilot 1.0 and 2.0

BP

EV

In **2020**, BP set to increase low carbon investment to $5B in reinvention strategy
In **2019**, announced that it aims to fully charge electric cars in 5 minutes by 2021
In **2019**, announced the start of its roll out of 400 ultra-fast electric vehicle (EV) charging-points across the UK
In **2019**, announced they have agreed to form a new joint venture with Didi Chuxing (DiDi) to build electric vehicle charging infrastructure in China
In **2019**, invested in PowerShare, one of China's leading electric vehicle charging platforms
In **2018**, acquired Chargemaster, the UK's largest vehicle charging company for $164M
In **2018**, invested $5M in FreeWire Technologies, a manufacturer of mobile EV rapid charging systems.
In **2018**, invested $20M in StoreDot, an ultra-fast charging battery company.
In **2018**, invested $10M in a Chinese private equity fund focus on automotive and energy infrastructure

BYD

EV

In **2020**, secured $113M in a Series A+ round for its chip making arm, BYD Semiconductor
In **2020**, announced that it will supply a further 30 eBuses for the Municipal Transport Company of Madrid
In **2020**, announced its plans to sell a range of EVs across Europe following an initial trial in Norway starting later in 2020
In **2019**, partnered with Toyota Motor Corp. to establish a joint company to conduct R&D for battery electric vehicles and was slated to be established in China in 2020
In **2019**, sold the most battery electric vehicles and plug-in hybrids in the world
In **2019**, 20,000 Shenzhen taxis are electric BYDs
In **2019**, planned to build a fourth electric-car plant valued at $1.5B
In **2018**, launched 6 new electrified cars "dynasty series"
In **2018**, announced the production of its 50,000th pure electric bus

AV

In **2020**, launched the Han EV which is equipped with 5G and run on Huawei's software for cars
In **2019**, signed a strategic cooperation agreement with Huawei
In **2019**, partnered with AutoX to develop the First Electric Sedan designed for self-driving
In **2018**, produced 100 units of Apolong, China's first L4 fully autonomous bus
In **2018**, launched new D++ open-source platform for autonomous vehicle technology
In **2018**, launched the SkyRail autonomous driving system for its monorail train in Yinchuan
In **2018**, announced plans to mass-produce self-driving cars in partnership with Baidu by 2021

DHL

EV

In **2020**, launched electric StreetScooter delivery vans in U.S., with full deployment expected by 2022/23
In **2020**, Amazon, IKEA and DHL have all joined a new corporate alliance in North America to further electric vehicle development
In **2019**, approximately 13% of its fleet (~1,800 vehicles) was electrified
Planned to electrify 70% of its first and last-mile delivery fleet by **2025**
In **2017**, reached a fleet of 3,400 Ford's electric StreetScooter vehicles
In **2017**, replaced 3,400 of its diesel delivery vans with electric vans
Committed to net-zero emissions goal by **2050**

AV

In **2019**, started regular autonomous drone deliveries in China in partnership with EHang
In **2017**, partnered with Nvidia and auto supplier ZF to start testing self-driving trucks by 2018
In **2017**, ran a six weeks pilot test of an electric unmanned mail robot in Germany
In **2016**, successfully integrated an unmanned drone into its logistics chain

HONEYWELL

EV

In **2020**, launched a new business unit dedicated specifically to urban air mobility and unmanned aerial systems
In **2019**, partnered with Denso to create electric propulsion systems for urban air mobility
In **2019**, partnered with Pipistrel to design electric vertical take-off & landing (eVTOL) aircrafts
In **2015**, partnered with Blink and CarCharging to provide EV chargers at Honeywell offices

AV

In **2020**, Honeywell Aerospace has begun flight testing an automated system that will help urban air mobility (UAM) vehicles land autonomously
In **2020**, expanded its navigation offerings for autonomous vehicles
In **2019**, announced prototyping of autonomous car on IMUs in partnership with VSI Labs
In **2019**, announced a deal to develop autonomous flight systems with Volocopter
In **2018**, signed agreement LG Electronics to jointly develop AV security solutions
In **2018**, collaborated with VSI Labs to support AV application
In **2017**, started partnership with Lear to work on automotive cyber security

PANASONIC

EV

In **2020**, created JV with Toyota to produce prismatic lithium-ion batteries, solid-state batteries and next-generation batteries for EVs
In **2020**, said it will boost the energy density of the EV batteries it supplies to Tesla by 20% over the next five years, and aims to deliver a cobalt-free battery by 2022-2023
In **2019**, launched EV charging stations in India
In **2019**, Tesla had $11B in debt and $16B of purchase obligations for Panasonic cells
In **2019**, significantly reduced planned investment in Tesla's Gigafactory expansion plans
In **2018**, announced its plan to double battery production in China
In **2014**, partnered with Tesla to build a large-scale battery manufacturing plan

AV

Announced launch of autonomous driving system by **2022**
Planned to nearly double its automotive business revenue by **2022**
Developed a self driving vehicle for CES 2018 and 100th anniversary of the company
In **2019**, announced a partnership with ANA to develop self driving wheelchair
In **2017**, established automotive R&D division transferring about 350 engineers

ROYAL DUTCH SHELL

EV

Shell plans to spend $30B a year in capital investments, from current $1B - $2B, on its New Energies division, which includes investments in electricity, clean energy, electric vehicle charging, and alternative fuels
In **2020**, announced that it plans to increase its EV fast-charging presence in Germany, up to 200 total charging points from 100
In **2020**, said that it wants the UK government to accelerate the ban of petrol and diesel vehicles to 2030
In **2019**, Shell's first Greenlots electric vehicle fast charger landed in Singapore
In **2019**, acquired of Greenlots, a startup offering software and services for EV charging networks
In **2019**, collaborated with EVgo, Chargepoint and GM to build an electric vehicle charging network
In **2018**, invested in Sonnen, an intelligent lithium based energy storage
In **2018**, led a $31M investment into Ample, an EV charging startup
In **2018**, partnered with Volvo trucks to provide EV charging
In **2017**, announced plans to spend $1B in renewable energy and EV investments by 2020
In **2017**, Shell bought NewMotion and acquired of 30,000 charging stations in Western Europe

AV

In **2019**, Shell Ventures participated in $530M funding round of Silicon Valley start-up Aurora

SOFTBANK

EV

In **2020**, announced that it is in talks to pick up minority stake in Mahindra Electric Mobility
In **2019**, invested $250M in Ola Electric Mobility
In **2019**, pledged to invest for electric vehicles ecosystem in Indonesia
In **2018**, invested $99M in Nemaska Lithium, lithium development company
In **2018**, Ola spun-out electric vehicle business and promised one million EVs in India by 2021
In **2017**, invested $2B in Ola with Tencent

AV

In **2020**, led $500M investment in Didi
In **2020**, SB Drive started operating a AV bus service on a fixed, 2.5-km long route in Japan
In **2019**, invested to date about $30B in autonomous driving and e-hailing
In **2019**, Honda Motor and Hino Motors joined former Japan's JV with Toyota
In **2019**, announced $1B investment in Uber's self-driving unit ATG with Toyota and Denso
In **2019**, invested $940M in AV delivery Nuro
In **2019**, announced a $1.6B investment in Didi
Announced satellite navigation services to help power AV buses, drones and farm machinery
In **2018**, invested $2.25B in Cruise
In **2018**, invested $500M in Cambridge Mobile Telematics, a driving analytics company
Formed a joint venture with Toyota for self-driving vehicles named MONET, effective 2019
In **2017**, acquired robotics company Boston Dynamics from Alphabet for an undisclosed sum
In **2017**, invested with BMW and GM in Nauto
In **2016**, created the JV SB Drive with Advanced Smart Mobility to commercialize AV tech
In **2016**, raised $100B vision fund from Apple, AbuDhabi, Foxconn, Daimler, Qualcomm, Sharp
In **2016**, acquired the British chip designer ARM Holdings for $31.4B

TOTAL

EV

Total wants to grow its "low-carbon energy assets" from 5% of the total today to 20% by **2035**
In **2020**, Metropolitan Region Amsterdam Electric' (MRA-Electric) has awarded Europe's largest concession contract for electric vehicles charging to Total. It will install and operate up to 20,000 new public charging points in the Netherlands
In **2020**, announced that Total-Peugeot joint venture aims for 10-15% of electric vehicle battery market, producing batteries for one million electric vehicles per year by 2030
In **2019**, partnered with Tianneng to scale e-mobility and business storage in China
In **2018**, acquired G2 mobility the French leader in EV charging stations
In **2018**, signed EV charging deal with Chargepoint
In **2016**, acquired French battery maker Saft for over $950M

UPS

EV

In **2020**, UPS Ventures completed a minority investment in Arrival. UPS also announced a commitment to purchase 10,000 e-vans to be built for UPS with priority access to purchase additional electric vehicle
In **2019**, counted 300 electric vehicles and 700 hybrid electric vehicles in Europe and in the US
In **2018**, partnered with Arrival to develop a fleet of electric delivery vehicles for London and Paris
In **2018**, announced a partnership with Thor Trucks to develop fully equipped trucks
Invested more than $750M in alternative fuel and advanced technology vehicles since **2009**

AV

In **2020**, teamed up with Waymo to test delivery of packages along a pre-set route in its self-driving vans in Arizona
In **2019**, acquired a minority stake in autonomous trucking startup TuSimple, which was hauling cargo for UPS between Phoenix and Tucson, Arizona
In **2019**, formed a subsidiary drone business, UPS Flight Forward and received a highly-restricted air carrier certification from the Federal Aviation Administration
In **2019**, partnered with Matternet to experiment unmanned drones to deliver medical supplies
In **2018**, the US union heavyweight wanted to ban UPS from using drones or driverless vehicles
In **2017**, agreed to purchase 125 Tesla semi-autonomous driving Semi trucks

Follow our research and opinions:

DRAKE STAR PARTNERS