KPMG

Place your billion-dollar bets wisely

Powertrain strategies for the post-ICE automotive industry

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Foreword

For more than a century, the automotive industry has been defined by one constant and arguably dominant force: the reign of the internal combustion engine (ICE). Now, a tsunami of investment—some $200 billion—has hit the industry from automotive start-ups, established automakers and suppliers, even tech companies that are betting on a new powertrain king: the battery electric vehicle (BEV). As we publish this paper, the Biden administration has proposed a raft of new supports for the US EV business, including fresh buyer incentives.

Add in the momentum created by the enormous success of Tesla, global concerns around climate change, and new regulatory regimes that could literally outlaw ICE powertrains, and you have a new auto industry, dominated by BEV powertrains.

A BEV future is clearly the current conventional wisdom. But is it right? Or, as is often the case, is conventional wisdom, well, simply too conventional—or just overly simplistic?

This is not a theoretical question, given the billions at stake. We believe that the coming years will be far more complicated and unpredictable than the conventional wisdom suggests. For starters, billions of people live in developing economies where incomes and electric grids prevent consumers from switching to BEVs. Even in wealthy countries like the US, the charging infrastructure is not fully in place for BEVs. Nor is the grid sufficiently robust for a nation of BEV chargers—or safe from the scary threat of cyber intrusion, (or even severe weather).

Then there is physics, which heavily favors ICE. A full gas tank has the same energy as 1,000 sticks of dynamite. Gasoline has about 100 times the energy density of a lithium-ion battery. Notwithstanding the tremendous advances in battery technology, the physical advantages of oil and its abundant supply mean the ICE engine will be around for a long while, even if its importance is diminished.

So yes, conventional wisdom is too conventional. In this paper we describe an emerging automotive landscape that is far more complex and uncertain—but also exciting. Rather than a single, monolithic model for success, built around a single fuel/powertrain combination, the future industry will be fragmented—a mosaic. Think of a world with bespoke, sexy, and cool new vehicles powered by batteries or hydrogen. Hybrids and vehicles running on natural gas. Maybe even solar. And, yes, new cars with advanced ICE technology. Throw in progress in computing and AI to make autonomy real, and you have a new transportation ecosystem made up of many kinds of vehicles using the technologies that work best for the job.

In this new world, where should you place your bets? A lot depends, of course, on your current situation. If you're a startup you can go all-in on new technology. But what if your biggest single source of profits is trucks and SUVs—like most US automakers? What do you have to believe about your customers, the evolution of technology, growth of charging infrastructure, and future regulation to convince you to bet billions on EV technology and plant capacity now? What will be the cost in lost profits if you move too quickly and can't build product for your most profitable business? What is the cost if you move too slowly and you aren't in position to cash in when EVs reach the tipping point? What if you're a supplier? How much will you bet on the new players and new types of vehicles?

There are no simple answers. And the stakes could not be higher. No single company has the financial wherewithal to cover all the bets. Companies will need to think hard about where they can carve out a winning position—where they can make their billion-dollar bets—and where to use alliances and partnerships.

Our goal here is to offer ideas and approaches for weighing these mind-boggling options. We have created the mosaic framework to help you answer the big strategic questions: where to play, how to play, and—critically—when to play in this new automotive ecosystem. In short, the mosaic can help you make the billion-dollar bets—wisely.

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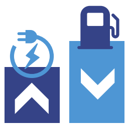
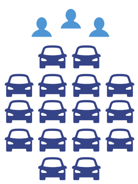
Key takeaways



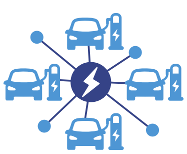
The century-long reign of the ICE powertrain is ending—but no one knows how quickly; analyst estimates of 2030 BEV penetration range from as little as 24 percent to nearly 40 percent.

The industry will look more like a mosaic. Contrary to the conventional wisdom and $200 billion-plus of investments, the future won't just be BEVs. There will be multiple fuel/powertrain combinations—including ICE hybrids, and hydrogen-electric—to meet the needs of the market.

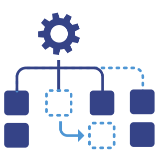


Too many players, too few consumers? Today, many BEV players are aiming at a narrow ($50,000 and up) slice of the U.S. market, representing only 2.4 million units or 17 percent. By 2030, even if BEV penetration reaches 30 percent (including more lower-price models) the available market may only be 5.1 million out of a 17 million-unit market.

Massive ICE manufacturing overcapacity. If the 30 percent BEV penetration forecast is even close, by 2030 there could be nearly 40 million units per year of excess ICE manufacturing capacity globally—the equivalent of 200 assembly plants. That does not include the multiplier effect on suppliers and their plants.



Unanswered infrastructure questions. Not only is there uncertainty about building out infrastructure (for EVs and hydrogen vehicles), but also about the needed electrical supply. Nearly 4 billion people live in countries with inadequate electrical infrastructure for EVs. Even in wealthy economies, the electric grid is vulnerable and not ready for widespread EV use.



Sweeping structural change. In almost any scenario, the industry can expect massive structural change. New competitors will take share. Value chains will be shattered, and supply chains will be reconfigured; companies will need to adjust their portfolios of businesses.

The stakes could not be higher. The bets—and the uncertainty and complexity—are enormous. New dominant positions will be built, and old empires may fall. A decade from now, there could be a new pecking order in automotive—and one or more of today's top players may have been acquired or disappeared.

The mosaic can show how to place your bets wisely. To win, companies will need to choose new strategic postures and adopt a dynamic decision-making framework to plan and place their bets. They need the mosaic.

WELCOME TO MOSAIC MOTOR CITY

Types of fuel: ICE | Natural Gas | Battery electric vehicle (BEV) | H_2 Hydrogen | Hybrid

From a monolith to a mosaic

For a century, a single fuel-powertrain combination—the petroleum-powered internal-combustion engine (ICE)—has dominated the global automotive industry. How automotive companies are structured, how they are financed, how they go to market—everything was optimized for producing and selling ICE-based vehicles.

Yet, ICE was not always destined to dominate. In the early days of the industry, ICE was only one powertrain option. And long before the internal-combustion engine appeared, inventors were tinkering with battery-powered vehicles. Indeed, in the early 1900s, electric vehicles outsold the noisy, dirty and smelly gas-powered cars.[1] Henry Ford and Thomas Edison were exploring electrics, and Ferdinand Porsche invented the first hybrid. Brands were built on steam powertrains, and Stanley "steamers" were sold until the mid-1920s.

It took 20 years, but by the 1920s gas-powered ICE vehicles drove the competitors off the road—because of advantages that remain today. Petroleum (gasoline and diesel fuel) has extraordinary energy density, so a small tank could keep a car going for hours. Thanks to the adoption of kerosene for lighting in the 1800s, there was already a nationwide network for distributing petroleum products. Mass production and engineering refinements quickly drove down the cost of ICE engines and improved reliability and performance, while makers of battery-powered drivetrains ran up against the limitations that engineers continue to wrestle with today. Finally, as the network of well-paved roads expanded, motorists wanted to go faster and farther than they could in a battery-electric.

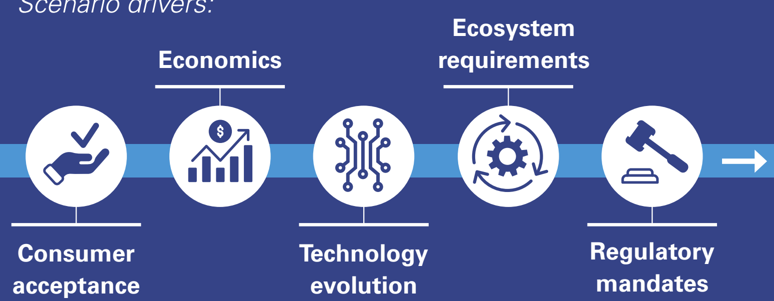
Now, the conventional wisdom says that the battery-electric powertrain will triumph—becoming the dominant force in the automotive business that ICE has been. Yet, we still don't know when BEVs might reach a tipping point and become popular with a wide swath of consumers, and capable of generating the sales—and profits—to justify billion-dollar bets. By 2025? By 2035? Never? Predictions are all over the map.

For the next 10 to 20 years, multiple fuel/powertrain combinations (including gasoline/ICE) will coexist, and innovation will continue on multiple fronts. So, instead of a monolith built around one dominant fuel/powertrain combination, the industry will look more like a mosaic.

The mosaic is both a metaphor for shattering the old ICE model and a framework for understanding the highly complex and uncertain future. It can help you evaluate possible scenario drivers—economics, technology evolution, regulation, etc.—to place billion-dollar bets wisely and to revise strategies as factors change over time.

The mosaic is a framework to view scenarios on multiple dimensions

Scenario drivers:



[1] Jake Richardson, "38% Of American Cars Were Electric In 1900," CleanTechnica, February 25, 2018.

A crack in the ICE: fracturing the industry model

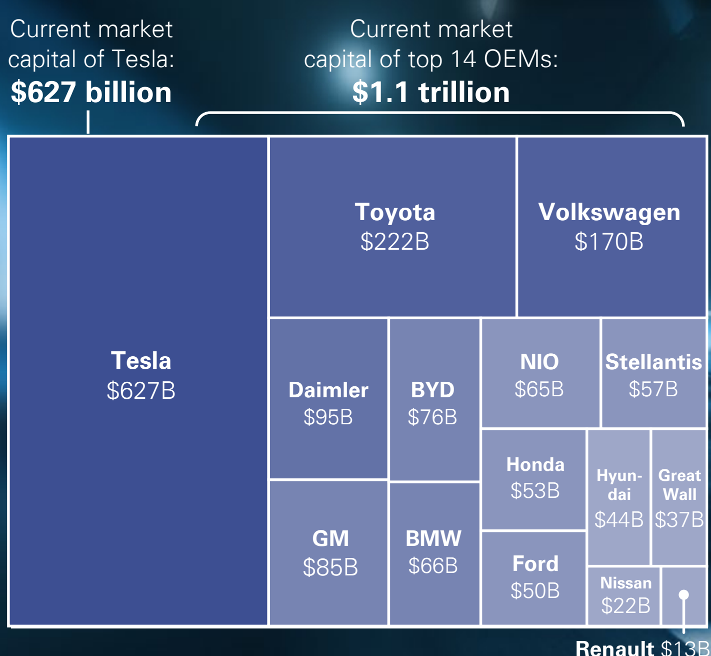
Efforts to create alternatives to ICE powertrains never entirely disappeared, and after the oil crisis of the 1970s they got a boost as nations sought energy independence. In the US, Congress passed the Electric and Hybrid Vehicle Research, Development, and Demonstration Act, which led to a flurry of investment in fuel cells, electric motors and batteries, and other electric-powertrain technologies. In 1990, General Motor Corp. introduced its EV1, the first commercial US electric model in decades.

The EV-1 was a short-lived experiment—too costly to build and attracting too few customers.[2] But advances in lithium-ion battery packs and modern electronics have paved the way for commercial success.

The breakthrough that really put BEVs on the map came from a startup called Tesla. Instead of building a $30,000 bare-bones econobox with an electric motor—a proposition attractive only to the most ardent green consumers—Tesla made high cost a virtue. Its $70,000-plus cars were high-performance computers on wheels that quickly became an object of desire for well-heeled techie trendsetters. Tesla also upended traditional sales and marketing models to offer a unique customer experience—and by 2020 had become the most valuable automotive company on the planet.[3]

Tesla is worth more than established automakers

Top 15 Auto OEM market capitalization ($ billions)



Note: Market capitalization shown as of March 19,2020.
Source: CapIQ

[2] Source: "A Brief History and Evolution of Electric Cars," Interesting Engineering website, July 1, 2020.
[3] Source: "Tesla closes day as fifth most valuable US company, passing Facebook," CNBC.com, January 8, 2021.

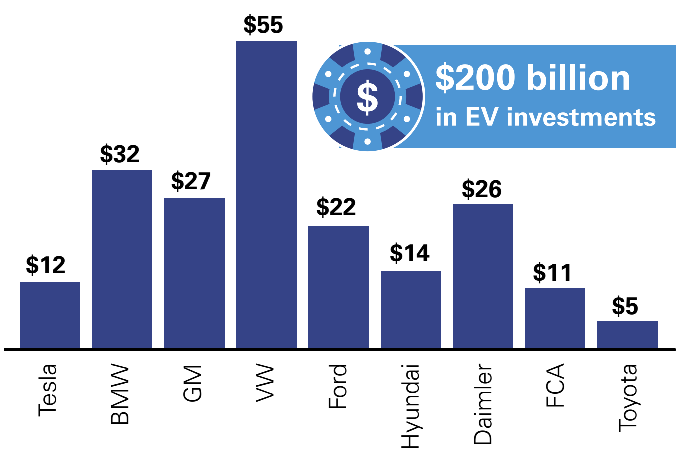
With Tesla pointing the way, auto companies across the world have doubled down on electric vehicles. Almost every major car manufacturer is now offering at least one BEV model, if not several. In addition to high-end high-performance cars, they are selling or developing plug-in pickups (a new Hummer powered by a 1,000-horsepower electric engine delivering 11,500 lb.-ft of torque is slated for 2022) and a range of mid-priced electric crossovers such as the new Mustang and Volkswagen's ID.4.[4] A raft of new competitors, such as Rivian, Lucid, Fisker, and Nio are designing electric sedans, SUVs, for the US market as well. GM has gone all-in, declaring that it will only produce EVs after 2035. And Jaguar has upped the ante, saying it will be all-electric by 2025.[5]

A tsunami of investment

We count more than $200 billion in EV investments by the top 10 global automakers. To put that in perspective, it's more than the US spent over the 13 years on the Apollo space program to land a man on the moon (adjusted for inflation). It's enough to develop more than 200 new car platforms—aimed at a market that today accounts for less than 5 percent of global auto sales. And $200 billion doesn't even count the estimated $60 billion that has gone into startups or the tens of billions being invested by smaller automakers and parts suppliers. Nor does it include needed investments in complementary industries, such as money to enhance the electric grid or for gas stations to add hydrogen pumps or charging stations.

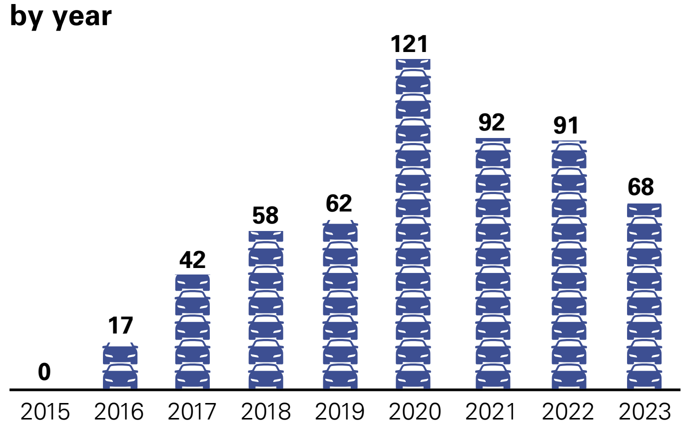
Top 10 auto makers (plus Tesla) have announced $200 billion in EV investments and hundreds of models

Announced investments in EVs and FCVs, 2020–present ($B)



Source: OEM announced investments are not directly comparable across OEMs. For example, some announcements reflect only R&D while others include capital expense for new EV production plants.

Global EV new model launches/refreshes by year



Note: (a) 2016–2020 historical data; 2021–2023 expected based on announcements; (b) Includes BEV models only
Source: LMC

For many automakers, these bets are too big to fail. But clearly, not all these bets will pay off. Some bets may wind up losing because the hoped-for technology breakthrough didn't happen. Others will have aimed at a vehicle type or customer segment that won't transition easily to EVs. Some bets will fail because of poor timing.

[4] Source: "Every Electric Vehicle That's Expected in the Next Five Years," Car and Driver, January 12, 2021
[5] Source: "Jaguar cars to go all-electric by 2025 as JLR plans full range of e-models by 2030," CNBC.com, February 15, 2021.

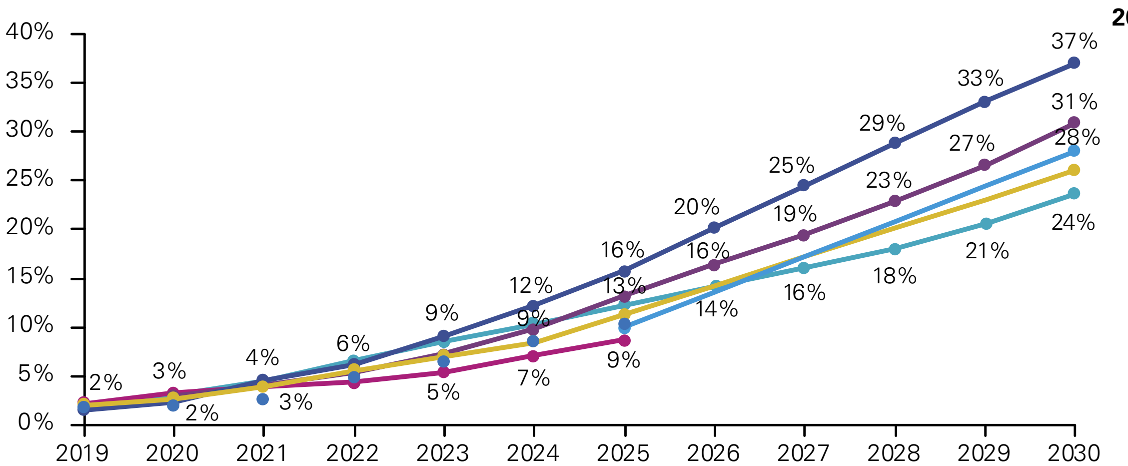
Risky business

Even now, there remains wide disagreement on when a mass EV market will materialize. Depending on the analyst, EVs could capture up to 37 percent of the global market by 2030—or as little as 24 percent. Even if the high estimate proves accurate, there still may be far too many players vying for too few customers.

At year-end 2020, LMC Automotive counted 284 EV models for sale and predicted the number could approach 500 by 2023.[6] These models will be produced by an estimated dozens of companies, ranging from the newest startups to the world's oldest auto brands.

There is no consensus on EV adoption

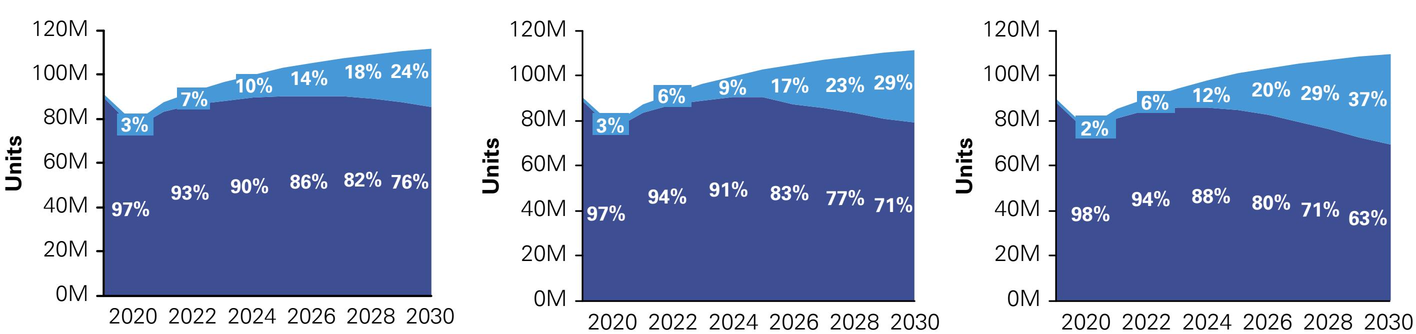
Global BEV sales forecast—analysts' viewpoints



Sources: JPMorgan; UBS; RBC Capital Markets; Morgan Stanley, LMC; Bloomberg
Note: 2030 units are based on analyst BEV share estimates and LMC 2030 volumes for consistency

As EV sales rise, the available ICE market will shrink

Low estimate **Average estimate** **High estimate**



ICE, hybrid, and other BEV

Note: Overall industry volume taken from LMC 2021 Q1 LVSF for consistency in comparison, mix has been taken from analyst forecasts

[6] Source: LMC

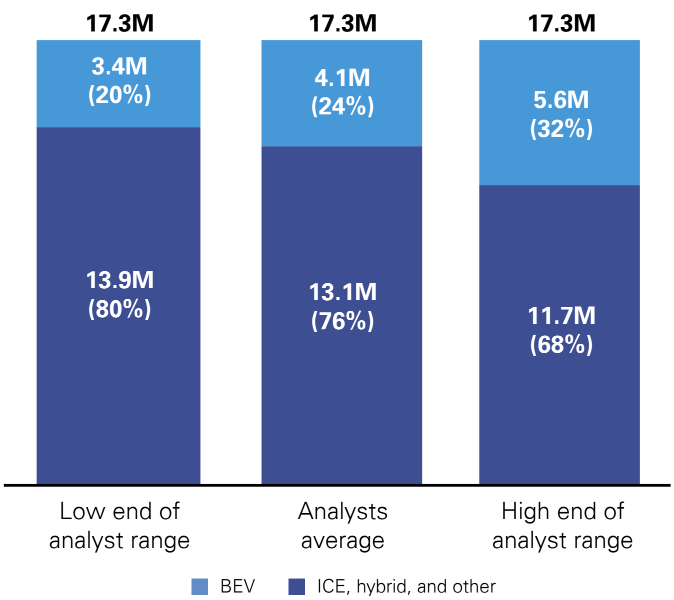
The risks are particularly complex for established automakers, which will have to manage the decline of ICE sales as they pursue EVs. No matter how quickly or slowly the EV share grows, the share of ICE vehicles sold will drop by 2030. In the US, for example, there could be anywhere from 3.4 million to 5.6 million fewer ICE vehicles sold in 2030 than in 2020 (assuming a 17.3-million-unit market). The implication is that automakers will be fighting harder to hold share in the conventional vehicle market, even as they vie for a slice of the EV market.

The struggle could be especially difficult for established players adopting all-in EV strategies. As the charts below show, these companies would need to do extraordinarily well in EVs to maintain their current market shares. In the high-case scenario, an incumbent would need to grab three times its current market share in the new EV business to stay even. In other words, a player with 5 percent of the market today would need to capture 15 percent of the EV market in 2030. If the low estimate holds and EVs only grab about 20 percent of the 2030 market, the 5 percent player would need to capture more than 25 percent of the EV segment to maintain unit-volume share.

Under an all-in EV strategy, incumbents will need to capture a huge amount of EV sales to maintain overall market share

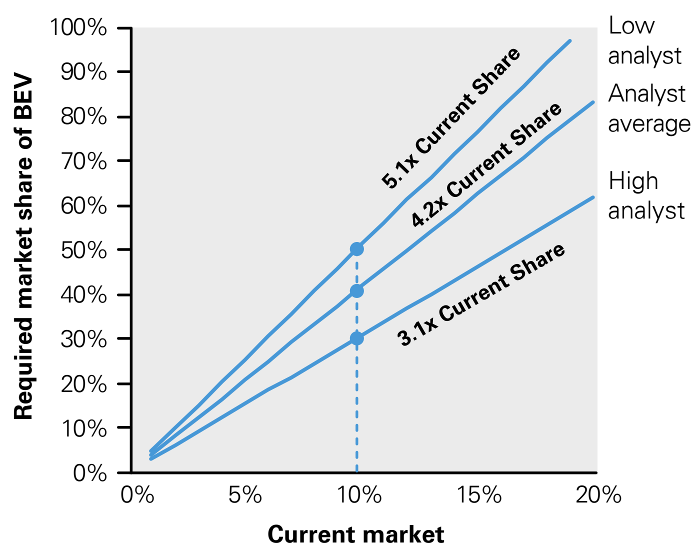
US market view

Hypothetical US BEV 2030 TAM (total addressable market)



Notes: (a) Overall industry volume taken from LMC 2021 Q1 LVSF
(b) Analyst average includes LMC, UBS, and RBC

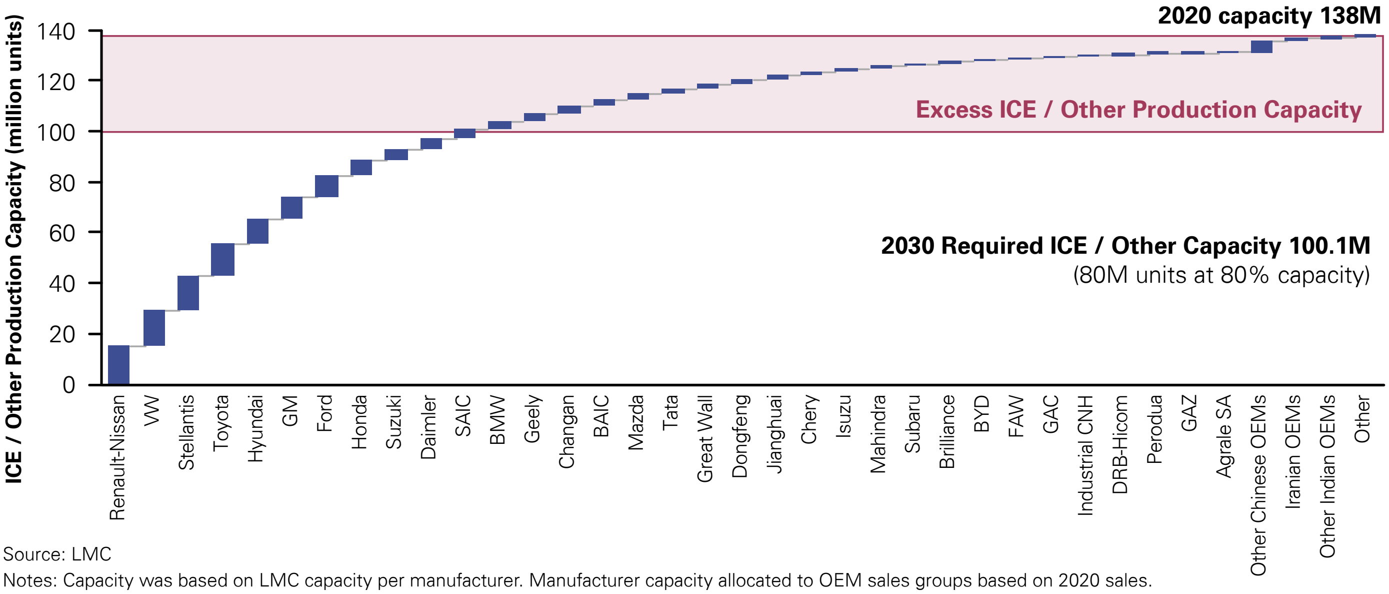
Required market share increase to maintain competitive position



Another consideration for incumbents: the implications of a declining ICE business for their asset bases and capital structures. We estimate that at 30 percent EV penetration, there could be global manufacturing capacity to build nearly 40 million more ICE vehicles than the market will demand (globally) in 2030. That would be the equivalent of 200 un-needed assembly plants.

There could be nearly 40 million units per year of excess ICE capacity in 2030

Illustrative analysis of required ICE production capacity



Source: LMC

Notes: Capacity was based on LMC capacity per manufacturer. Manufacturer capacity allocated to OEM sales groups based on 2020 sales. Numbers were adjusted to remove estimated BEV, EREV, and FCEV capacity

Betting on non-BEV powertrains

Even as dozens of players target the BEV segment, billions of dollars are being bet on alternative scenarios. For example, General Motors, Toyota, Honda, and Hyundai continue to invest in hydrogen fuel-cell EVs (FCEVs). FCEVs don't have the range limitations of BEVs but face similar obstacles—the high cost of fuel cells and the need for new fueling infrastructure.

Auto companies are also expanding their hybrid options. The hybrid price premium vs. ICE models is narrowing, and hybrids are available in almost every passenger-vehicle configuration, from subcompacts to SUVs and pickups, providing an attractive option for consumers who are not prepared to make the leap to BEVs.

What's more, ICE isn't going away anytime soon. Vehicles with ICE powertrains are far cheaper to buy and are likely to remain so—making them the practical choice in developing economies. Moreover, ICE vehicles are more versatile—ICE powertrains are used in everything from motorcycles to tractors and semis.

They work in all terrains, at all altitudes and in all kinds of weather. But when the temperature drops so does battery life.

Meanwhile, ICE technology continues to advance. With new engine designs and electronics, gas-powered cars can be cleaner and less fuel hungry. For the 2020 model year, average estimated real-world CO_2 emissions were projected to fall 12 grams per mile (g/mi) to 344 g/mi, and fuel economy was projected to increase 0.8 miles per gallon (mpg) to 25.7 mpg.[7] And there are "clean" ICE variations, such as natural-gas-powered city buses.[8]

The bottom line: Both established players and start-ups need to look at all the possibilities on every dimension—customer needs, economics, infrastructure evolution, regulation, time—when should place their billion-dollar bets? And how do they sustain current business as they invest in the new?

[7] Source: 2020 Automotive Trends Report, US Environmental Protection Agency, epa.gov, January 2021

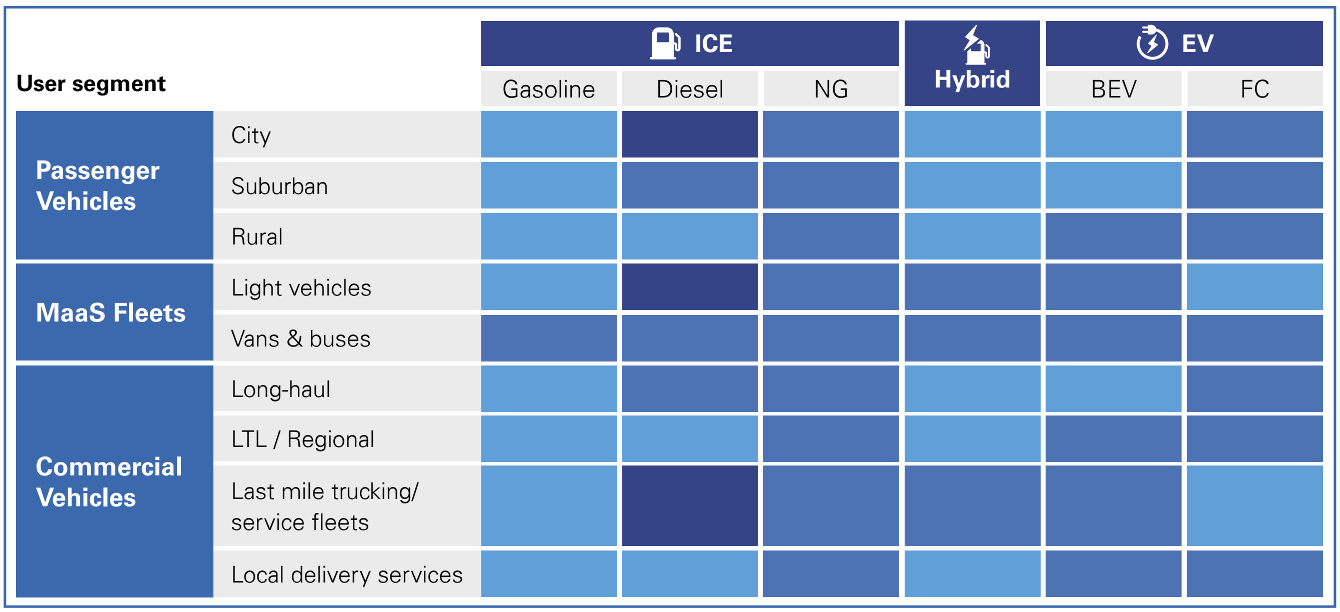
[8] Source: Natural gas powers more than 175,000 vehicles in the United States and roughly 23 million vehicles worldwide; Alternative Fuel Data Center. US Department of Energy, afdc.energy.gov.

Play it smart: Use the mosaic to assess the possibilities

The mosaic framework gives us a way to look at the various constraints (and opportunities) as automotive companies place their bets. It helps decision makers ask the critical questions about what they would need to believe about variables such as battery cost curves, charging infrastructure buildout, grid maturity, and customer preferences to make strategic decisions.

A mosaic view of auto industry scenarios

Example multi-factor evaluation—trucking sector



Drivers and considerations

Consumer acceptance
- Driver experience
- Mile range/ range anxiety
- Value perception
- Social preferences

Economics
- Total cost of ownership (acquisition cost, depreciation / residual, fuel, maintenance, insurance, etc.)

Technology evolution
- Solid state batteries
- Advances in fuel cell design and materials
- Increases in computing power

Ecosystem requirements
- Private sector investments in upstream / downstream capabilities
- Government-driven investments & coordination

Regulatory mandates
- Restrictions
- Subsidies / Tax incentives

Consumer preferences and vehicle missions

Understanding the automotive buyer is more important than ever. Where do they drive? How often? How far and for what purpose? Would they rather use mobility services than buy a car? At this point, BEVs do not fit all customer needs. Today BEVs beat out ICE mainly on performance and environmental concerns—they trail in cost, convenience, range and perceived value.

What will it take to convince drivers of pickups and SUVs—the most popular consumer vehicles in America—to switch to an electric model? Why isn't it equally plausible that the next move for many buyers will be to buy hybrids? For about $10,000 less than one of the all-electric pickups on the drawing boards, a consumer today can get a hybrid that will go more than 800 miles on a tank of gas and do zero to 60 in about 5 seconds.[9]

Even though upcoming BEV models are spec'd to deliver more than 400 miles on a charge, consumers still cite range anxiety as a reason not to buy EVs. The average gasoline-ICE vehicle (a small SUV), can go for about 410 miles before needing a fill-up, while current EVs can only go about 250 miles—and a lot less if it's cold out.[10] While 80 percent of U.S. motorists travel 50 miles or less per day on average, they still want to know that they can drive long distances and not worry about if there will be a place to refuel/recharge.

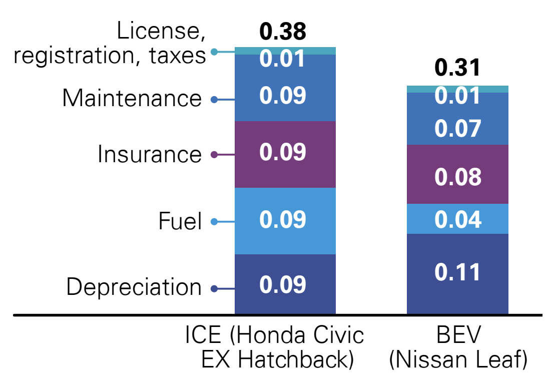
On the other hand, battery-electric powertrains look like winners in emerging automotive applications, such as autonomous vehicles for urban mobility services and local-delivery vans (with drivers or autonomous). In these uses, the high purchase cost is amortized over more hours of daily operation and range is not a worry. What's more, these vehicles don't need the performance and styling that are the basis for consumer vehicles. The drawback: this market doesn't yet exist, although it's getting closer. Amazon, for example, has tested delivery vans that it developed with Rivian Automotive on routes in Los Angeles.[11]

BEVs could dominate in urban MaaS

BEVs will likely become the dominant light vehicle for urban mobility-as-a-service (MaaS) fleets. MaaS fleet operators would not have range anxiety (all trips would be local) and high utilization rates would lead to low cost of ownership, despite higher purchase costs. MaaS providers could rely on their own charging facilities, so finding a charging point would not be an issue. Autonomous BEVs for MaaS could also get a boost from regulators who might mandate the use of BEVs for livery services. We have estimated that 90 percent of autonomous MaaS vehicles could be EVs in 2030.[12]

BEV has significant cost advantages in high mileage MaaS operations

ICE vs. BEV cost per mile for MaaS operations



Notes: Key assumptions: Useful life–6 years; miles per year–50,000; maintenance costs–per AAA; gasoline price–$2.87 (AAA assumption); ICE fuel economy–32 MPG combined; EV efficiency–0.3 kWh per mile; electricity price–0.132 per kWh; License, registration, taxes, insurance–per AAA
Source: KPMG Analysis

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[9] Source: Comparison based on 2021 Ford F150 XLT with Powerboost Hybrid V6 configured (MSRP of $57,760) vs. Rivian R1T ($67,500).
[10] Source: Institute of Transportation Studies, University of California, Davis website; EVAdoption.com.
[11] Source: "Amazon is testing Rivian electric delivery vans in Los Angeles," CNBC.com, February 3, 2021.
[12] Source: For more detail, see EV Plan B, KPMG 2020.

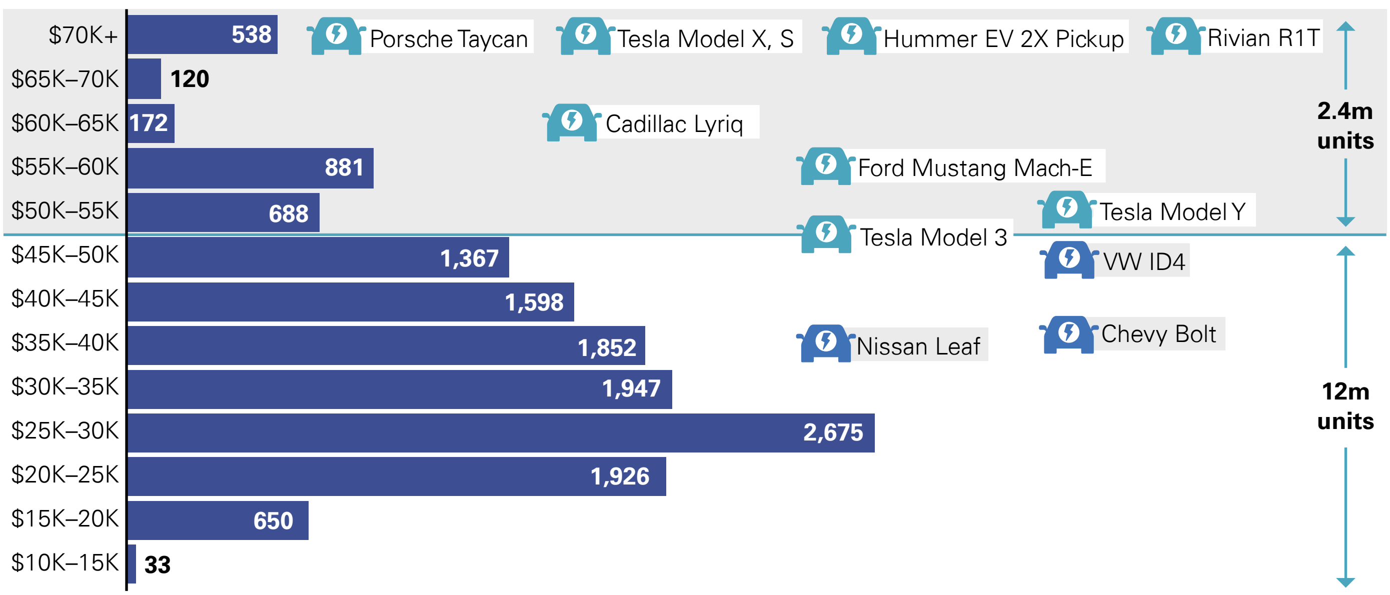
Economics and technology evolution

BEVs are still too pricey for most consumers to consider. Even though daily driving costs can be lower than for an ICE vehicle, the sticker price limits the potential market. The problem remains the cost of battery packs—despite an 85 percent drop in the cost of lithium-ion batteries over the past 10 years. Even so, battery packs for a midsize BEV still cost upwards of $10,000.

While Tesla and luxury/performance brands such as Jaguar, Mercedes and Porsche are finding a market for pricey EVs, with MSRPs exceeding $100,000, it is a limited market. Only about 2.4 million of the 14.5 million light vehicles sold in the US in 2020 fetched $50,000 or more at retail.[13] That is only about 17 percent of the US market.

Only 17% of US passenger vehicles sell for $50,000 or more

US 2020 light vehicle sales by price level (thousands of units)



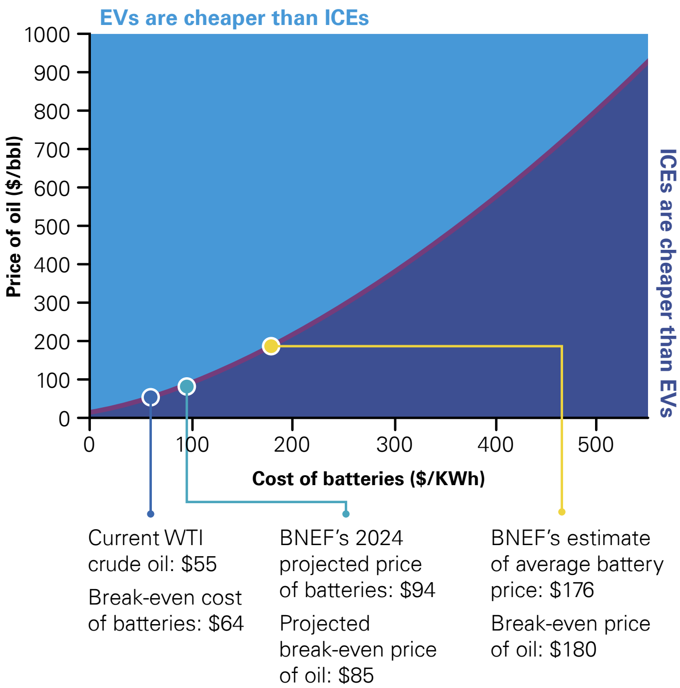
Notes: (a) Trim prices pulled: Tesla Model X, S, Y, 3–Long Range; Porsche Ocean–4S; Rivian R1T–Average; Cadillac Lyriq–N/A; Ford Mustang Mach-E–Premium; VW ID4–1st Edition; Nissan Leaf–S Plus; Chevy Bolt–LT / Premier Average
(b) Includes all vehicles with more than 1000 units sold in 2020, representing 99.8% of US Light Vehicles sold.
(c) Prices based on "Edmunds Suggests You Pay" price for the middle priced trim of each vehicle.

In other words, cost is still a barrier. And, assuming that approximate cost parity with ICE vehicles is required for mass market appeal, BEVs still have a way to go. As the following chart demonstrates, as long as gas is cheap (and/or battery prices remain high), BEVs are at a price disadvantage. At today's oil prices—about $60 per barrel—a battery pack would need to cost $100 per kilowatt hour (kWh) to be competitive. In 2020, the average EV battery cost $126 per kWh.[14] The median estimate among analysts pegs the average battery price at around $100 in 2024.

[13] Edmunds.com.
[14] Source: Battery Pack Prices Cited Below $100/kWh for the First Time in 2020, While Market Average Sits at $137/kWh, Bloomberg NEF, December 16, 2020.

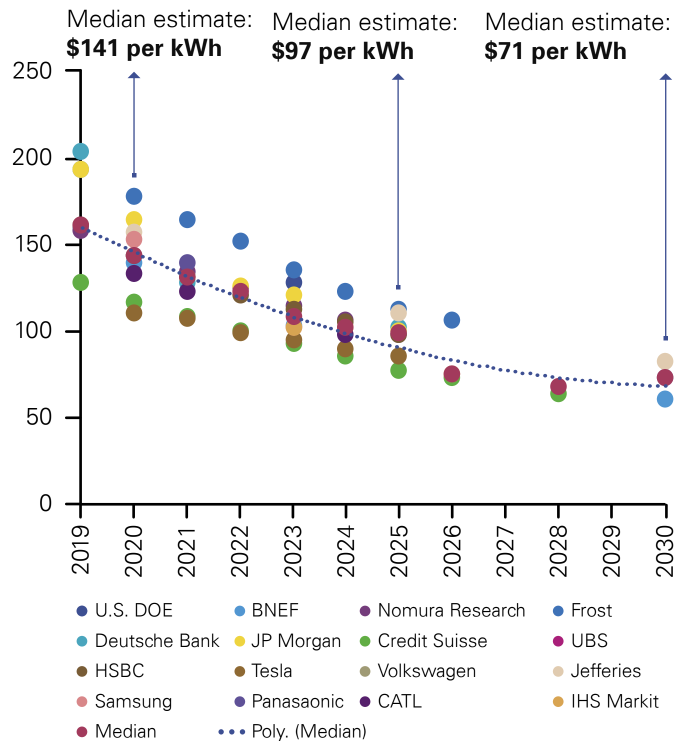
When will battery prices fall enough to make EVs competitive with ICE vehicles?

Breakeven for an ICE vehicle vs. an EV with 250 miles of range



Sources: BNEF estimate, Greenstone, M. (2020).The Global Energy Challenge: State of the Global Economy. *Energy Policy Institute at the University of Chicago.;* Greenstone et. al., "Will We Ever Stop Using Fossil Fuels?"

Battery pack cost curve: Analysts projections



Note: Includes Li-ion battery pack cost or price estimates

Sources: Bloomberg NEF; US Department of Energy; Deutsche Bank; Nomura research; JP Morgan; Credit Suisse; UBS; HSBC; Global Lithium-ion Battery Production and Capacity Expansion, Frost; Tesla, Cleantechnica; VW press conference; "The Global Energy Challenge", Michael Greenstone

But solving the technical problems to reduce battery cost is only part of the equation. The price—and availability—of raw materials for EV batteries is another critical variable. There are already growing shortages of critical materials such as nickel and lithium.[15] And, European Commission President Ursula von der Leyen recently warned that the scarcity of raw materials could stymie the EC's efforts to decarbonize by switching to EVs; she also estimated that 98 percent of raw materials needed for a clean economy are controlled by China.[16]

Cost is also a barrier for hydrogen fuel cell vehicles. Honda's Clarity fuel cell vehicle, for example, currently leases for almost twice the cost of the company's battery-powered model.[17]

[15] Source: Guy Burdick, "Battery makers face looming shortages of high-quality lithium", UtilityDive.com, June 25, 2020.
[16] Source: Finbarr Bermingham, "China's rare earth dominance casts shadow over Europe's ambitious climate targets," South China Morning Post, Feb. 26, 2021
[17] Source: Avery Thompson, "Where Are All the Hydrogen Cars We Were Promised?", Popular Mechanics, August 27, 2020.

Ecosystem requirements

The timing of widespread adoption of EVs—whether they plug into the electric grid to charge batteries or use fuel cells that convert hydrogen to electricity—also depends on when the supporting infrastructure for recharging or refueling is in place. There are 31,753 public EV charging facilities in the US but, only 4,325 of these have DC fast chargers (with 17,409 outlets). This compares with 168,000 gas stations, which typically have eight or more fuel pumps. It is estimated that it would cost more than $2 billion just to equip homes and workplaces with enough chargers to meet anticipated 2025 needs in 100 top metro areas--and many times that to replicate the current US gasoline distribution network.[18]

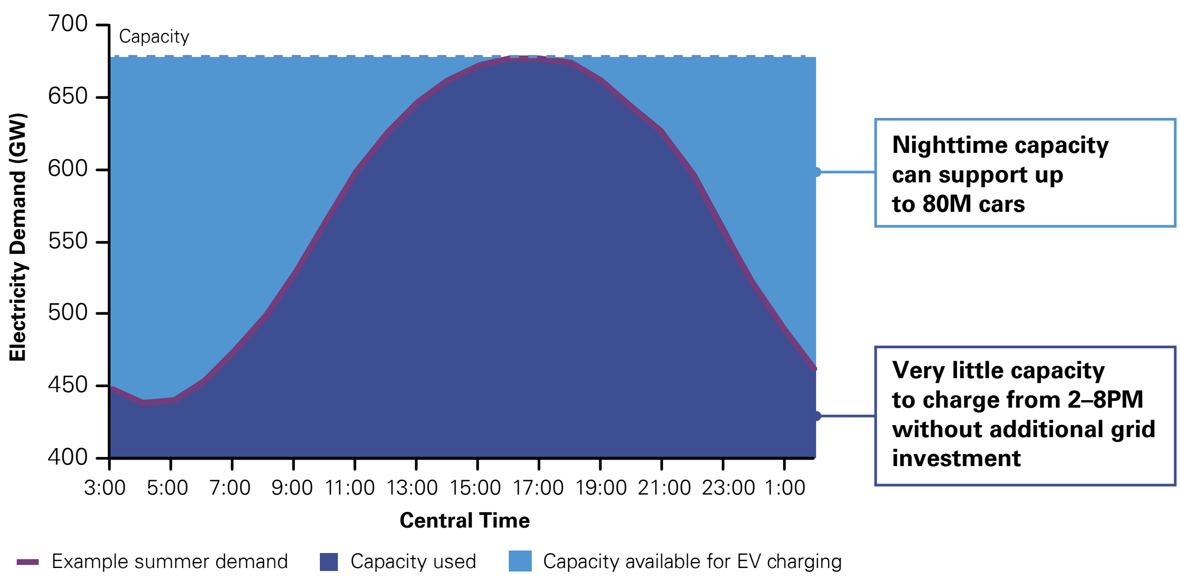
Like battery-powered EVs, hydrogen fuel-cell-powered vehicles also would have to have their own infrastructure—that is, a hydrogen production, storage, and distribution network, in addition to a network of refueling stations (currently less than 100 hydrogen stations exist in the US).

Based on current EV demand, the market is unlikely to create charging infrastructure by itself. It will take public-sector action, as well as strategic investments from automakers to build out their own charging systems (a move already made by Tesla). If enacted, President Biden's infrastructure bill could provide funding for 500,000 charging stations in the US[19]

There are other infrastructure issues to overcome before BEVs can become attractive to most motorists. For example, home charging is not so simple in large apartment blocks in major cities—the markets where EVs are most likely to catch on (at least initially). Even if apartment owners have an on-site parking space, these are usually not wired.

The grid challenge

US summer electricity demand during August



Notes: Summer demand from August 2016
Source: KPMG analysis

[18] Source: Jacqueline Toth, "Report: $2.2 Billion Needed to Meet US Electric Car Charging Demand Through 2025," Morning Consult, August 13, 2019.
[19] Bengt Halvorson,, "Electric car rebates, charging stations: What's in $2 trillion Biden infrastructure plan?" Green Car Reports, March 31, 2021.

Then there is the problem of the electric grid. The US grid was not designed for a nation of motorists who arrive home after work every night and plug in their BEVs—or to provide the surge of power used by commercial quick-charge stations. The problem can be partially addressed with demand-management systems that would let utilities coordinate charging times—dynamically scheduling individual customers for EV charging hours to avoid excessive loads. According to KPMG analysis, the US has generating capacity to charge 80 million EVs if utility-managed charging is used. However, there are still bottlenecks in transmission and distribution that would require additional investments. Electricity infrastructure is a greater barrier to EV adoption in developing economies, which have some of the world's fastest-growing automotive markets.

Rising incomes (and lower EV costs) will help close the affordability gap. But today, 3.9 billion consumers live in developing economies with inadequate electric grids.[20] When that will change, no one can tell.

In developing economies, there are nearly 6.6 billion people who lack infrastructure and financial means to switch to BEVs

Countries classified by GDP per capita and grid reliability

	2019 population	2019 auto sales	2032 estimated auto sales
Income > $25,000 and high grid reliability	1.0B	44.1M	45.2M
Lower income and/or lower grid reliability	6.6B	45.6M	66.8M

Note: Nearly every country with GDP per capita over $25,000 was classified as having a reliable electrical grid. Of the 6.6B people in low income countries, 2.2B were classified as having reliable electric grids. 3.9B were classified as having unreliable grids and 0.5B were not classified

[20] Source: World Bank, World Economic Forum

The X factor: What will regulators do?

The choice of non-ICE technology and business strategy is also driven by regulation—another variable that adds a high degree of uncertainty. The internal combustion engine is in the crosshairs of regulators because motor vehicles are a leading source of carbon emissions. In 2018, greenhouse gas emissions from transportation accounted for about 28.2 percent of total US greenhouse gas emissions, making it the largest contributor of US greenhouse gases.[21]

With increasing evidence of climate-change impact—and rising political pressure—regulators have gone from limiting carbon emissions across vehicle fleets and encouraging BEV adoption to outright ICE bans. Seventeen countries have announced mandates to stop sales of ICE vehicles, starting as early as 2025.[22] Other pro-BEV policy measures include industry mandates to automakers to make BEV models available, financial incentives to buyers, subsidized charging infrastructure, and campaigns to increase consumer awareness. On March 31, 2021, the Biden administration unveiled a $2 trillion-plus infrastructure bill that includes a range of supports for EV sales. These include new federal tax credits for EV purchases and funding for charging stations.[23]

How much, if any, of the Biden EV plan will be enacted is difficult to predict. We do know from experience that policies can change direction without warning. In the past 12 years, the US has gone back and forth on support for EVs and other environmental measures between the Obama, Trump, and Biden administrations—and could flip back again with the next election.

Norway builds for EVs

Norway has the highest EV penetration in the world. In 2020, more than 50 percent of Norway's light vehicle sales were battery-electric vehicles.

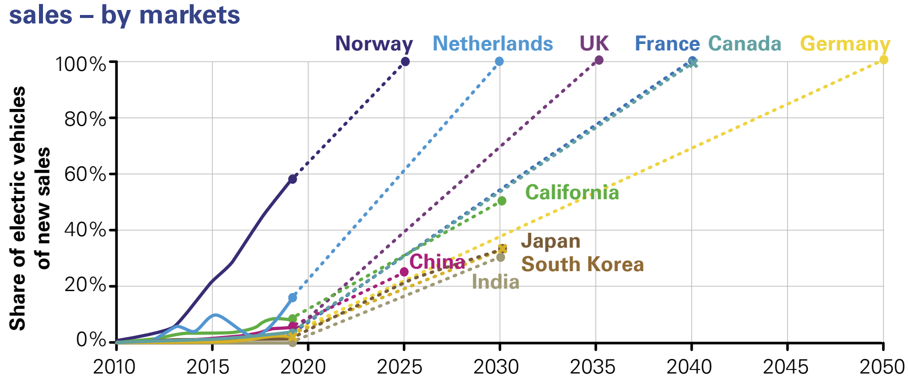
The country has invested heavily in building the infrastructure to support this transition to EVs, spending more than €3 billion through 2018 and committing €2 billion more for the 2018–2029 period.

This represents a total government investment of roughly $1,800 per household or potentially $3,200 per BEV sold through 2029, based on expected volumes.

While these costs are feasible for high-income countries, they would be prohibitively expensive for developing economies.

	Norway	**US**	**India**
Population (2020)	5.4 million	331 million	1.3 billion
Annual auto sales	0.1 million	15.5 million	2.3 million
Motorization rate (vehicles per capita)	0.514	0.838	0.041
GDP per capita (USD)	$75,400	$65,300	$2,100
Estimated cost for BEV infrastructure ($B)	$5.4 billion	$339 billion	$1.4 trillion

Historical and targeted electric shares of new passenger vehicles sales – by markets



Source: Update on the global transition to electric vehicles through 2019, The International Council on Clean Transportation.

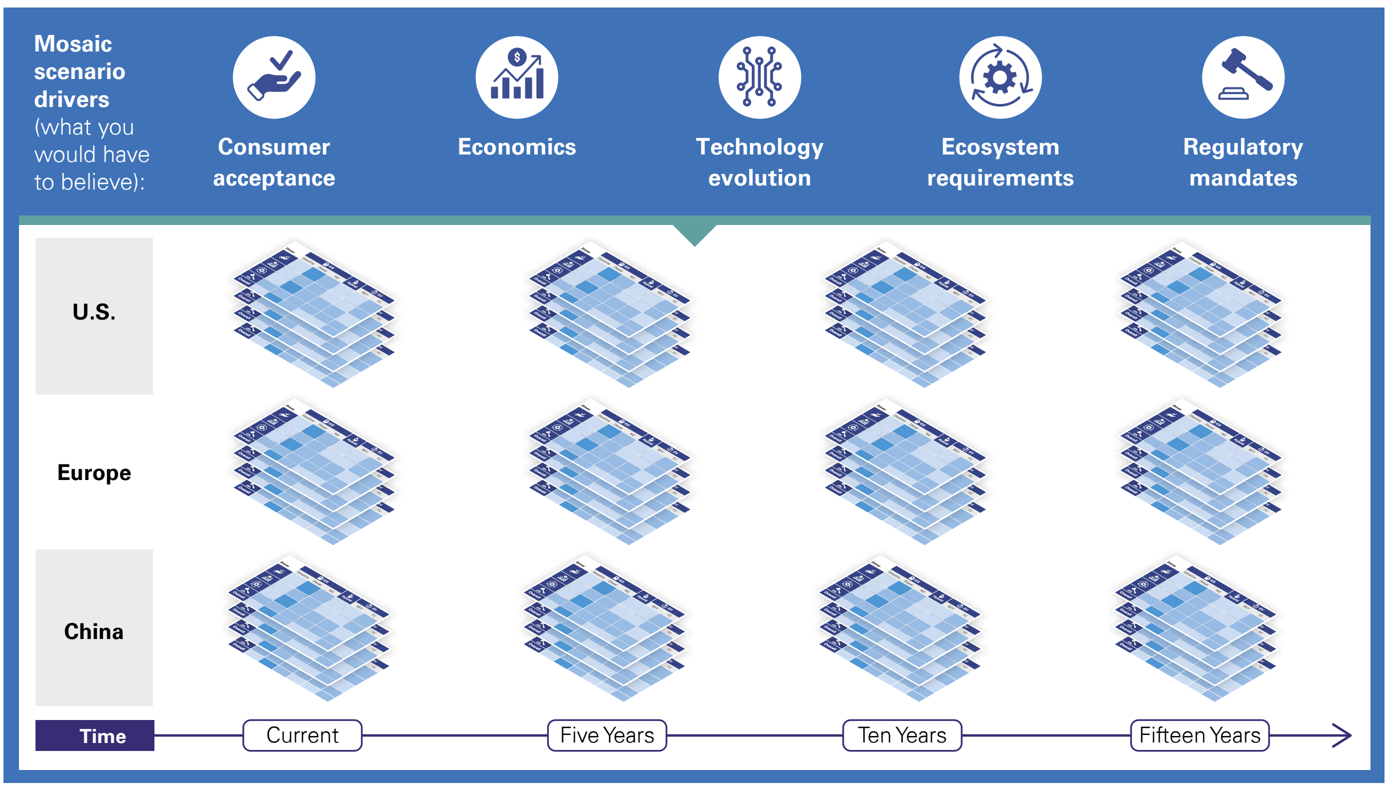
[21] Source: Sources of Greenhouse Gas Emissions. US Environmental Protection Agency.
[22] Source: Actions by countries to phase out internal combustion engines, theclimatecenter.org.
[23] Source: Niraj Chokshi, "Biden's Push for Electric Cars: $174 Billion, 10 Years and a Bit of Luck," The New York Times, April 1, 2021.

Strategy for an uncertain future

The automotive business is morphing. For all its complexity—global supply chains feeding thousands of parts to networks of assembly plants to build hundreds of different models—the automotive business has been a mature industry. Everybody was making cars using ICE technology and they all used similar operating models. Now, the industry is becoming a mosaic of multiple possibilities—and risks. The strategic choices have multiplied: companies have to reconsider what models to build, how to design them, where to build them—or whether to farm out manufacturing entirely.

These decisions are being made under great uncertainty and require a dynamic and flexible process: What do you have to believe to make a billion-dollar bet on a particular EV technology or market segment? What needs to happen to make this scenario come true? How does this vary by country and market segment? What happens if conditions change?

What do you have to believe?



Companies must not only place big bets on fuel/powertrain combinations, they must also think about how they will function in the new automotive business. There will be new operating and business model choices. There will be new profit pools and the industry structure—and the structure of individual players—will change to fit the new business.

Assets that were built up around ICE may be less relevant. There may be more opportunities to partner and outsource.

To craft strategy in this environment, companies need new approaches. They need ways to move ahead even in the face of irreducible uncertainties. And, they need the flexibility to adapt to surprises along the way.

Key questions for automakers, suppliers, and other players

1 What is a realistic range of scenarios for industry end-states, as a function of consumer acceptance, economics, technology, infrastructure, and regulation, under which we would make different investment decisions?

2 What are the resulting mosaic(s) for each scenario?

3 For each scenario:

- What is my competitive positioning now and in the future?
- What is my strategic posture do I want to adopt?
- What capital investments do I need to make?

4 Looking across the scenarios, what decisions, investments, and actions are common? (no-regrets)

5 What are the high commitment decisions that require additional diligence?

6 How can I better understand these decisions?

- War gaming
- Agent based modelling / game theory

7 Where should I go-it-alone or partner, or should I acquire?

Preparing for structural change

The end of a single focus on ICE and the emergence of the mosaic is setting off structural change across the automotive industry. Old value chains are being shattered and new operating models are appearing. Supply chains are being reconfigured and companies are re-examining their portfolios of businesses and assets. Automakers have new choices about production, from vertical integration to contract manufacturing. They have new choices of distribution models—from selling direct to maintaining dealer networks.

The most obvious change is the influx of new competitors. For the first time in decades, barriers to entry have fallen. Agile, well-funded startups such as Rivian, Lucid, Fisker, Nio, Xpeng, and Lordstown and many more are staking their claims. The new competition also includes tech giants such as Alphabet, Amazon and Apple.

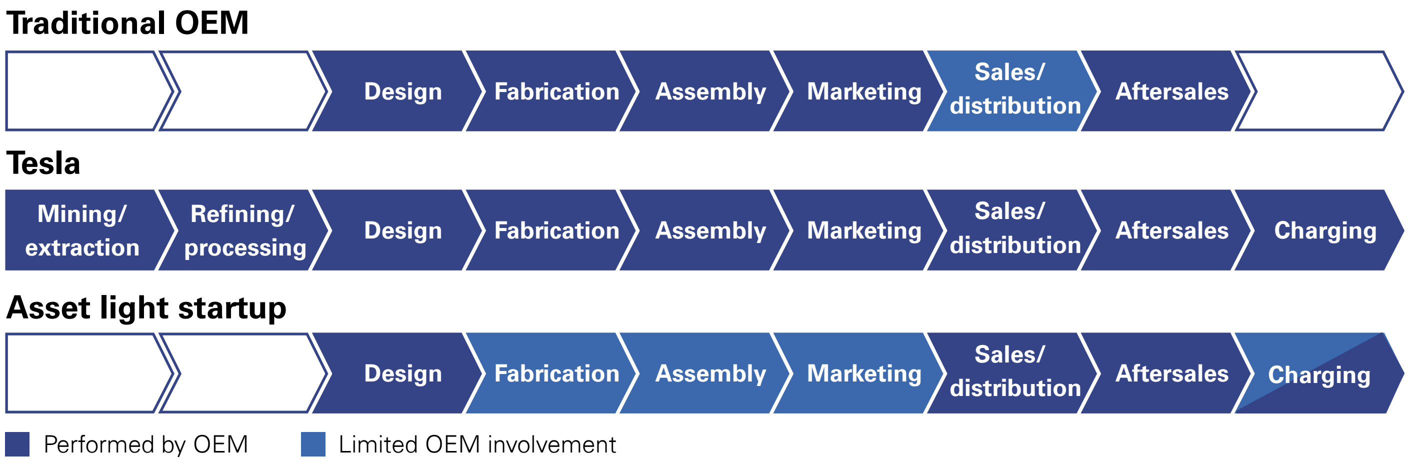
The transition to EVs is also creating new production models. Fisker has outsourced production of current designs to Magna International and recently announced a deal to partner with Foxconn, the contract manufacturing giant that makes iPhones.[24] The company says Foxconn will produce 250,000 units per year starting in 2023. Foxconn, which previously signed deals with China's Byton and Zhejiang Geely Holding Group, and with the Fiat Chrysler unit of Stellantis, says it is considering Wisconsin and Mexico for EV plant sites.[25]

At the other extreme, Tesla has declared its intention to be as vertically integrated as possible. It fabricates everything from batteries to seats and builds its own production equipment. The company is even investing in a network of quick-charging stations. It's a costly bet, but founder Elon Musk maintains this will allow the company to keep ahead of competitors in an increasingly competitive business.[26]

EVs are also bringing structural change to auto retailing. The vast majority of new entrants are selling direct. And, EVs could further endanger the economics of legacy dealer networks. EVs have few moving parts compared with ICE vehicles (20 parts in a powertrain vs. thousands in an ICE engine), requiring much less maintenance. That threatens one of dealers' last reliable sources of dealer profits—service and parts.[27]

[24] Source: Akanksha Rana, Ben Klayman, Apple supplier Foxconn teams up with Fisker to make electric vehicles, Reuters, February 24, 2021.
[25] Source: Yimou Lee, "Foxconn eyes EVs for troubled Wisconsin plant, may go to Mexico," Reuters, March 16, 2021.
[26] Source: "Elon Musk Explains Tesla's Vertical Integration Vs 'Catalog Engineering,'" InsideEVs, October 22, 2020.
[27] Source: The future of automotive retailing, KPMG 2020.

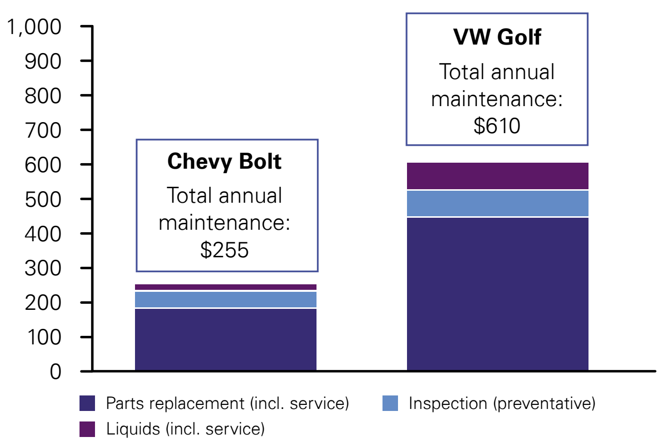
Three value-chain approaches



Lower EV maintenance requirements could cut aftermarket revenue

EVs have lower maintenance cost vs ICEs...

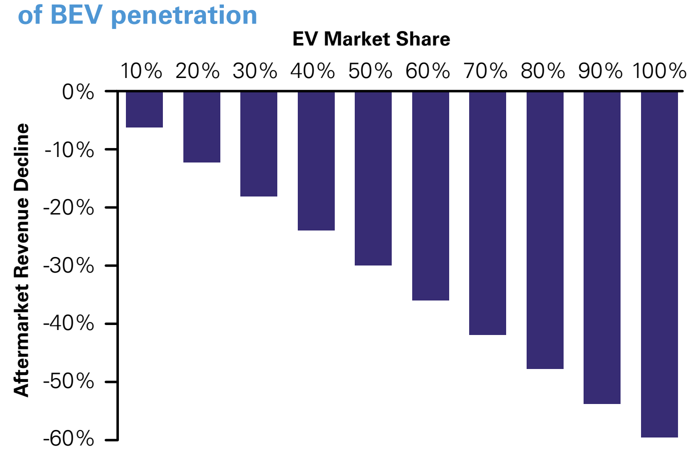
Comparison of total annual maintenance of Chevy Bolt and VW Golf ($ maintenance cost per year)



Source: UBS estimates

And up to 60% less aftermarket revenue as EV penetrates market

Reduction in aftermarket revenue for various levels of BEV penetration



Source: UBS Auto

When to bet: timing is everything

As always, timing will be critical for successful strategy. The shift to electric power trains and the unwinding of existing ICE capacity will be non-linear—adoption will accelerate quickly once the proverbial tipping point for EVs is reached. But it is still difficult to determine when that tipping point might occur.

Start-ups can race into the future now—indeed, that's what they're all about. But incumbents need to sustain their core businesses. This will require a delicate balancing act. Companies need to determine when to commit to new technologies and how to safely unwind ICE capacity. Based on their customers and geographic footprints, some incumbents might see significant first-mover advantages. Others could conclude that it makes more sense to be a fast follower.

Emerging strategic postures

In this environment, companies can choose from a range of strategic postures:

Reserving multiple options. Toyota may be the best example of this posture. The company is investing in multiple strategies across the mosaic, reflecting Toyota's position as the most global player, serving markets such as India and Indonesia as well as Japan, the US and Europe. It has been a market leader in hybrids and is developing plug-in EVs as well as fuel-cell models. In the home market, Toyota President Akio Toyoda has been sharply critical of a possible government mandate to end ICE production, which he said would cause the Japanese auto industry to collapse. He also estimates that "the infrastructure needed to support a fleet consisting entirely of EVs would cost Japan between ¥14 trillion and ¥37 trillion, the equivalent of $135 billion to $358 billion."[28]

Market shaper. GM signaled its strategy on January 2021, when CEO Mary Barra declared that GM will end production of ICE vehicles in 2035.[29] In effect, this announcement says that GM plans to lead the shift to electric versions of the cars, trucks and SUVs that Americans buy today and shape the future market.

> We'll offer EVs across all of our brands and at price points and span the global EV market from the Wuling Hong Guang Mini to the Cadillac CELESTIQ.[30]
>
> *GM CEO Mary Barra*

Partnering to share the cost and risk. Then there are unprecedented strategic partnerships. In 2019, Ford and Volkswagen joined forces in a global alliance to collaborate on an EV platform that will be used by both companies. They are pooling the risks of platform development and expect to produce 15 million Volkswagen MEB EV platforms a year in 2028. And, arguably the Stellantis merger of Peugeot and Fiat Chrysler is intended in part to share the costs of the transition to EVs. More consolidation is likely.

Scaled-down to focus. In February, Daimler-Benz announced what Chairman Ola Källenius called "a profound reshaping" of the company to position itself as the leader in electric luxury cars. The company plans to separate its truck business, which will focus on fuel-cell electric and self-driving trucks. Mercedes will focus on hybrids and EV passenger cars.

> The infrastructure needed to support a fleet consisting entirely of EVs would cost Japan between ¥14 trillion and ¥37 trillion, the equivalent of $135 billion to $358 billion.[31]
>
> *President Akio Toyoda*

Supplier strategies. Tier 1 parts suppliers also have to consider new strategic postures. Can they compete in the new world of batteries, electronics, and electric motors? Or will they go for more scale in the traditional parts business—adopt a "last man standing" strategy and buy up competitors? BorgWarner, for example, recently completed the acquisition of Delphi Technologies to strengthen its position in electric powertrains and electronics, and has announced plans to acquire German battery maker AKASOL. Other parts suppliers—Johnson Controls, for example—have concluded it's a good time to exit the business.

The choice of strategic posture will depend both on judgments about how and where to play in the new business and the company's "path dependence"—the history, distinctive capabilities market position and assets that each organization has. Companies need to be realistic about which choices are within their grasp.

[28] Source: Toyota's Chief Says Electric Vehicles Are Overhyped," Peter Landers, The Wall Street Journal, Dec. 17, 2020.
[29] Source: General Motors Co (GM) CEO Mary Barra on Q4 2020 Results - Earnings Call Transcript, Seeking Alpha, February 10, 2021.
[30] Source: GM CEO Mary Barra, Feb. 10, 2021 earnings call
[31] Source: Toyota President Akio Toyoda, the Wall Street Journal, Dec. 17, 2020.

How to make strategic decisions amid uncertainty

Traditionally, automotive strategy has dealt with known knowns (business as usual) and knowable unknowns—like how sales of various vehicles will behave under different economic conditions. But to place bets on the future industry (the mosaic), auto company strategists must work increasingly in the realm of the unknowable.

Right now, the biggest bets appear to be on a scenario in which battery technology continues to evolve on a predictable curve: manufacturing costs come down, range goes up, BEV sales accelerate. This scenario also seems to assume supportive government policy for EV adoption.

But there can be other plausible scenarios in which the opposite is true—where technology stalls, costs keep consumers away, and government incentives disappear or are ineffective. In this end state, mass EV adoption would occur much later. So, clearly, an automaker would make different decisions under one scenario versus another.

To make large, difficult-to-reverse decisions, companies will need to use a structured approach like the mosaic to identify a handful of plausible scenarios. If you believe costs will not come down rapidly what is the scenario for BEV market evolution? What do you have to believe about charging infrastructure? Based on your beliefs about EV adoption, what are your assumptions about the ICE business? Once you have sketched out several alternative scenarios, then you can use simulations and other analytical tools to assign probabilities and determine the most likely scenarios.

Conclusion

A new automotive game is commencing, and companies need to place their bets. For many companies, betting wrong now could have life-and-death consequences. In this paper, we have highlighted the idea of the mosaic as a way to analyze how various factors could determine the outcome as the reign of ICE technology begins to wane.

We believe the mosaic is a useful tool for breaking down complex problems into manageable parts. It helps you find answers to the critical questions about consumer behavior, economics, technology, regulation, infrastructure needs, etc. These answers can help inform critical decisions about where to invest, how much to invest, when to go it alone, when to partner, and when to make your move.

Our goal has been to encourage automotive executives and their strategy teams to create their own vision of the future industry, based on sober, data-driven analysis—of both the automotive market and of the value of the assets and capabilities that their organizations bring to the new automotive game. These are the most consequential decisions this generation of automotive leaders will make. Place your bets wisely.

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