Report

Roland Berger

MUNICH / GERMANY

E-Mobility Index 2021

ROLAND BERGER – ADVANCED TECHNOLOGY CENTER
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MANAGEMENT SUMMARY

The E-Mobility Index, now in its tenth year, provides a regular overview of the global automotive industry. Produced by Roland Berger in cooperation with fka GmbH Aachen, the report focuses on the seven leading automotive nations: Germany, France, Italy, the United States, Japan, China and South Korea. We assess their performance with regard to electric vehicles along three key parameters: technology, industry and market. In this latest edition of the Index, we also investigate the impact of COVID-19 on the electric mobility industry and look at possible future developments in CO_2 compliance and European emission standards.

The key takeaways from the E-Mobility Index 2021 are striking:

- **Overall, China retains its competitive lead for the second year in a row. The United States, last year in number two position, drops to fourth place, with Germany now in second place and France in third**
- **While COVID-19 has had a negative impact on vehicle markets around the world, sales of electric vehicles (xEVs) have grown strongly, especially in Europe**
- **Increased sales volumes in Europe are to a large extent due to the purchase incentives contained in stimulus packages**
- **Thanks to increased penetration rates for xEVs, vehicle manufacturers (OEMs) now have a realistic chance of meeting the European emission targets for 2021**
- **However, the EU Commission is considering tightening emission limits for new vehicles by 2030**
- **Automotive OEMs and suppliers must prepare themselves for additional regulation in the area of real consumption data and emissions across the entire vehicle lifecycle**

FAST FACTS & CONTENTS

SCAN ME

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1/ COMPETITIVE POSITION OF LEADING AUTOMOTIVE NATIONS — 4

1.1 Technology
1.2 Industry
1.3 Market

2/ COVID-19 AND THE EUROPEAN XEV INDUSTRY — 11

3/ CO_2 COMPLIANCE AND EUROPEAN EMISSION STANDARDS — 14

3.1 Possible future developments
3.2 Implications for OEMs and suppliers

CONCLUSION — 16

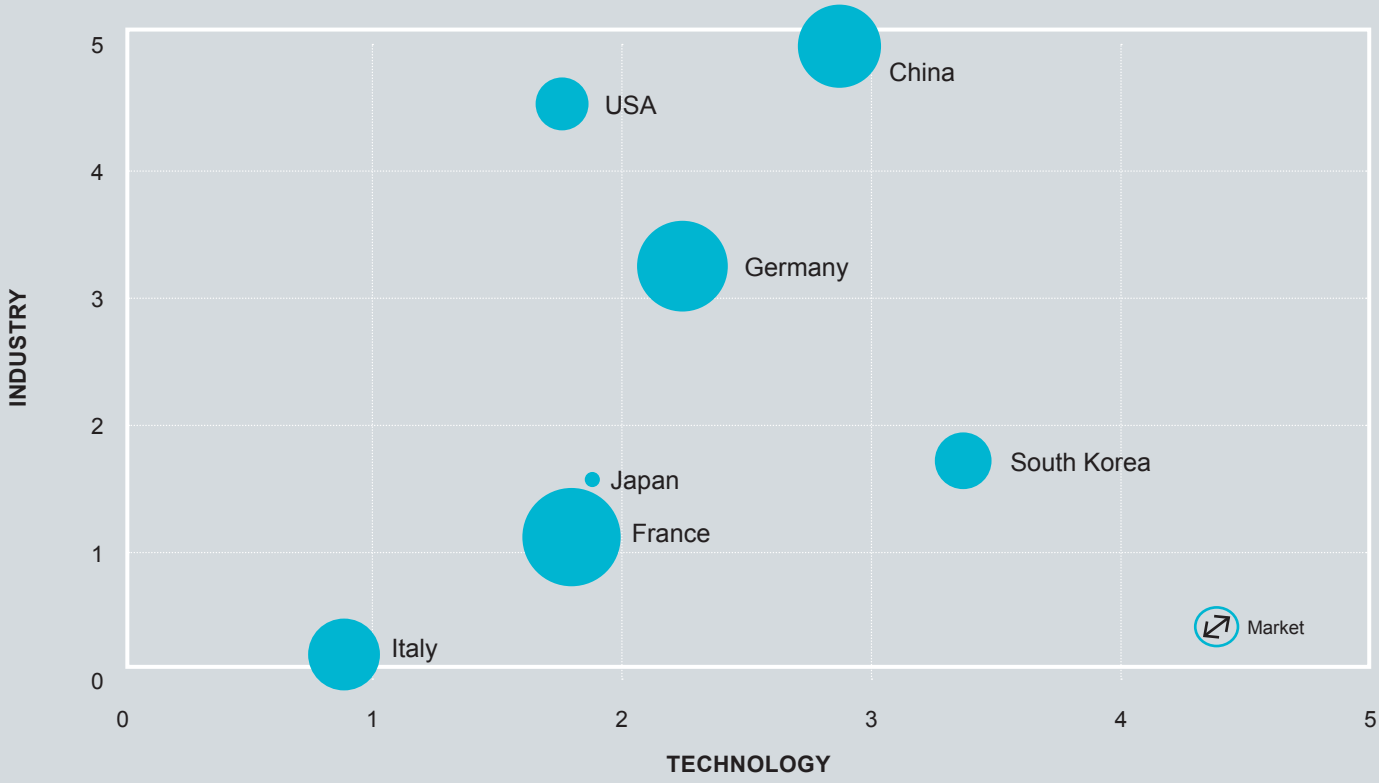
METHODOLOGY — 17

1 / Competitive position of leading automotive nations

As in previous editions of our E-Mobility Index, we begin by comparing the competitive position of the world's seven leading automotive nations: Germany, France, Italy, the United States, Japan, China and South Korea. For the second period in a row, China is in the lead position overall. The United States drops from second place to fourth due to its weak market figures compared to other nations. In its place, Germany moves up to the number two position, ahead of France, both nations having seen strong improvements in their market indicators. → A → B

A / Overall competitive position of leading automotive nations

China retains the exclusive lead. Germany and France in 2nd and 3rd now ahead of USA. Korea ranks 5th ahead of Italy



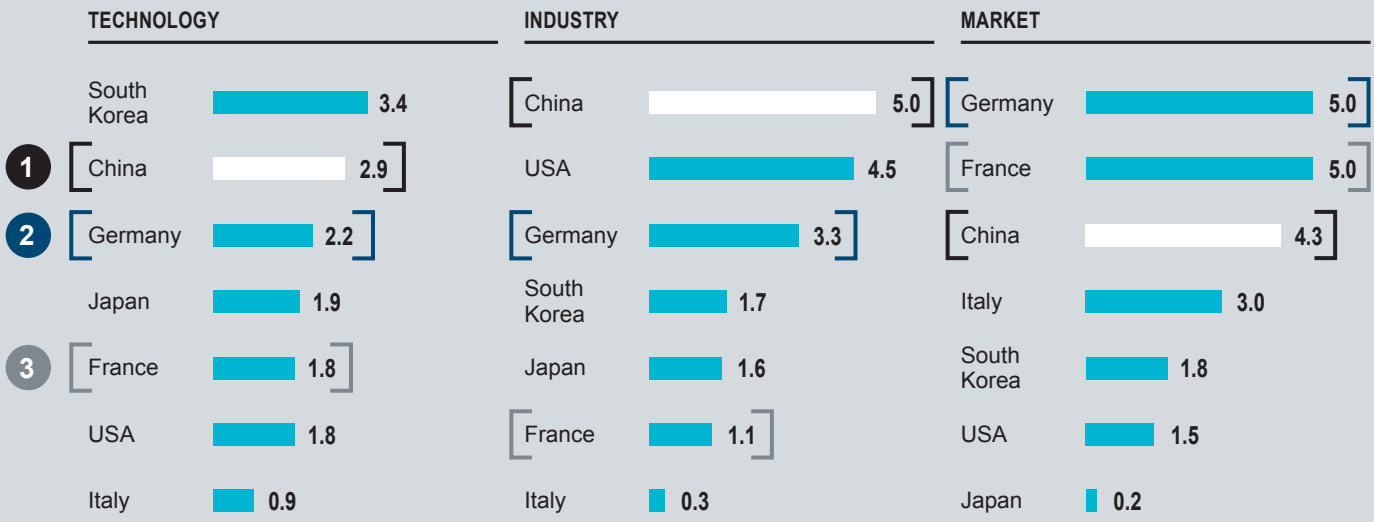
Note: Circle size shows share of BEV/PHEV in total vehicle market

Source: fka, Roland Berger

While positive developments occur everywhere across the market and industry indicators, the indicator for technology shows greater variation due to changes in the ratio of all-electric vehicles (BEVs) to plug-in hybrids (PHEVs). The cost/performance ratio of the vehicles on offer also causes changes in this indicator. → C

B / Country rankings by indicator

China first overall due to strong industry, second in technology but loses market lead to Germany. Korea is new technology leader[1]; Japan slips on industry and market, placing last overall



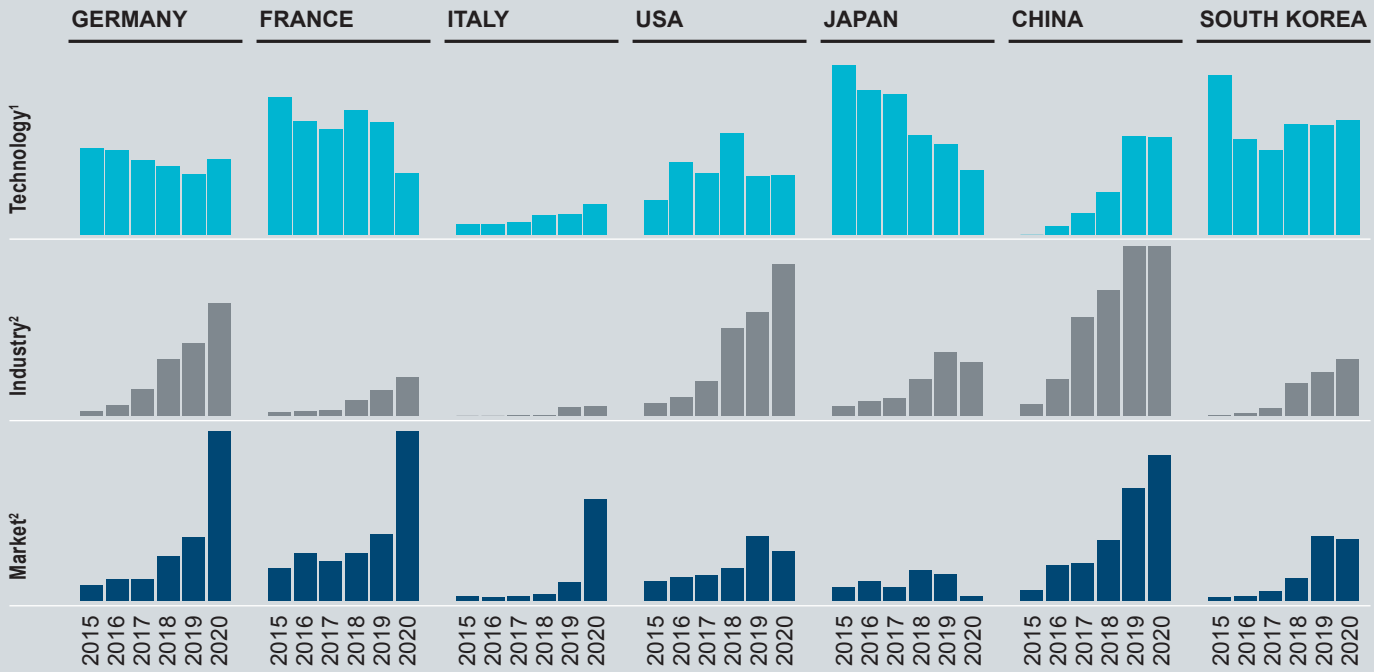
1 In the E-Mobility Index 2021, the technology indicator is based solely on vehicle performance and no longer takes into account R&D volumes

[ ] Overall ranking

Source: fka, Roland Berger

C / Changes in competitive positions of leading automotive nations by indicator

China, Germany and France slip down the technology rankings, USA overtakes Germany on industry, while Germany and France jostle for pole position in the market indicator



1 In the E-Mobility Index 2021, the technology indicator is based solely on vehicle performance and no longer takes into account R&D volumes; historical indicators have been recalculated accordingly

2 In the E-Mobility Index 2021, measurement thresholds for market and industry were once again adjusted to reflect increasing market penetration of BEVs and PHEVs and production volume of battery cells and vehicles; historical indicators have been recalculated accordingly

Source: fka, Roland Berger

1.1 / Technology

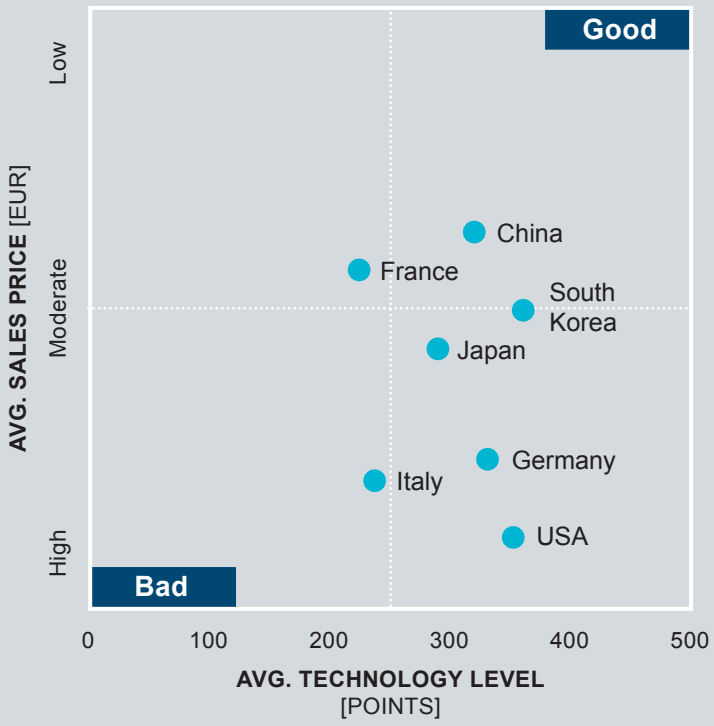
Government support for research and development (R&D) in the field of e-mobility is losing importance in all of the markets analyzed. State subsidies are now strongly focused on sales of xEVs and building infrastructure. In the E-Mobility Index 2021, we therefore base the technology indicator solely on an evaluation of vehicle performance.

In a change on the previous period, **South Korea takes over the lead** from Germany in terms of technology. South Korean automotive OEMs continue to improve the technology that they use in existing models, rather than introducing new models. The average performance of South Korean vehicles has improved, with vehicle prices edging up correspondingly. However, the country has also introduced some new PHEVs in the SUV segment. Owing to the greater weight of such vehicles, average efficiency (measured as the range/battery capacity ratio) has decreased slightly. Nevertheless, South Korean OEMs still offer a very good price-performance ratio in their vehicles. → D

China continues to improve the level of its technology, remaining in second place in terms of this indicator. Chinese manufacturers are constantly enhancing the range, efficiency and safety of their xEVs. Vehicle prices are also increasing, but they remain the lowest of any of the countries examined.

D / Value for money of market-ready BEVs and PHEVs

USA and Korea lead on technology; focus on high-priced models reduces value for money in Germany and USA



Source: fka, Roland Berger

South Korea
- Slight increase in technology level, continued good cost effectiveness with focus on compact cars/SUVs
- Balanced BEV/PHEV offering

USA
- US models show slight improvement in performance and cost effectiveness
- Still a strong focus on SUVs and high-priced vehicles

Germany
- Increasing dominance of compact BEVs, but continuing strong trend towards electrification (PHEVs) in executive and mid-range segments

China
- Increased technology level (efficiency, charging)
- Vehicle prices rising, but still the lowest level of all countries examined

France
- Ongoing shift from small BEV-focused portfolio to expansion of PHEV offering leads to a reduction in technology level; average sales price constant

Japan
- Further expansion of PHEV offering, especially in SUV segment, results in reduced dominance of compact BEVs and an increase in average sales price

Italy
- Italy is widening its vehicle portfolio with PHEVs
- Still only one BEV model

Compared to the previous period, Germany has improved its rating for vehicle technology. This is due to increased efficiency and charging power. However, owing to the fact that we no longer consider R&D when calculating the technology indicator, Germany moves into third place for this indicator. German OEMs continue to focus on fully electric (BEV) compact vehicles, with an increasing number of models available and growing production volumes. This extension of the vehicle portfolio to include compact BEVs leads to improved value for money in the vehicle pool considered in our study. We also note an ongoing trend towards electrification in the executive and SUV segments, especially in the form of PHEVs.

Japan ranks fourth in terms of technology. Japanese manufacturers are currently launching very few new electric vehicles on the market, and those that they do launch are mostly PHEVs, leading to a lower score on efficiency and charging technology in this year's E-Mobility Index.

France was in fourth place last time but has not been able to maintain this position. For years, the country has had a rather limited vehicle pool, focused mainly on small, cost-efficient BEVs. It is also constantly expanding its range of PHEVs, which generally have a smaller electric range and lower electrical top speed. Given their lower battery capacity, most of these vehicles are only equipped with basic charging technology. As a result, France achieves a lower average technological performance for the vehicles we consider in this study.

The xEVs produced in the United States lead the way with regard to driving performance and electric range. They also display good charging power. However, American OEMs are increasingly offering electrified SUVs, which pushes down the average range/battery capacity ratio of the vehicles under evaluation. This negative impact outweighs the positive impact of US mid-size BEVs, which currently lead production volumes. US vehicles, like their German counterparts, are in the high-priced segment, yet an improvement of cost effectiveness has taken place as the model portfolio expanded over the latest period. Italian OEMs, for their part, are beginning to mass produce PHEVs, and their xEVs will also soon be available in the rest of Europe.

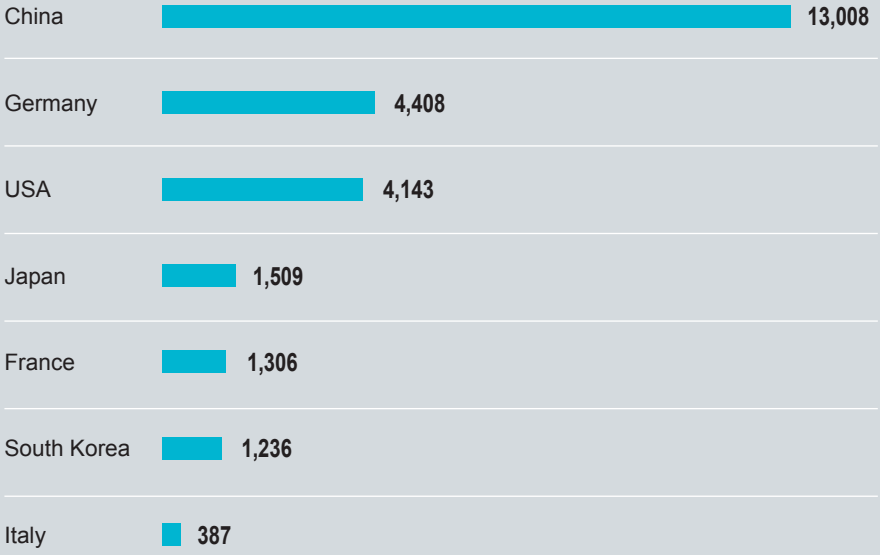
1.2 / Industry

China leads the way in terms of industry, producing the largest number of xEVs and battery cells. Total production of BEVs and PHEVs in the period 2018-23 is up 13 percent on the previous period. Cumulative domestic battery cell production capacity created in the period 2018-23 is expected to account for more than 70 percent of installed capacity worldwide, and China is increasing its leadership even further by expanding local production capacities. German OEMs are likewise achieving strong growth in vehicle production, and now account for the second-largest volume of vehicle production. However, Germany's production capacity for battery cells is small, putting it in third place behind the United States on the industry indicator. → E → F

E / Projected cumulative EV/PHEV production, 2018-23

China retains a clear lead in EV/PHEV production. Reduced growth in USA, Germany takes second place

PROJECTED EV/PHEV PRODUCTION ['000 VEHICLES]



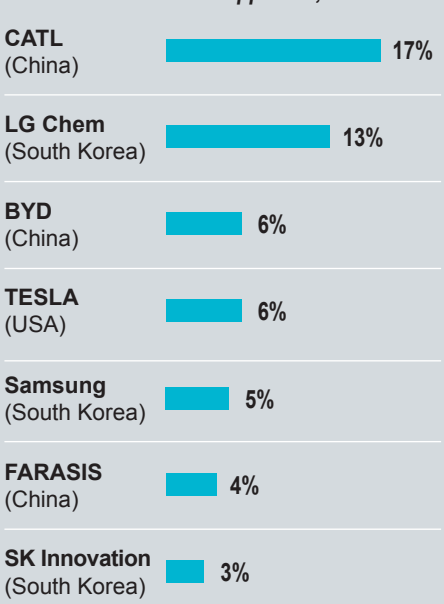
TOP 3 MODELS PER COUNTRY
BAIC EU5; Guangzhou Auto Aion S; Changan Eado EV
Volkswagen ID 3; Volkswagen ID 4; BMW 5 Series
Tesla Model 3; Tesla Model Y; Ford Mustang MachE
Nissan Leaf; Mitsubishi Outlander PHEV; Toyota Prius PHEV
Renault Zoe; Peugeot 208; Renault K Z.E.
Hyundai Kona; Hyundai Ioniq; Kia Niro
Fiat 500e; Jeep Compass; Jeep Renegade

Source: fka, Roland Berger

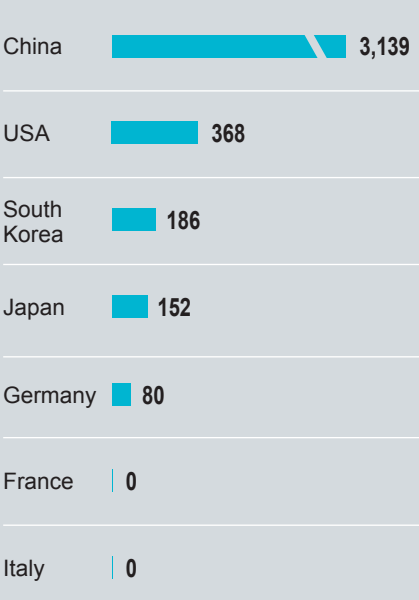
F / Projected global market share and domestic cell production capacities, 2023

China establishes itself as the frontrunner in battery production. USA leaves former leaders Japan and Korea behind.

PROJECTED GLOBAL MARKET SHARE, 2023



CUMULATIVE DOMESTIC CELL PRODUCTION CAPACITY, 2018-23 [GWH]



China	• China is increasing its lead even further through strong growth of local production • CATL is the world's leading producer
USA	• US production continues to grow strongly • Tesla has a significant lead in the US, followed by LG Chem
South Korea	• Slight growth in local production • LG Chem leads Samsung by some distance, ahead of SK Innovation
Japan	• Japan is losing touch, production stagnating • Panasonic overtaken by LG Chem and CATL as world's leading producer
Germany	• Production volumes set to rise when CATL and Farasis start production
France	• No significant cell production
Italy	• No significant cell production

Source: fka, Roland Berger

Japan was previously in second place but now cedes this position to the **United States,** which although **experiencing reduced growth in vehicle production,** is at the same time seeing continued expansion of its domestic cell production capacities. Japanese production of xEVs is also declining and its supplier footprint shrinking, pushing it down into fifth place. South Korea remains in fourth place, its expected vehicle and cell production capacities increasing moderately compared to the previous period. France is still in second-to-last place, despite strong growth in vehicle production, which almost reaches the volumes of Japanese OEMs; the reason for its low ranking is its lack of cell production. Bringing up the rear once again is Italy, which lacks cell production capacity. The country is also only slowly extending its small model range.

1.3 / Market

Automotive markets around the world have been negatively impacted by COVID-19. Sales of xEVs, however, showed a mixed picture in 2020. Thus, Japan slumped and China and the United States showed moderate growth, while Germany, France, Italy and South Korea prospered during the period.

China was in pole position on the market indicator for several years, with the highest sales volume and highest share of xEVs in the total market of all the countries examined. It drops to third place in the period. In 2020 growth slowed, with sales of xEVs rising only slightly, from 1.2 million vehicles in 2019 to 1.3 million. However, our market indicator only takes into account the share of xEVs in the total market. This was more than four percent in China in 2019, and climbed to almost 5.7 percent in 2020 – the third-highest share of the seven countries examined.

Japan has seen massive losses and now comes bottom of the rankings. Total sales of xEVs shrank by 28 percent and the market share of xEVs fell by 20 percent, to just 0.7 percent of the total market. The United States was the second-largest market for xEVs in the period, absolute sales increasing moderately by four percent and market share growing by 22 percent. Nevertheless, in terms of the market indicator, the United States falls from fourth position in 2019 to last but one in 2020.

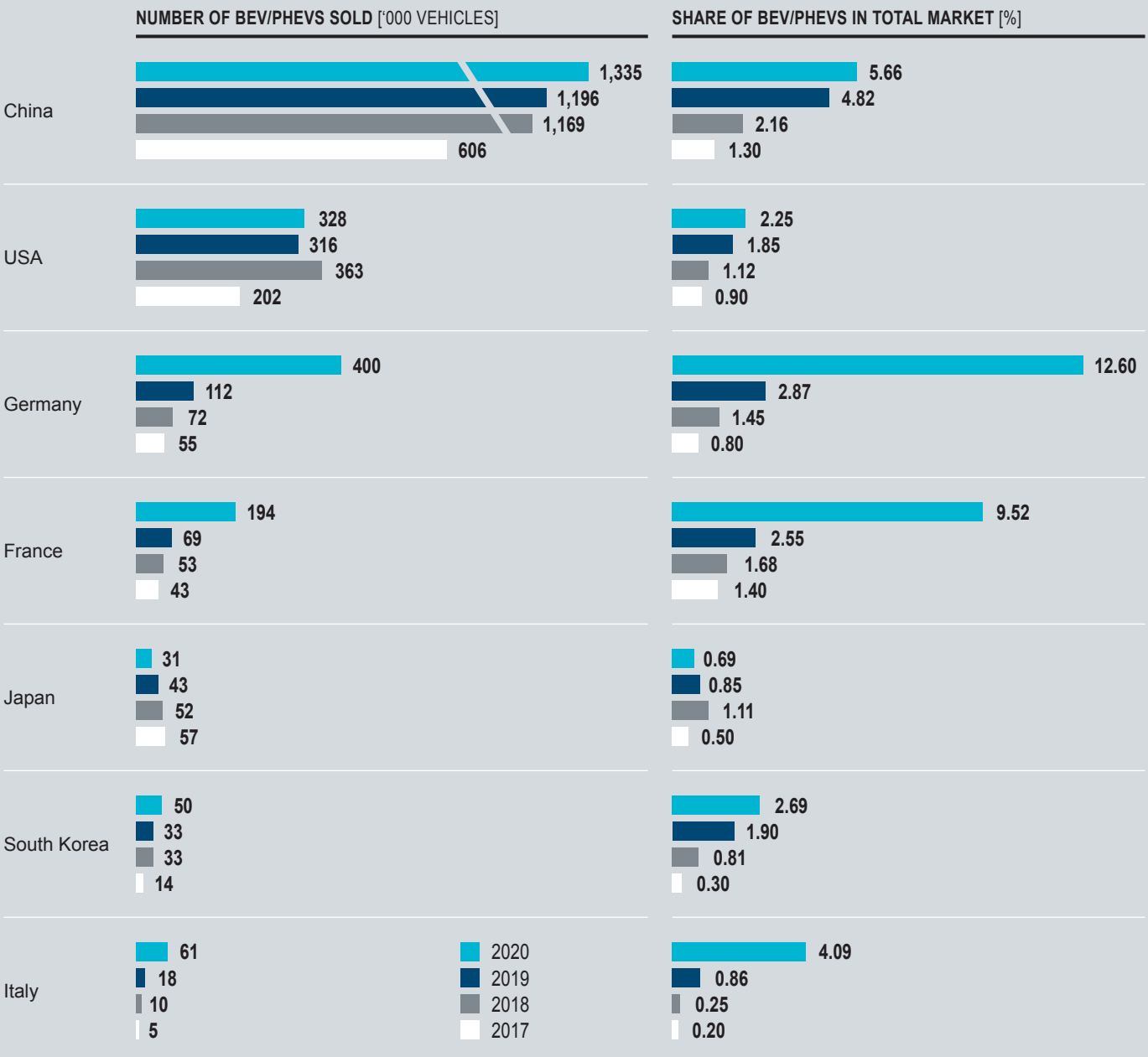
Europe has enjoyed strong market growth, led by Germany and Italy. Both markets saw sales growth of more than 200 percent. In Germany, now top of the market indicator rankings, sales of xEVs rocketed from 112,000 to more than 400,000 vehicles, making Germany now the second-biggest market for xEVs. This was accompanied by a drop in total automotive sales, giving xEVs a market share of more than 12.6 percent.

Next in the ranking comes France. The country remains in second place thanks to a strong increase in the market share of xEVs, from 2.5 percent in 2019 to 9.5 percent today. Italy also saw sales of xEVs grow by 160 percent, resulting in a market share of 4.1 percent compared to just 0.9 percent in 2019. Italy thus demonstrates the best progress in terms of xEV market share, up 376 percent;

it now ranks fourth in terms of market. South Korea comes in fifth place, having shown some growth; the value of its market indicator is lower than in the previous E-Mobility Index due to changes to the threshold value. → G

G / Volume of new BEV/PHEVs sold, 2017-20

Drop in vehicle sales enhances xEV share in all markets. High growth in Germany, France and Italy, Germany now frontrunner in BEV/PHEV share of total market



Source: fka, Roland Berger

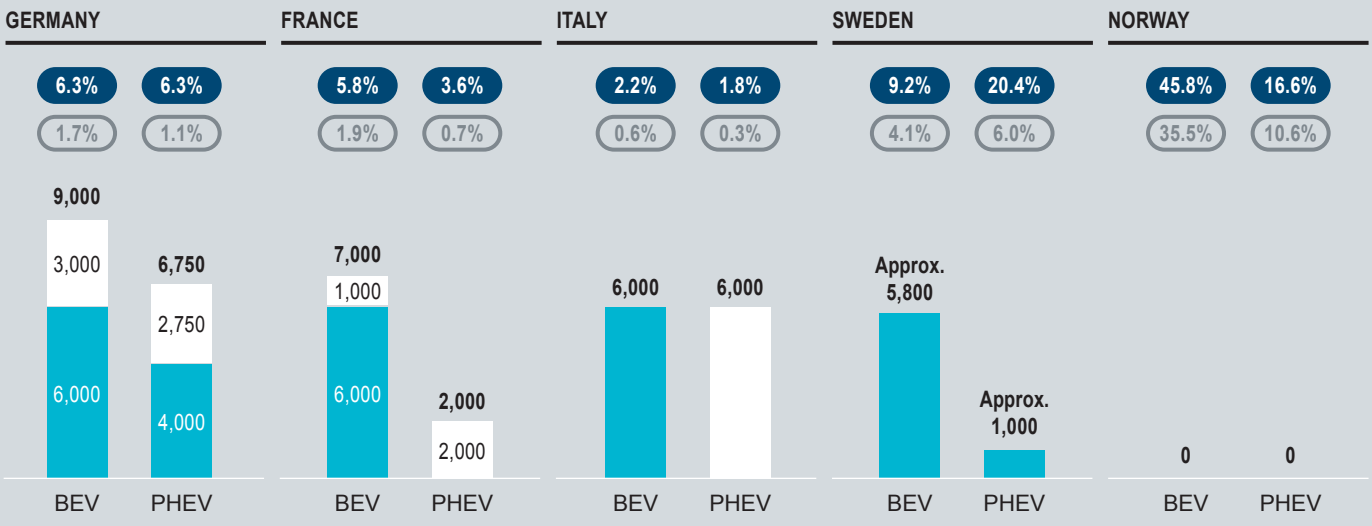
2/ COVID-19 and the European xEV industry

The automotive industry in general has been hit particularly hard by the COVID-19 crisis, not just as a result of disruption to global supply and value chains but also due to a drastic decline in demand. Thus, average worldwide sales of light vehicles fell by 15 percent in 2020 compared to 2019. This slump was particularly severe during the lockdowns in the first two quarters of 2020, which saw a decline in sales of up to 30 percent. Despite recovery in the second half of 2020, vehicle sales for the full year remained below the previous year's figures.

Governments in many countries took action to counter this trend. Several introduced economic stimulus packages with a special focus on promoting xEVs (both BEVs and PHEVs). This was particularly noticeable in European countries that produce vehicles, such as Germany, France and Italy. Here, in contrast to the overall trend in the automotive market, xEV sales flourished. → H

H / Buying incentives in selected European countries

Maximum purchase premium for electric vehicles [EUR][1]



- Strong push for direct subsidies for BEV/ PHEVs
- Available until end of 2021

- Bonus-malus scheme with focus on BEV subsidies
- Additional scrappage bonus of EUR 5,000 if exchanged for a low-emission vehicle

- Additional malus tax of up to EUR 2,500 for cars emitting more than 250g CO_2/km

- Additional reduced annual tax for zero-emission vehicles

- Massive tax deduction, e.g. no value added tax and no import fees
- Additional BEV benefits, e.g. free parking

Pre-COVID-19 incentives (2019) | Increase due to COVID-19 economic stimulus packages (2020) | XX% Share of BEV/PHEVs sold in 2019 | XX% Share of BEV/PHEVs sold in 2020

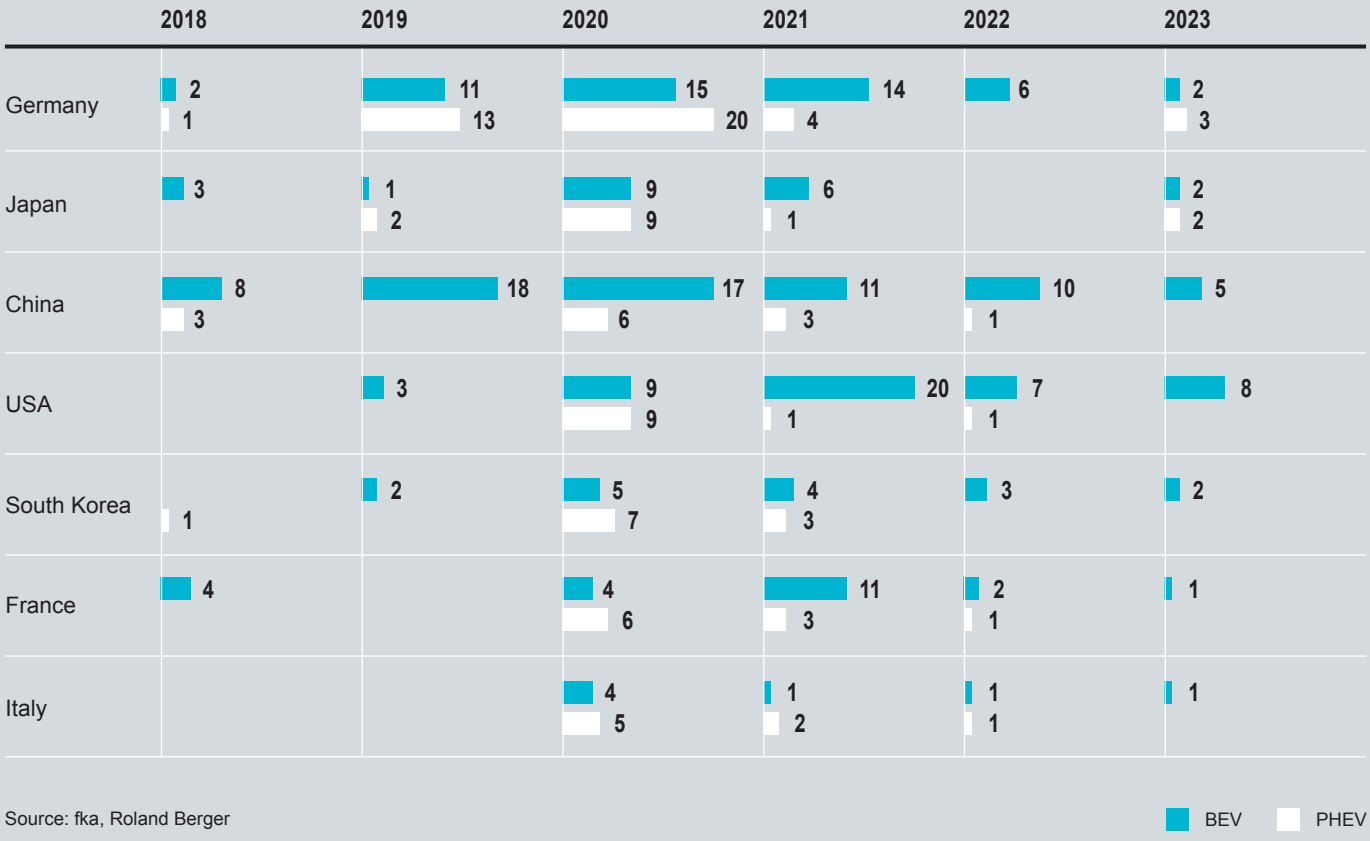
1 Maximum possible incentives for private new car buyers, including government and OEM contribution and depending mainly on overall vehicle price (BEV/PHEVs) and electric driving ranges (PHEVs)
2 SEK 60,000 for new zero-emission vehicles; SEK 10,000 for PHEVs with ≤70g CO_2/km

Source: fka, Roland Berger

The variety of vehicles available with electrified powertrains has increased massively in recent years. A choice of xEVs is now available in each segment. Many new or updated BEV and PHEV models were launched in 2020, and more are expected to follow in the coming months. In addition, OEMs had already been increasing their xEV production capacity in preparation for the introduction in 2019 of the WLTP procedure (worldwide harmonized light vehicle test procedure) – a unified standard for calculating pollutant levels, CO_2 emissions, fuel consumption and range – and they continued to do so during the period in question, which means that they are likely to be able to meet the 95g CO_2/km average fleet emissions target in 2021. → I

I / New xEV models announced by country

Market introduction of xEV models expected to be high in 2020/21 due to launch of new xEV platforms by OEMs

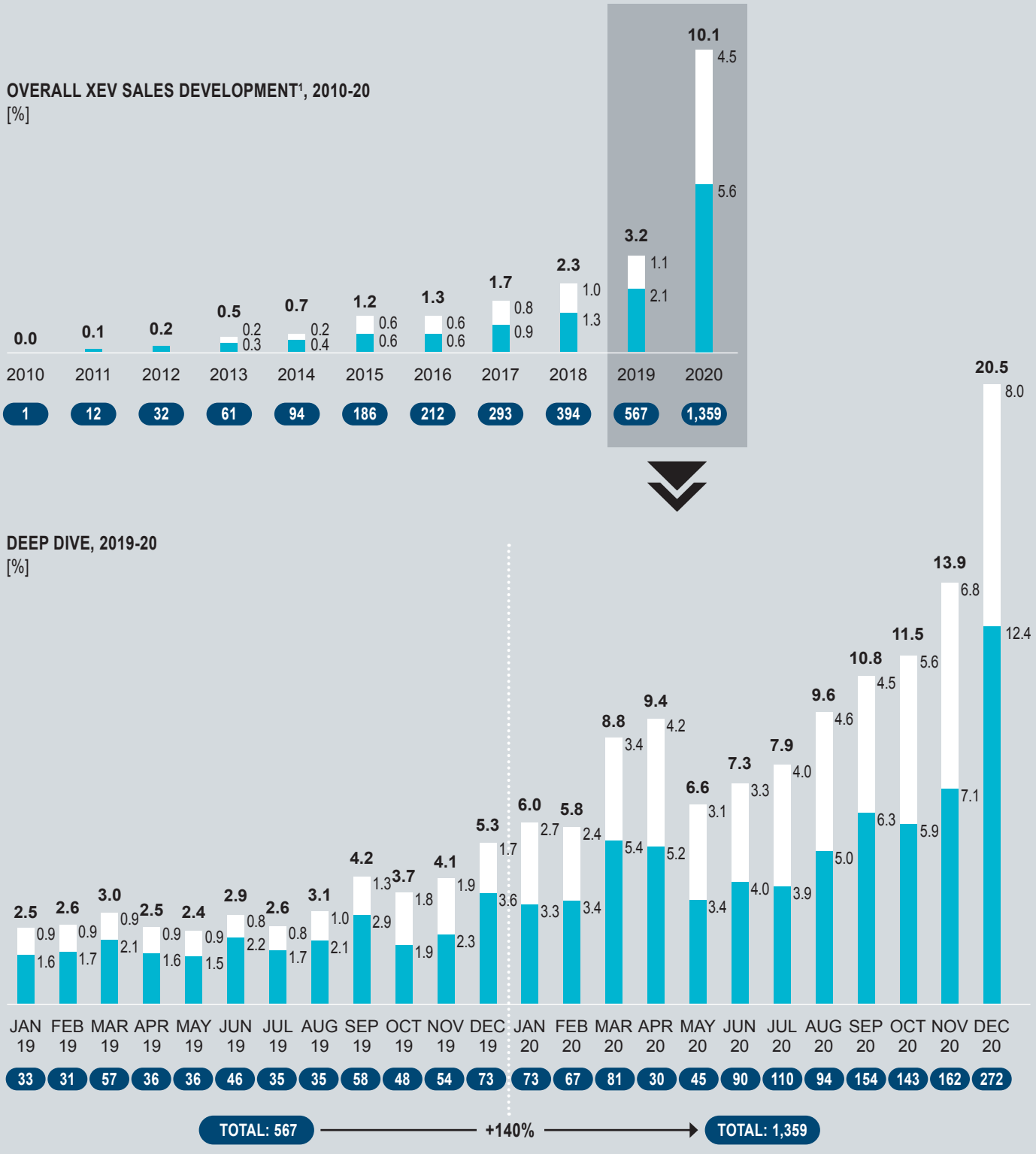


Source: fka, Roland Berger

As a result of both increasing incentives and wider vehicle offerings, new registrations of electric vehicles almost doubled in the period under discussion. This increase actually began as early as September 2019, with a further jump in March 2020. Indeed, some OEMs already reached their capacity limits for xEV models as early as mid-2020, and in other cases buyers faced long waiting times. → J

J / Development of new xEV sales in Europe, 2010-20

Absolute xEV sales in Europe until end of 2020 increased by ~140% compared to 2019 despite COVID-19



1 Passenger vehicles; BEV+PHEV; EU27 + UK + Norway; possible errors due to rounding

Source: EV-volumes, Roland Berger

While xEV sales boomed in Europe, the proportion of xEV sales in the United States and China remained largely constant. The Chinese government extended its subsidy for new energy vehicles (NEVs) until 2022, albeit at a lower rate than before. In the United States, the Trump administration relaxed the CAFE (Corporate Average Fuel Economy) standards, which deal with fuel economy and greenhouse gas emissions. The country lacks uniform nationwide subsidy guidelines and currently risks falling even further behind the European Union and China in terms of e-mobility.

3 / CO_2 compliance and European emission standards

3.1 / Possible future developments

Thanks to the increase in xEV sales described above, European OEMs are currently likely on track to meet the EU emission targets for 2021. However, three potential changes to regulations could make it harder for OEMs to comply in the future.

First, the EU Commission is considering **tightening the CO_2 emission limits** for new vehicles by 2030, aiming to reduce emissions by 50 percent rather than 37.5 percent compared to 2021 levels. Target values for OEMs depend on their specific fleet emissions in 2021, but this would mean that average fleet emissions would need to be cut to 47.5 g/km instead of the currently targeted 59.4 g/km.

Second, an analysis of the **real consumption rates of PHEVs** shows that in most markets these are two to four times higher than in the laboratory. Particularly noteworthy is the fact that commercially used fleet PHEVs are charged less often and make greater use of their combustion engines than vehicles used privately (Fraunhofer ISI Working Paper 09/2020). Climate groups and politicians alike are increasingly calling for an end to emission credits and subsidies for PHEVs, or at least for such mechanisms to consider real consumption data rather than laboratory values. Questions remain about how to collect such data in light of Europe's General Data Protection Regulation. Nevertheless, OEMs will need to take bold decisions about whether they continue to develop PHEV solutions or focus more strongly on BEVs.

Finally, regulators are increasingly taking an interest in the **lifecycle assessment (LCA) of CO_2 emissions,** rather than just looking at emissions during use. At the moment, CO_2 limits in Europe and elsewhere are based on tailpipe emissions – in other words, they do not consider emissions during production, recycling, or emissions arising further upstream during the production and provision of propulsion energy in the form of fuel or electrical energy. Moreover, they consider a standardized driving cycle, ignoring any higher or lower distance-related emissions resulting from other usage patterns. They also ignore the annual mileage or lifetime mileage of a vehicle.

There are now signs of a general change taking place from considering tailpipe emissions in an isolated manner to a more holistic LCA of emissions. This shift was initially driven by pressure from society but is now being pushed for by both industry and legislators. For example, EU Directive 2019/631 states that the European Commission must assess the possibility of integrating the entire lifecycle into CO_2 regulations by 2023 and, if possible, prepare initial proposals for concrete integration into the regulations. No potential date for the introduction appears in the Directive, but this could well affect the generation of regulations after 2030.

3.2 / Implications for OEMs and suppliers

Even integrating individual aspects of LCA into the regulations could trigger major disruption in the industry, significantly changing the technological and strategic considerations of automotive players. It is the vehicle manufacturers who bear direct responsibility for CO_2 emissions in the legislation; they are also the most important when it comes customer purchase decisions. But other players could also be strongly impacted. For example, only 10-20 percent of production emissions are in fact caused by OEMs – the rest are associated with suppliers.

In light of this development, key competencies regarding managing emissions across the lifecycle, especially in the upstream value chain, are likely to be transferred to Tier 1 suppliers. Tier 2 suppliers will also have to take action, including monitoring their own CO_2 footprint. Indeed, all members of the value chain, including Tier 3 suppliers, will potentially have to bring their innovation, design and process decisions into line with LCA regulations.

> *"Europe wants to become the first climate-neutral continent by 2050. E-mobility is a central pillar of this, which has experienced an enormous boost in recent months. Together with political leaders, our OEMs and automotive suppliers can lay the foundations today so that we will still be a leader in mobility solutions in 20 years. In other parts of the world, the target for e-mobility has long been clear and European economies cannot afford to lag behind in this field."*
>
> **Dr. Wolfgang Bernhart**
> Senior Partner, Roland Berger

CONCLUSION

COVID-19 has had a major negative impact on the automotive industry as a whole. But its effect on electric mobility has been the reverse, with sales volumes burgeoning thanks to government stimulus packages, particularly in Europe. With European penetration rates of up to 20.5 percent in December 2020, the trend towards electrification now appears to be unstoppable.

OEMs have committed themselves to creating xEV platforms, and model availability is increasing each year. Consequently, the manufacturers are very likely to meet the emission targets set by regulators in the short to medium term. However, the potential threat of tighter limits, real consumption data assessment and LCA for emissions mean that both OEMs and suppliers need to think about what additional action they can take now to improve their emission footprints.

Methodology

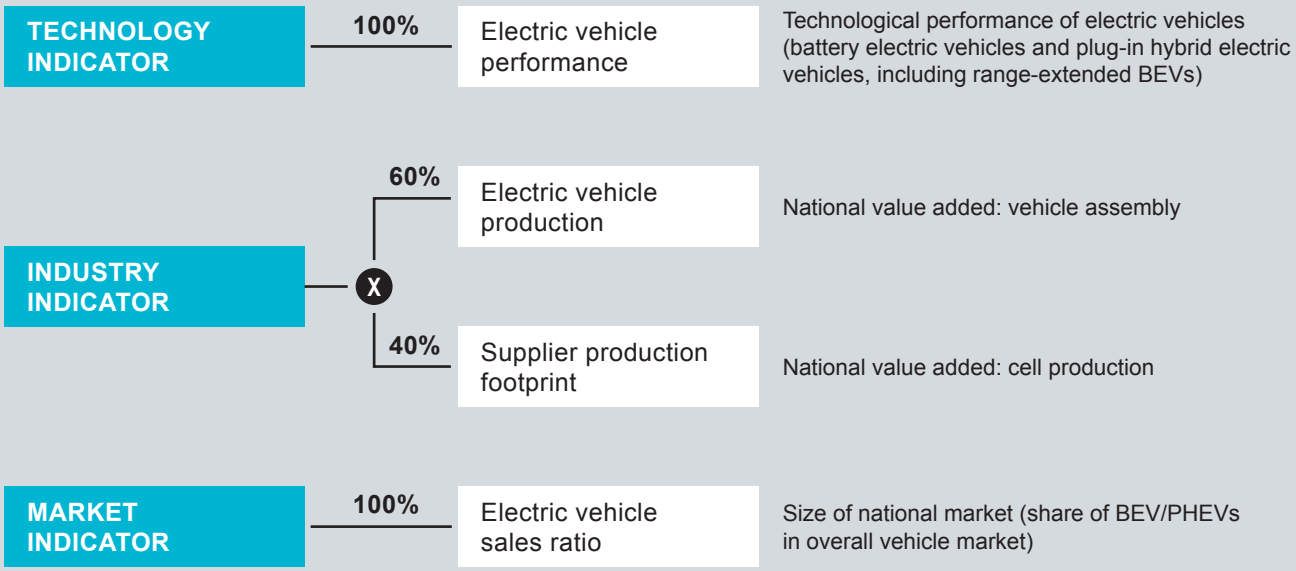
Our ranking compares the competitive positions of individual automotive nations against those of others on the basis of three key indicators:

- **Technology,** that is, the current status of technological development in electric vehicles made by OEMs in the country in question
- **Industry,** or the regional value added in the electric vehicle industry by national production of vehicles, systems and components
- **Market,** or the size of the domestic market for electric vehicles, based on current customer demand

The precise criteria that we apply in calculating each of these indicators is described further below. For the purpose of the E-Mobility Index, we weight each of the three indicators with a value range of 0-5 and then combine them. The Index allows us to compare the competitive positions of the world's seven leading automotive nations – Germany, France, Italy, the United States, Japan, China and South Korea – and assess their individual automotive markets on the basis of uniform global standards. It also reveals the extent to which individual nations are benefiting from the market that e-mobility is creating. → K

K / Methodology of the E-Mobility Index

The E-Mobility Index compares the automotive nations based on three parameters



Source: fka, Roland Berger

TECHNOLOGY

> ***The technological performance and value for money of the electric vehicles that are currently available on the market or soon to be launched***

In the E-Mobility Index 2021, we no longer consider national e-mobility R&D programs in determining the technology indicator. This changes countries' technology values compared to previous editions of the Index. For the sake of comparability, we have recalculated the historical data underlying Figure C.

INDUSTRY

> ***Cumulative national vehicle production (passenger vehicles, light commercial vehicles) for the period 2018-23, both BEVs and PHEVs***
> ***Cumulative national battery cell production capacities (GWh) for the period 2018-23***

In this year's E-Mobility Index, we have again adjusted the measurement threshold for national vehicle production and battery cell production capacity to reflect increasing production. This adjustment is necessary in order to allow assessment of the indicator in a value range of 0-5. The new, higher threshold reduces countries' industry values compared to previous editions of the Index. For the sake of comparability, we have recalculated the historical data underlying Figure C so that it takes into account the new thresholds.

MARKET

> ***Electric vehicles' current share of the overall vehicle market (January-December 2020)***

In the E-Mobility Index 2021, we have once again adjusted our measurements to reflect the increasing market penetration of BEVs and PHEVs. This adjustment is necessary in order to allow assessment of the indicator in a value range of 0-5. The new, higher threshold reduces countries' market values compared to previous editions of the Index. For the sake of comparability, we have recalculated the historical data underlying Figure C so that it takes into account these new thresholds.

AUTHORS

Dr. Wolfgang Bernhart
Senior Partner +49 711 3275-7421 Wolfgang.Bernhart@rolandberger.com

Stefan Riederle
Principal +49 89 9230-8169 Stefan.Riederle@rolandberger.com

Tim Hotz
Project Manager +49 89 9230-8319 Tim.Hotz@rolandberger.com

Ingo Olschewski
Head of Strategy & Consulting +49 241 8861-160 Ingo.Olschewski@fka.de

Alexander Busse
Senior Consultant +49 241 8861-167 Alexander.Busse@fka.de

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03.2021

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Publisher:
ROLAND BERGER GmbH
Sederanger 1
80538 Munich
Germany
+49 89 9230-0

RB_REP_21_002