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McKinsey Center for Future Mobility

Why the automotive future is electric

Mainstream EVs will transform the automotive industry and help decarbonize the planet

IAA 2021: charticle

September 2021

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Introduction

That hum in the distance is the sound of the concept of mobility changing – for the better. While challenges to the electrification of the vehicle parc persist, opportunities worth fighting for also lay ahead. This is particularly evident in cities, where emissions, congestion, and safety constitute major issues today. If the status quo continues, mobility problems will intensify as population and GDP growth drive increased car ownership and vehicle miles traveled. In response, the mobility industry is unleashing a dazzling array of innovations designed for urban roads, such as mobility-as-a-service, advanced traffic management and parking systems, freight-sharing solutions, and new transportation concepts on two or three wheels.

The current opportunity to transform the way we move fundamentally results from changes in three main areas: regulation, consumer behavior, and technology.

Regulation. Governments and cities have introduced regulations and incentives to accelerate the shift to sustainable mobility. Regulators worldwide are defining more stringent emissions targets. The European Union presented its "Fit for 55" program, which seeks to align climate, energy, land use, transport, and taxation policies to reduce net greenhouse gas emissions by at least 55% by 2030, and the Biden administration introduced a 50 percent electric vehicle (EV) target for 2030. Beyond such mandates, most governments are also offering EV subsidies.

Cities are working to reduce private vehicle use and congestion by offering greater support for alternative mobility modes like bicycles. Paris announced it will invest more than $300 million to update its bicycle network and convert 50 kilometers of car lanes into bicycle lanes. Many urban areas are also implementing access regulations for cars. In fact, over 150 cities in Europe have already created access regulations for low emissions and pollution emergencies.

Consumer behavior. Consumer behavior and awareness are changing as more people accept alternative and sustainable mobility modes. Inner city trips with shared bicycles and e-scooters have risen 60 percent year-over-year and the latest McKinsey consumer survey suggests average bicycle use (shared and private) may increase more than 10 percent in the post-pandemic world compared with pre-pandemic levels (See also "The future of micromobility: Ridership and revenue after a crisis", July 2020). In addition, consumers are becoming more open to shared mobility options. More than 20 percent of Germans surveyed say they already use ride-pooling services (6 percent do so at least once per week), which can help reduce vehicle miles traveled and emissions (See also "Shared mobility: Where it stands, where it's headed", August 2021).

Technology. Industry players are accelerating the speed of automotive technology innovation as they develop new concepts of electric, connected, autonomous, and shared mobility. The industry has attracted more than $400 billion in investments over the last decade – with about $100 billion of that coming since the beginning of 2020. All this money targets companies and start-ups working on electrifying mobility, connecting vehicles, and autonomous driving technology (See also "Mobility's future: An investment reality check", April 2021). Such technology innovations will help reduce EV costs and make electric shared mobility a real alternative to owning a car.

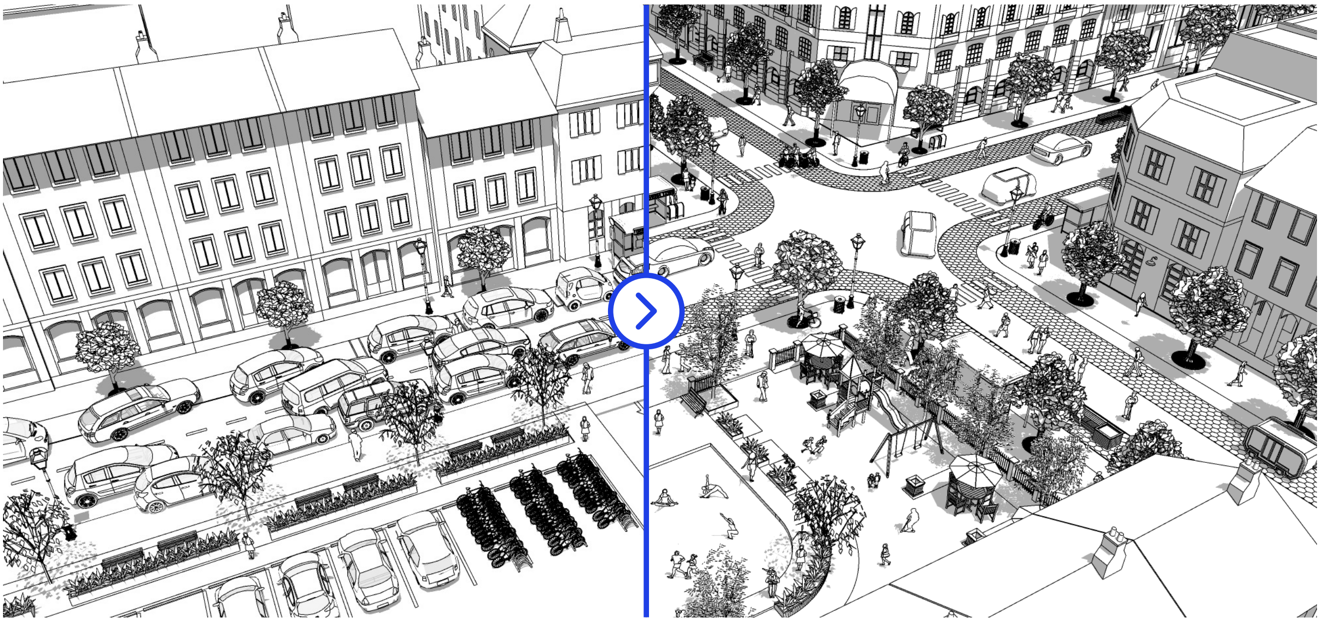
Electrification will play an important role in the transformation of the mobility industry and presents major opportunities in all vehicle segments, although the pace and extent of change will differ. To ensure the fast, widespread adoption of electric mobility, launching new EVs in the market is an important first step. In addition, the entire mobility ecosystem must work to make the transformation successful, from EV manufacturers and suppliers to financers, dealers, energy providers, and charging station operators – to name only a few.

Regulation, technology, and consumer behavior will change the mobility landscape

Illustrative change of the city landscape between today and 2030

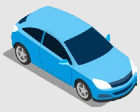
Today
Cities suffer from emissions, congestion, and safety ...

2030
... which is set to change with the arrival of new integrated mobility solutions

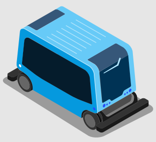


Electrification is one of the key enablers for new integrated mobility across vehicle segments, e.g.,

Scooters
Paris recently granted a 2-year contract for the implementation of 5,000 e-scooters



Passenger cars
Oslo reached 66% passenger EV adoption adoption in July 2021



Buses
Shenzhen has already fully electrified its 16,000 unit bus fleet as well as 22,000 taxis

Source: McKinsey Center for Future Mobility

Content

1. The future of passenger vehicle powertrains is electric; the transformation is ongoing

The tipping point in passenger EV adoption occurred in the second half of 2020, when EV sales and penetration accelerated in major markets despite the economic crisis caused by the COVID-19 pandemic. Europe spearheaded this development, where EV adoption reached 8 percent due to policy mandates such as stricter emissions targets for OEMs and generous subsidies for consumers.

In 2021, the discussions have centered on the end date for internal combustion engine (ICE) vehicle sales. New regulatory targets in the European Union and the United States now aim for an EV share of at least 50 percent by 2030, and several countries have announced accelerated timelines for ICE sales bans in 2030 or 2035. Some OEMs have stated their intentions to stop investing in new ICE platforms and models and many more have already defined a specific date to end ICE vehicle production. Consumer mindsets have also shifted toward sustainable mobility, with more than 45 percent of car customers considering buying an EV.

However, the continued acceleration of electrification is putting significant pressure on OEMs, their supply chains, and the broader EV ecosystem to meet these targets. This is particularly obvious with respect to setting up the required charging infrastructure.

2. By 2035, the largest automotive markets will go electric

Regulatory pressure and the consumer pull toward EVs vary greatly by region. Europe is mainly a regulation-driven market with high subsidies, while in China consumer pull is very strong despite reduced incentives. In the United States, EV sales have grown slowly due to both limited regulatory pressure and consumer interest, although the regulator trend is set to change under the new administration.

On a global level, we expect EV (BEV, PHEV, and FCEV)[1] adoption to reach 45 percent under currently expected regulatory targets. However, even this transformative EV growth outlook is far below what's required to achieve net zero emissions. EVs would need to account for 75 percent of passenger car sales globally by 2030, which significantly outpaces the current course and speed of the industry.

We believe Europe — as a regulatory-driven market with positive consumer demand trends — will electrify the fastest and is expected to remain the global leader in electrification in terms of EV market share. In addition to the European Commission target, which requires around 60 percent EV sales by 2030, several countries have already announced an end to ICE sales by 2030. In line with this, seven OEM brands have committed to 100 percent EV sales by 2030 within the European Union. In the most likely accelerated scenario, consumer adoption will exceed regulatory targets and Europe will reach around 75 percent EV market share by 2030. The European Union announced a zero-emissions target for new cars by 2035.

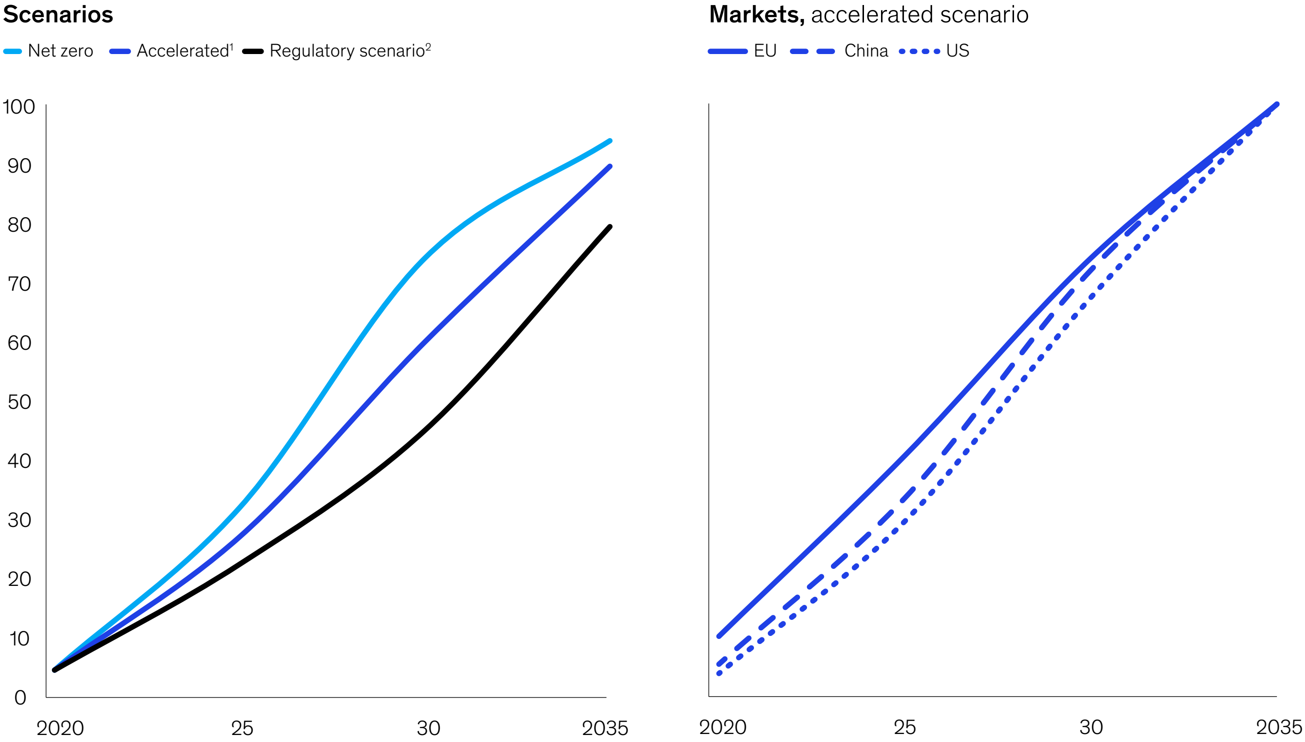
China will also continue to see strong growth in electrification and remain the largest EV market in absolute terms. Uptake results from strong consumer pull, despite low EV subsidies and no official end date for ICE sales. However, the government's dual-credit policy has led to an increased EV share in OEMs' portfolios. Our adoption modeling yields a Chinese EV share above 70 percent for new car sales in 2030 in the accelerated scenario.

In the United States, the Biden administration announced a 50 percent electrification target for 2030, strong investments in charging infrastructure, and more stringent fleet emissions targets. EV uptake will result mainly from regulatory support in California and other states that follow its CARB ZEV regulation. US OEMs support electrification targets and have declared ICE bans by 2035, meaning the United States will follow Europe and China in EV uptake with a small delay; it is expected to exceed current regulatory targets and reach 65 percent EV sales by 2030 in the accelerated scenario.

1 Battery electric vehicles, plug-in hybrid electric vehicles, and fuel cell electric vehicles.

By 2035, the largest automotive markets (the EU, US, and China) will be fully electric

EV (BEV, FCEV, PHEV) sales in percent of new passenger vehicle sales



1. Most likely scenario under which consumer adoption will exceed regulatory targets
2. Scenario under which currently expected regulatory targets will be met

Source: McKinsey Center for Future Mobility; McKinsey Electrification Model; literature search; ICCT; EV-volumes.com; IHS Markit

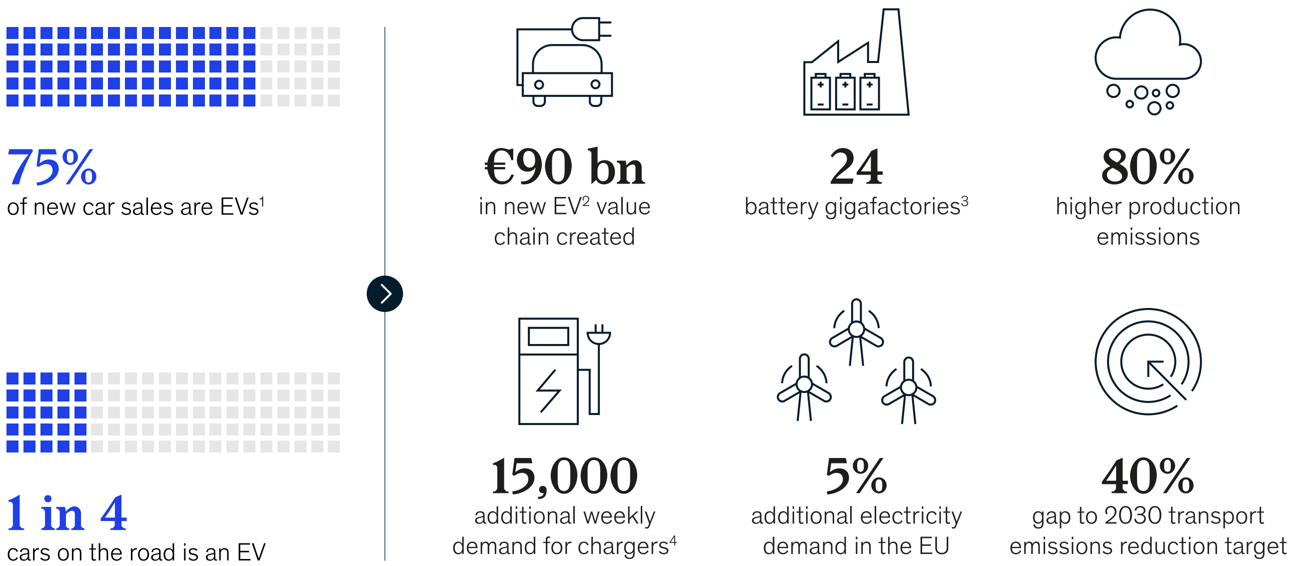
3. The e-mobility transformation will disrupt more than the automotive industry

In the European Union, achieving the accelerated scenario of around 75 percent EV sales by 2030 will have implications for the entire EV value chain and ecosystem. In parallel, the industry must decarbonize the full lifecycle of vehicles to get closer to a net-zero target.

Incumbent automotive suppliers need to shift production from ICE to EV components. Europe will have to build an estimated 24 new battery giga-factories to supply local passenger EV battery demand. With more than 70 million EVs on the road by 2030, the industry will need to install large numbers of public chargers and provide maintenance operations for them. Renewable electricity production needs to increase by 5 percent to meet EV charging demand. Finally, emissions from BEV production must decline, since BEVs currently have 80 percent higher emissions in production than ICE vehicles.

The e-mobility transformation will disrupt more than the automotive industry

Passenger vehicles, EU+GB+CH+NO, 2030, accelerated scenario



1. EVs include BEVs, PHEVs, FCEVs
2. Includes electric drive, battery packs, power electronics, and thermal management
3. Assumes an average gigafactory with annual capacity of 25 GWh
4. Assumes an ideal EV–charger ratio of 10:1 and refers to public chargers, including chargers in multifamily homes

Source: McKinsey Center for Future Mobility; EU Regulation 2019/631 amendments; McKinsey Battery Demand Model

3.1. Electrification will cause a major shift in the entire automotive supply chain

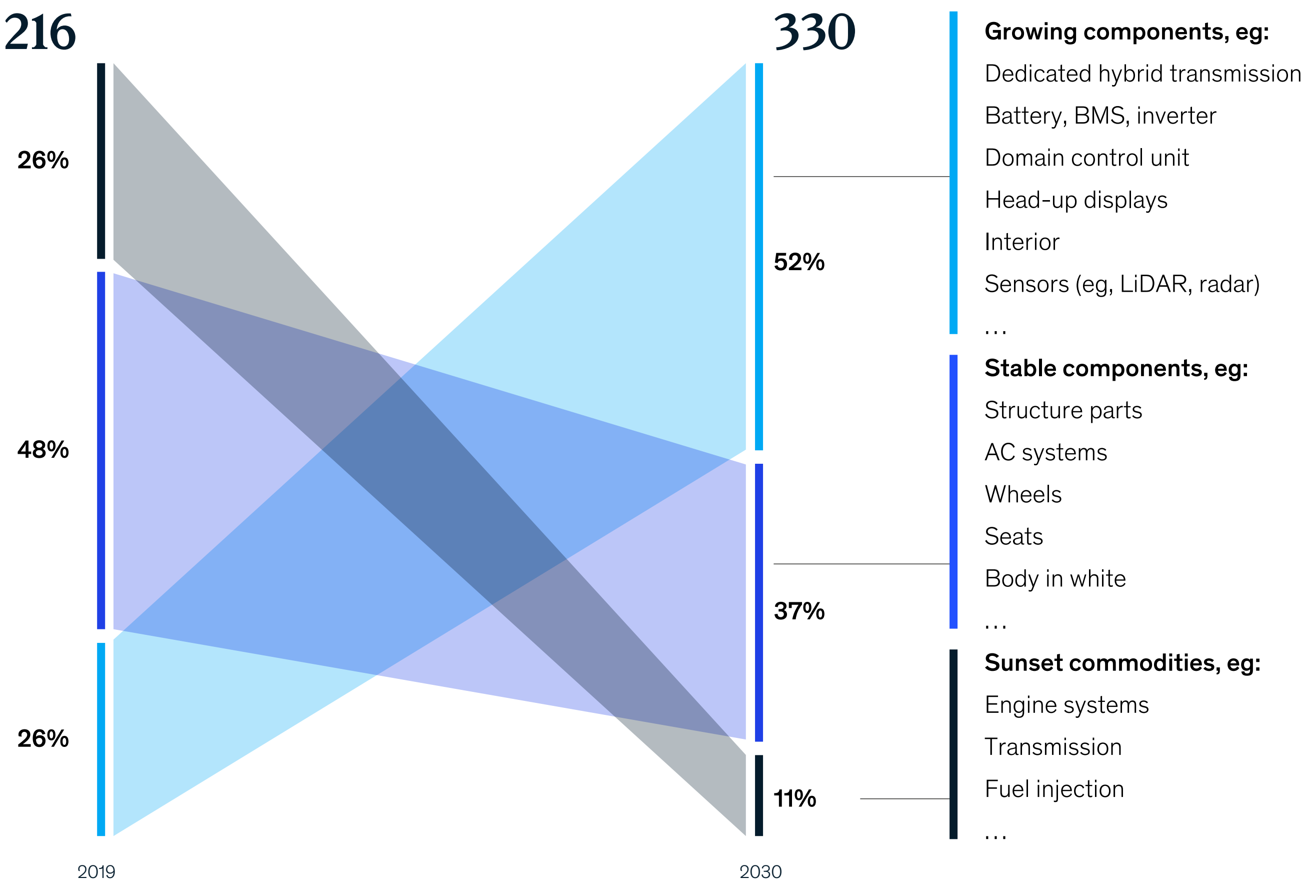
The transformation of the automotive industry toward electrification will disrupt the entire supply chain and create a significant shift in market size for automotive components. Critical components for electrification such as batteries and electric drives and for autonomous driving like light detection and ranging (LiDAR) sensors and radar sensors will likely make up about 52 percent of the total market size by 2030. Components only used in ICE vehicles such as conventional transmissions, engines, and fuel injection systems would see a significant decline to around 11 percent by 2030 – about half the size of 2019 levels. Such a drastic shift will force traditional component players to adapt quickly to offset decreasing revenue streams.

The scale of disruption will be significant: according to the Institute for Economic Research (Ifo) in Munich, more than 100,000 jobs will change in the German automotive industry by 2030. That is roughly five to ten times the scale of jobs compared with the phaseout of coal power that Germany announced for 2038.

Electrification will cause a major shift in the entire supply chain

Accelerated scenario, European market

Market size development
€ billions



Source: McKinsey Center for Future Mobility

3.2. Announced EU battery production will likely stay just ahead of demand

Based on announced buildup plans, we expect a 20-fold increase in battery production capacity in Europe to 965 GWh by 2030. Assuming the full capacity is built by 2030, Europe should meet expected demand of 874 GWh. BEV passenger cars and commercial vehicles will drive 90 percent of this battery demand. While on paper announced capacities seem to follow and match demand, in reality temporary implementation risks will likely occur given giga-factory production issues, typically slow yield ramp-ups, fragmentation of the supply chain, and large inflexible OEM contracts. Thus, in an accelerated EV adoption case, battery demand would come very close to exceeding announced supply in the medium term. In the next ten years, we expect the mining industry to slow down and other geopolitical and supply chain crises to pop up periodically, leading to some short-term price spikes in commodities like nickel and lithium.

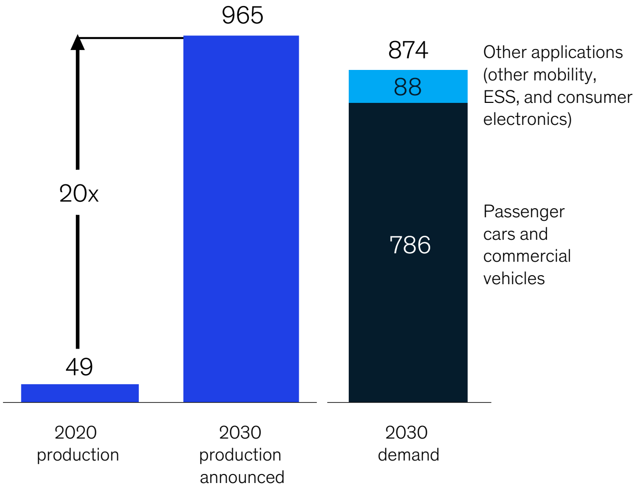
Battery cell production is moving physically closer to vehicle assembly plants. While ten years ago almost all cells were imported from Asia, regional production hubs exist today in Eastern Europe, for example. Furthermore, multiple plants will go onstream in key vehicle-producing countries like Germany, the United Kingdom, and France and in low-carbon-emitting environments such as Norway and Sweden.

In addition to incumbent battery cell players from Asia setting up locations in Europe, some entirely new companies are entering the space. One key development in battery sourcing involves the backward integration of OEMs from packs and modules up to cell production – mostly in the form of joint ventures with cell manufacturers. OEM backward integration plans result from their growing battery cell demand, the desire for control and certainty of supply, and the ambition to keep a significant part of vehicle value creation inhouse. OEMs are also seeking areas for differentiation, with battery technology, durability, and performance seen as key evaluation criteria for BEVs.

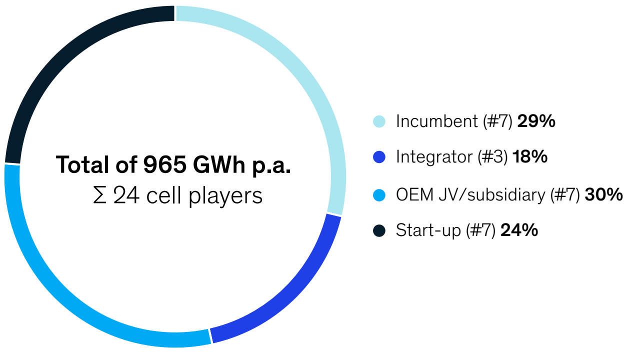
Production of raw materials and battery components follow the localization trend of battery cell plants. However, there is a time lag and only some of the raw materials needed, which include nickel, cobalt, lithium, and graphite, are available for local sourcing in Europe. Companies must therefore compete globally to secure required volumes and do it sustainably in line with environmental, social and governance (ESG) criteria. While all four commodities must ramp up quickly, with potential price variation in the future, nickel will likely be the commodity under the most pressure in the short to medium term.

EU battery cell production sufficient to meet demand

Battery cell demand and announced supply
GWh, accelerated scenario for demand



Battery cell players by archetype in Europe in 2030
Number of players, percent market share of total production capacity



Source: McKinsey Center for Future Mobility; McKinsey Battery Supply Tracker (August 2021)

3.3. Acceleration in charging infrastructure buildup needed

In line with EV uptake, the buildup of charging infrastructure needs to accelerate to avoid becoming a potential bottleneck and limiting consumer-driven EV adoption. Building charging infrastructure in sync with the EV fleet will be essential in the coming decade.

While first-generation EV buyers relied mainly on private charging (in 2020, 80 percent of EV buyers in Europe had access to private charging), the next generation will depend on public charging. More than 50 percent of Europeans will be living in multifamily homes without private charger access, and public chargers will ensure practicality of EVs for long-distance trips, which prospective EV buyers still consider a main concern.

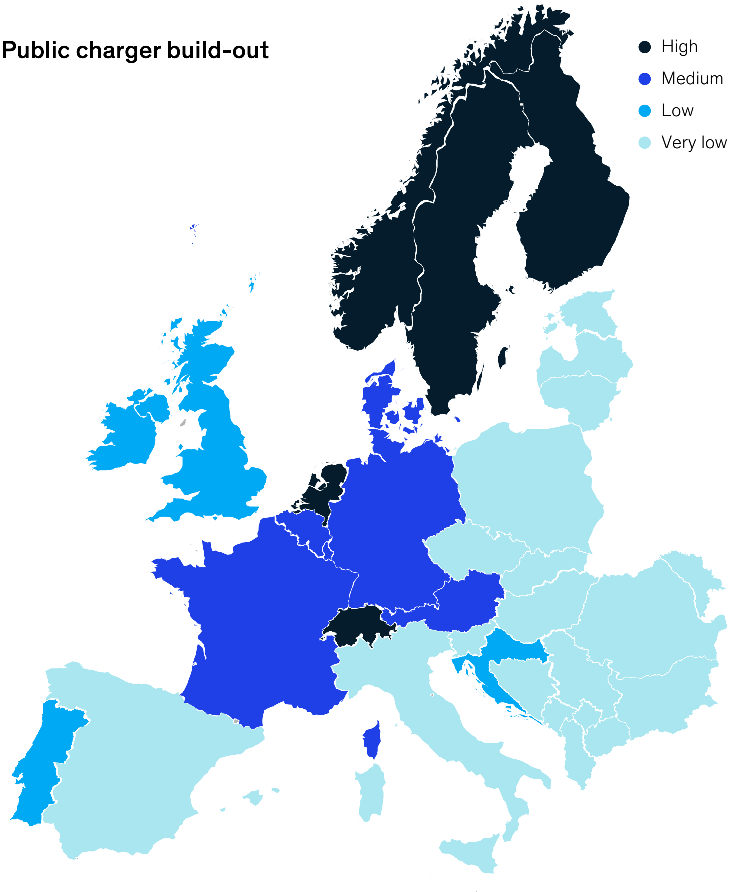
Likewise, regulatory processes to install chargers in private homes require simplification and production capacity for wall boxes must increase. Production scale-up and simplified regulation (in terms of shortened permit and building times) are also necessary for public chargers, in addition to the creation of demand-based coverage.

We estimate the industry needs to install more than 15,000 chargers per week by 2030 within the European Union. Simplified regulations are needed to facilitate charger siting, since it can currently take up to three years to obtain approval for grid extensions for a fast-charging station. Ensuring the EU-wide coverage of public charging is essential to avoid having chargers located only in profitable locations.

EVs are poised to command on average more than 5 percent of electricity demand in 2030 in Europe. It will be important to reduce charging during peak load periods through “managed charging” by controlling charging time, duration, and intensity with vehicle-to-grid (V2G) technology as an enabler. In a scenario with appropriately managed charging devices in place as well as incentives to charge during nonpeak hours, much of the customer impact on the electric grid will be mitigated.

The EV charging infrastructure buildup faces operational, regulatory, and financial hurdles

Public charger build-out



Fast rollout

+15,000

chargers to be installed per week[1]

Buildup in rural areas

+30%

of population living in rural areas

High capex

+90%

investment for less than 25% of charge points (fast charger)

Public charging coverage

+50%

of Europeans living in multifamily homes

1. Semi-private (multifamilyl homes) and public chargers covered

Source: McKinsey Center for Future Mobility

3.4. Reaching net zero also means decarbonizing EV production

There is a clear path to reducing CO_2 equivalent (CO_2e) emissions from passenger cars in operation. A recent International Council on Clean Transportation (ICCT) analysis stated that the shift from ICE to BEV would reduce total lifecycle CO_2e emissions by around 65 percent based on the current average energy mix in Europe and by 83 percent with entirely green electricity.

As the electricity supply evolves and charging with green energy for a larger fleet of EVs becomes feasible, materials and production will become the dominant sources of emissions in an EV's lifecycle. Today an EV's production generates an almost 80 percent higher emissions intensity compared with an ICE car, due mainly to the battery and the vehicle's higher share of aluminum.

When aiming to reduce material emissions, two main issues matter:

Increasing recycled content. Replacing virgin/primary materials with recycled alternatives will save a large share of emissions associated with the initial generation of raw materials. Replacing 30 percent of primary material with recycled material can save 15 to 25 percent [2] of production emissions. Recycled material use, however, comes with multiple challenges, including the reality that end-of-life (EOL) collection remains very immature, making it difficult to achieve an automotive-grade materials stream. Furthermore, multiple industries are interested in using recycled material to achieve their decarbonization targets, which will result in supply bottlenecks and the higher prices of several recycled materials.

Shifting to green raw materials. Using primary materials produced in a low/no-carbon process enables high-grade materials with low emissions footprints. Examples of this approach include inert anode aluminum smelting via hydroelectricity or steel produced through hydrogen-based direct reduced iron in an electric arc furnace (H2 DRI-EAF steel). Around 80 to 90 percent of today's typical material emissions can be eliminated with 2030 technologies. The main approaches involve decarbonizing the raw material refining processes by using renewable electricity, for example, and decarbonizing the forming as well as other high-energy manufacturing processes, also via electrification.

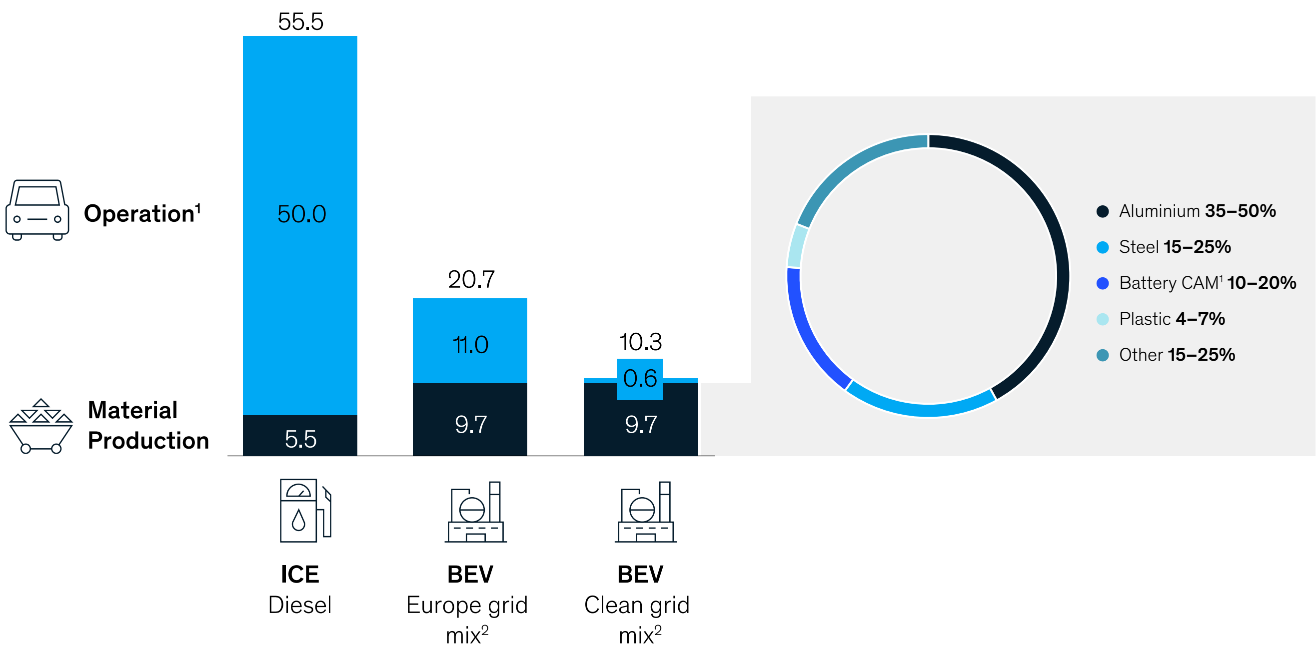
While a switch in electricity resources is simple, the shift from today's processes to manufacturing routes that avoid CO_2e emissions altogether—rather than capturing or gradually reducing them—will require significant investments in plants and equipment. A predictable demand for green materials and long-term commitments between suppliers and buyers would help overcome this obstacle in the next decade.

A determined approach to decarbonizing and combining these methods could produce vehicles with 10 to 30 percent of today's production emissions by 2030—a challenging feat but necessary to fulfill the Green Deal aspiration. Nevertheless, decarbonizing the supply chain and achieving Scope 3 emissions reductions may cause vehicle costs to rise at a time when OEMs are trying to lower prices to boost consumer interest and achieve sustainable long-term margins.

2 The abatement rate depends on the level of required treatment of end-of-life (EOL) materials for reuse and the type of material.

Material emissions will dominate vehicle lifecycle emissions when clean energy is used for charging and are the next frontier for automotive emissions reduction

t CO_{2e} emissions over lifecycle mileage of a lower medium segment passenger car



1. Use phase emissions including fuel/electricity production, fuel consumption (real-world values) and maintenance; based on a lifecycle mileage of 243,000 km with 18 years vehicle lifetime for a lower medium segment passenger car
2. Life-cycle GHG emissions of the vehicle's lifetime average electricity mix for a 2021 car based on IEA's Stated Policy Scenario and Sustainable Development Scenario as well as renewable electricity mix of solar and wind energy

Source: McKinsey Center for Future Mobility, ICCT (a global comparison of the lifecycle GHG emissions of combustion engines and electric passenger cars, July 2021)

3.5 A 55 percent transport emissions reduction target by 2030 versus 1990 requires more drastic measures

Current regulation and targets are not sufficient if the road transport sector wants to fully contribute to the 55 percent CO_2e emissions reduction target by 2030 versus 1990 as required by the Fit for 55 program.

However, passenger cars have one advantage over other industries from a decarbonization point: The zero-emissions option (e.g., the BEV) is cheaper than the current alternative (ICE) from a total cost of ownership perspective in some countries today and by 2025 at the latest in countries without incentives. This is not the case in most other industries, where decarbonizing results in higher costs for both producers and consumers.

However, with the average car age at ten years in Europe, it will take time for EV sales to have an impact at the parc level. The current regulation on sales is therefore not sufficient to meet the goal of a 55 percent emissions reduction from 1990 levels by 2030.

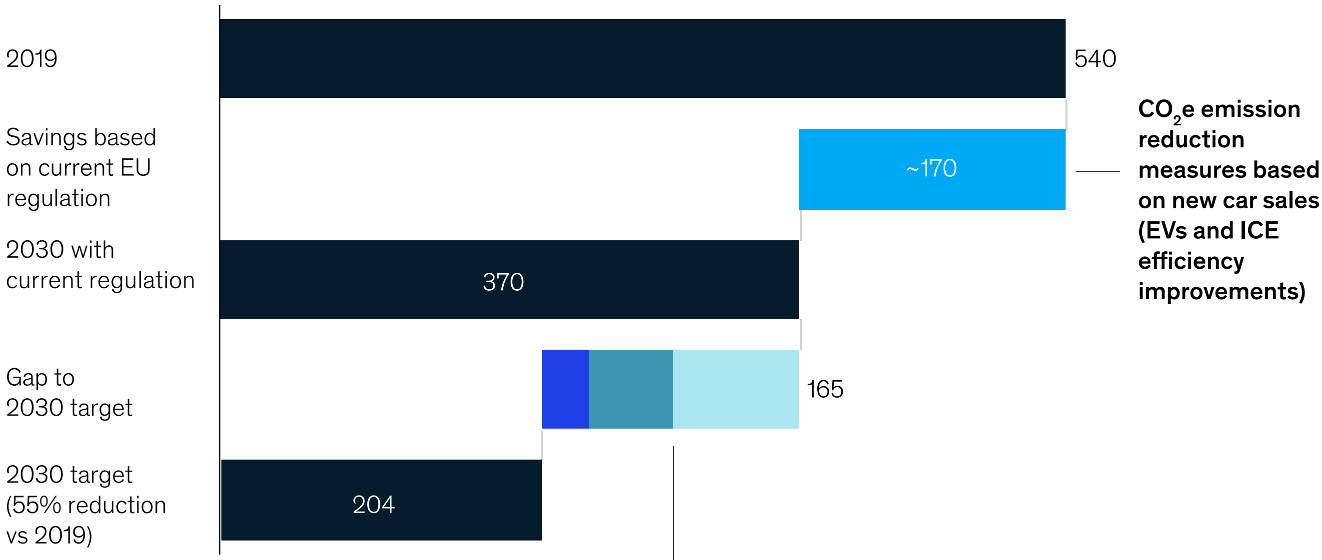
Closing this gap will require further measures targeting CO_2e emissions of the vehicle parc. ICE vehicle kilometers traveled could be decreased by reducing private car kilometers, increasing shared mobility, and changing consumer perspectives on walking/biking.

At the same time, the most efficient lever is to accelerate the ICE parc turnover and remove highly polluting ICE vehicles from the fleet with, for example, “cash-for-clunkers” programs for old ICE cars.

Another way to reduce CO_2e emissions from ICE vehicles is to increase the share of bio- and e-fuels as these have a low carbon footprint and are compatible with the existing ICE parc. However, the majority of bio- and e-fuels supply will be required to decarbonize marine/aviation and commercial road transport, for which only limited zero-emissions alternatives exist today.

Reaching 55% transport emissions reduction by 2030 vs 1990 requires more alternative measures

Annual emissions of passenger vehicle parc in EU[1],
Million tons CO_2e



CO_2e emission reduction measures affecting vehicle parc

Use bio- and syn fuels
Reduce total emissions by 5% if average blend rate increases from 6–11%

Reduce ICE vehicle kilometers traveled
Reduce total emissions by 10% by shifting 10% of private car kilometers to shared and public modes

Accelerate ICE parc turnover
Reduce total emissions by 15% by limiting car age to 15 years starting in 2025

1. Values rounded

Source: McKinsey Center for Future Mobility

Conclusion

Electric vehicles are coming, and we are on the right track regarding decarbonizing the transport sector, though more actions need to be taken. It is an industry transformation taking place at unprecedented speed. It is also crossing industry borders, involving energy, infrastructure, mobility, and automotive players. While a major challenge, it represents a huge opportunity for incumbents and new players to take a leading role in creating new multi-billion industries and jobs. The key will be to couple sustainability with economic viability through innovative technology and properly guided mobility transformation. Based on its diverse mobility landscape, its focus on sustainability and its proven technology leadership, Europe could emerge as a role model for other regions globally.

Our capabilities

The McKinsey Center for Future Mobility (MCFM) aims to help all stakeholders in the mobility ecosystem navigate the future by providing independent and integrated evidence about possible future mobility scenarios. Our view of trends are grounded in advanced multi-level driver based models that have been validated across industries and players. Each model is based on proprietary data and contributes to an integrated perspective on future mobility trends and scenarios including modal mix, miles traveled, vehicle sales, autonomy, powertrain electrification, battery demand, charging infrastructure, components, consumer behavior, and value/profit pools etc.

This charticle leveraged insights from multiple MCFM models and the broad MCFM Solution team. Please get in touch if you would like to learn more.

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