What is an EV?

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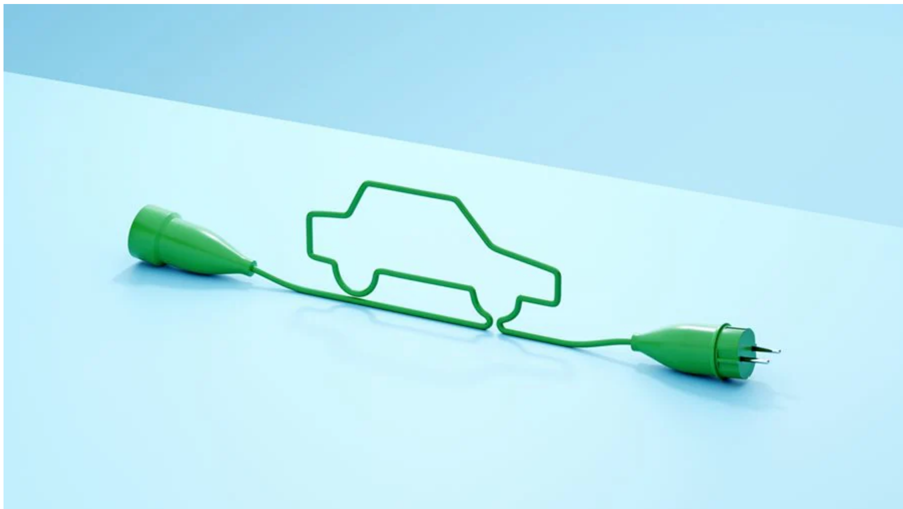
EVs are vehicles powered by electricity and an electric motor rather than a conventional gasoline-fueled internal-combustion engine.



Electric avenues: If you're driving a car that needs to be fueled up, chances are your vehicle runs on an internal-combustion engine (ICE), powered by gasoline or diesel fuel. Electric vehicles have a battery instead of a gasoline tank and an electric motor instead of an ICE.

But not all EVs are created equal. There are several types of EVs, all powered a little differently:

- *Battery electric vehicles (BEVs)* are powered by rechargeable electric batteries. BEVs produce no tailpipe emissions and have no combustion engine.
- *Plug-in hybrid electric vehicles (PHEVs)* are powered by an electric motor as well as a small combustion engine. They have an all-electric range from 20 to 60 miles and can be charged at a charging station.
- *Hybrid electric vehicles (HEVs)* have an internal-combustion engine and an electric motor that assists only at low speeds. The battery is charged either by the combustion engine or through recuperation when braking.
- *Fuel cell electric vehicles (FCEVs)* use electric motors. The electricity is generated in fuel cells and can be stored in a small buffer battery. Fuel cell vehicles require hydrogen (compressed into tanks) as a fuel.

The automotive future is electric—McKinsey projects that worldwide demand for EVs will grow sixfold from 2021 through 2030. Annual unit sales would go from 6.5 million to roughly 40 million over that period. In recent years, the COVID-19 crisis and the war in Ukraine have accelerated the momentum of sustainable mobility. Understanding EVs and e-mobility can illustrate how these vehicles are transforming the industry and helping to decarbonize the planet.

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Are there other EVs aside from cars?

The popularity of electric bikes and scooters, driven by their affordability and ease of access, represents a new chapter in micromobility.

On the opposite end of the EV spectrum are eTrucks. Demand for them is booming in response to a regulatory push to reduce emissions in the logistics and transport sectors. EU regulations now require new trucks to reduce carbon emissions 30 percent by 2030. California's recent Advanced Clean Truck regulation requires manufacturers of commercial vehicles to start selling eTrucks in 2024 and restricts all sales to electric models by 2045.

Today, eTrucks are becoming more economical for manufacturers to produce and for consumers to purchase and own. As a result of improvements in electric powertrain technology and declining battery costs, McKinsey predicts that within the next few years, the total cost of ownership for many eTrucks, depending on the specific use case, will be similar to or better than that of traditional ICE trucks. Toward the end of this decade, we expect that fuel cell electric trucks, powered by hydrogen, will also penetrate the commercial-vehicle industry, especially in heavy-duty applications and long-haul use cases, where pure battery electric powertrains might have limitations given battery size and weight.

And in the broader world of mobility, electric aircraft are also on the horizon. Electric vertical takeoff and landing (eVTOL) aircraft could be flying above cities as soon as 2030. The global electric-aircraft market is estimated to reach $17.8 billion by the year 2028, according to a recent report. Funding for advanced air mobility, including electric aircraft, exceeded $8 billion as of March 2021.

What is the range of EVs?

Range is how far an EV can go before recharging, an important consideration for customers in the market for EVs. That's because, at present, most EVs can travel only around half the distance of the typical ICE vehicle before recharging—and because charging stations are still few and far between, even in markets that have embraced EVs.

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What is fast charging for EVs?

There are two types of chargers:

- *Alternating current (AC) slow charging (3–22 kW)* provides energy for, on average, 30 miles for an hour of charging. These are found in private homes and in public charging stations. AC is also used in private homes and can be installed easily.
- *Direct-current (DC) fast charging (50–300 kW)* provides, on average, at least 150 miles for 20 minutes of charging. This type of charging is available only at public charging stations and requires a significant investment to install.

Fast chargers are a considerable expense—as of 2022, the hardware alone for a 300-kW charger costs from $50,000 to $100,000, and installation can be just as pricey. The costs could drop by about 40 percent over the next five to seven years as demand for fast charging increases to reflect the expanding EV customer base. The greatest opportunity in the EV-charging value chain will come from on-the-go charging, which allows drivers to pay a premium to charge within an hour.

Accelerating the rollout of charging infrastructure will be a crucial enabler for EVs to go mainstream. At present, there are about 1.15 million public charging stations in China, around 340,000 in Europe, and roughly 100,000 in the United States. The European Charging Infrastructure Masterplan, developed together with industry associations (including ACEA, Eurelectric, and WindsEurope), forecasts that until 2030 approximately 7,000 charging stations must be built every week to sustain the ramp-up of e-mobility.

Governments, utilities, and charging companies need to consider several questions as they build out the charging infrastructure. For instance, where should charging stations be located—bearing in mind accessibility, convenience, and equity? What charging speed is essential? And what's the best way to balance profitability and convenience?

How do EVs affect the electric grid?

As the mobility market continues to shift toward EVs, many observers are considering the effects on global energy grids. Generally, electrical capacity will need to expand to support the growing number of EVs on the roads, but analysis suggests that growth in e-mobility will not drive substantial increases in power demand in the short to medium term.

McKinsey's research on EVs in Germany—where up to 15 million EVs are expected to be on the roads by 2030—suggests that the majority of charging will take place at single- or multiunit homes, places of work, on highways and at public stations, and at retail destinations such as shopping malls. The greatest opportunities for growth will be at van or truck fleet hubs, which will need to evolve to meet both heavy demand and the need for fast charging.

One solution to mitigate much of the impact of EV customers on electric grids is "managed charging." That approach entails a combination of incentives for customers to use off-peak charging times and moves to enable utilities to turn charging on and off for areas or individuals, based on real-time use. Vehicle to grid (V2G) technology can facilitate managed charging.

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How does the rise of EVs affect natural resources?

Ecological concerns are central to the shift to EVs—for consumers as well as regulators.

The rise of EVs has direct implications for the supply chain of raw materials. The greater demand for EVs in recent years has meant greater demand for raw materials and EV inputs, including metals and ores such as cobalt, lithium, and nickel. Demand for lithium carbonate, for example, could rise to three million to four million metric tons in 2030, from 500,000 metric tons in 2021. As for nickel, McKinsey predicts a shortage in the middle of this decade. Exploding demand for nickel, as well as its use in several industries (such as steel production), is likely to drive this shortage.

Of course, fewer ICE vehicles in operation means less demand for oil and natural gas.

More broadly, when it comes to sustainability and the mobility industry, much attention is paid to bringing down tailpipe emissions—understandable, since they account for 65 to 80 percent of the emissions automobiles generate. But it's worth noting that efforts to reduce material emissions will be crucial, over time, to realizing the potential of the zero-carbon car. Mobility's longer-term net-zero transition entails both opportunities and risks, and coordinated responses from the public and private sectors can help ease the shift.

Is the automotive future electric?

Simply put, yes. Mainstream EVs will transform the automotive industry and help decarbonize the planet. There is essentially no other solution to decarbonize passenger transport. Hydrogen will probably not play a significant role in passenger mobility as EV-charging speeds and ranges increase and green hydrogen remains too expensive for the average private BEV owner. Other options have different limitations: synthetic fuels are too expensive, biofuels are not abundantly available—and both release emissions.

- *Regulation.* National and municipal governments have introduced new regulations and incentives to accelerate the shift to sustainable mobility. In the United States and Europe, new regulatory targets aim for an EV share of 50-plus percent by 2030. A number of countries, including those in the European Union, have gone well beyond this, announcing accelerated timelines for ICE sales bans in 2030 or 2035. Many national governments are also offering EV subsidies.
- *Consumer behavior.* People are more accepting than ever of alternative, sustainable mobility options. In 2021, the number of inner-city trips with shared bicycles and e-scooters rose by 60 percent year over year. Interest in EVs reflects this consumer shift: more than 45 percent of car customers in 2021 considered buying an EV.
- *Technology.* Automotive-industry players are accelerating the development of new concepts of mobility, including electric, connected, autonomous, and shared vehicles. These technology innovations will help reduce the cost of EVs and make electric shared mobility a real alternative to owning a car.

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Are EVs profitable? How can companies boost the profitability of EVs?

EV profitability remains at best slightly above breakeven for current models, although three-quarters of EVs analyzed show negative profit margins. This is mainly the result of high battery costs and expensive R&D efforts over still relatively low volumes.

But the market share for EVs is rising. McKinsey's analysis forecasts that if this continues, the average EV profit level will gradually improve thanks to cost reductions and economies of scale. Already, Tesla posted a 32% gross margin in Q1 2022.

For now, companies have ways to boost the profitability of EVs. These include incremental measures to spread industry best practices (such as direct-to-customer sales or design-to-value processes) to optimize costs. Automakers can also make more radical adjustments to their business models—for instance, by incorporating EV/battery-as-a-service offerings.

Reducing battery costs (despite increasing raw-material costs) through economies of scale, innovations in battery technology, and a better charging infrastructure (to avoid always-increasing range requirements) will help improve the cost position of electric vehicles.

How are chip shortages affecting the EV market?

A shortage of semiconductors, also known as chips, is affecting the vehicle market—electric and otherwise. The shortage is the result of a complicated confluence of events, including struggles during the COVID-19 pandemic, a lack of new capacity, geopolitical tensions, limited stock, and contract terms unique to the auto industry. The scarcity lowers car production and is responsible for billions of dollars of lost revenue.

Given the shortage and resulting losses, automotive EV-component manufacturers will need to rethink how and when they order semiconductors to meet the growing demand for EVs.

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How can ICE businesses stay competitive?

The last hundred years are known in the automotive industry as the ICE Age, when vehicles with internal-combustion engines dominated the roads and skies. While most vehicles on the road are still powered by ICEs today, EVs are slowly replacing ICE vehicles, especially in the European Union, China, and the United States. However, emerging markets will still use ICE vehicles into the 2040s, and aftermarket components will still be used through the 2050s and beyond.

To stay competitive, ICE suppliers need to explore ways to navigate the energy transition—and revisit their portfolios—as electric mobility continues to grow.

What is the Electric Vehicle Index?

McKinsey's Electric Vehicle Index (EVI) tracks the dynamic e-mobility market in 15 countries, focusing on BEVs and PHEVs. It emphasizes two key factors:

- *Market demand,* by analyzing the share of EVs in the overall market and the factors fueling the growth and adoption of EVs in each country. These factors include incentives (such as subsidies), existing infrastructure, and the range of available EVs.
- *Industry supply,* by examining how many of a country's manufacturers are producing EVs and EV components, such as e-motors and batteries.

The EVI then assesses the key performance indicators in each country's EV market and plots them on a scale from 0 to 5 for both supply and demand factors. The resulting analysis offers interesting insights on the regional dynamics and emerging trends of EVs.

For a more in-depth exploration of these topics, see insights from the McKinsey Center for Future Mobility.

Learn more about the McKinsey Center for Future Mobility and our Automotive & Assembly Practice, and check out automotive and mobility-related job opportunities if you're interested in working at McKinsey.

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