STUDY

E-MOBILITY INDEX 2019

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1. Key takeaways from the 2019 E-mobility Index

> China retains an overall lead in the 2019 E-mobility Index, ahead of the USA. Although Germany is the technological leader, China continues to be the leading country in terms of industry and market (Fig. 2).
> The market shares of BEV and PHEV vehicles are increasing significantly in almost all analyzed markets. China exceeds the five percent mark for the first time.
> The European automotive industry needs to overcome three key challenges to become a leader in electrical powertrains: Strengthen its position in the battery value chain; close the profitability gap between conventional and electric vehicles; and develop complementary zero-emission technologies.

2. Summary comparison of the rankings of the world's seven leading automotive nations

China no longer shares the overall lead with the USA; rather it has now set itself apart, pushing the USA into second place. Germany improves in the overall ranking and moves up to third place ahead of South Korea (Fig. 1 and Fig. 2). Changes in the competitive positions of the seven leading automotive nations since the last Index are shown in Figure 3. While the industry and market of electric mobility improves constantly in all assessed nations, technology indicators are subject to fluctuations due to changes in the BEV/PHEV ratio, as well as cost/performance ratio of the offered vehicles.

Technology – Germany is the leader

Germany takes the lead from France in terms of technology. German manufacturers (OEMs) are increasingly focusing on the full electrification (battery electric vehicle, or BEV) of compact and small cars, while full electrification of mid-size vehicles and partial electrification (plug-in hybrid electric vehicle, or PHEV) of SUVs continue to progress. Due to lower vehicle weights, this results in an increase in range/battery capacity ratio and thus an improvement in terms of the vehicles compared. Furthermore, the extension of the vehicle portfolio to include compact BEVs leads to improved value for money in the assessed vehicle pool. Slightly increased government subsidies for research and development intensify the battle for leadership of the technology indicator.

China is catching up quickly and ranks second in terms of technology for the first time. Chinese vehicles are improving significantly and becoming safer and more efficient. Due to new Chinese laws and regulations, charging technologies that enable faster charging with direct current (DC) are increasingly being installed in Chinese vehicles. Chinese OEMs continue to focus on a portfolio of low-cost small and mid-range BEVs.

The portfolios of Korean OEMs have changed only marginally compared to the previous Index. However, due to the good price-performance ratio of Korean vehicles, Korea defends its third place in terms of technology. Korean OEMs are less focused on introducing new models, and more on improving technologies. The average range and efficiency of Korean vehicles have increased, with correspondingly slightly higher vehicle prices.

France is not able to defend its first place in terms of technology, instead ranking fourth.
A growing offer of PHEVs results in a lower average technological performance among the assessed electrified vehicles. This is mainly due to the fact that plug-in vehicles generally have a smaller electric range and lower electrical top speed. Given their lower battery capacity, most are

also equipped with basic charging technology. France has also reduced its R&D subsidies significantly.

Japan drops from fourth to fifth place. As in the previous year, Japanese OEMs are focusing on the expansion of plug-in vehicles. Japanese manufacturers are placing few new all-electric vehicles on the market.

US BEVs are leaders with regard to electric range. However, the portfolios of all American OEMs increasingly include electrified SUVs and a bigger share of PHEVs, which reduces the average technological performance of the vehicles under evaluation. Both German and American vehicles belong in the high-price segment.

Italian OEMs have so far avoided the production of mass-produced BEV and PHEV models. However, it is expected that manufacturers will expand the production of BEV and PHEV models during the period under review, and that Italian electric vehicles will also be available in Europe for the first time.

Government support for research and development in the field of e-mobility is mostly constant in all analyzed markets. France and China have seen a reduction in funding because government R&D programs are being phased-out and reissued with a smaller volume or narrowed scope. For the first time, Germany receives the highest amount of funding as a percentage of the GDP, underscoring its technology leadership. France, on the other hand, has lost out here and ranks fourth (Fig. 5).

Industry – China is number one, followed by the USA

In terms of industry, China and USA share first place in indicator values. However, China leads with absolute higher xEV (BEV and PHEV) as well as cell production. High growth is expected in both countries in the next years. In China, battery cell production in 2017-2022 is expected to increase by more than 1,000% compared to the same period last year (2016-2021). No other nation plans such a large expansion of its domestic cell production, confirming China's leadership in terms of industry. The measurement threshold for national battery cell production was adjusted in the 2019 Index for the first time due to this increasing cell production. The adjustment is necessary to implement an indicator assessment in the value range from 0-5. While in the 2018 Index, the highest rating of 5.0 was awarded for countries that produced at least 75 GWh in the period 2016-2021, this threshold for the period 2017-2022 is set to 250 GWh in 2019. The higher threshold slightly reduces countries' industry values compared to previous editions of the Index.

Japan ranks second in the industry indicator (Fig. 6). Japanese xEV vehicle production increases while the evaluation of the supplier footprint is lower. This is due to the new threshold, as well as the expected cell production increasing only slightly. With the third-largest production volume of xEV and a strong increase in the expected battery cell production, Germany takes third place in terms of industry (Fig. 7). However, the supplier footprint is founded mainly on the activities of Chinese suppliers in Germany. Korea falls behind Germany to fourth place, as expected vehicle production and cell production increase only slightly during the period under consideration. Despite strong growth in vehicle production, France is back in penultimate place. The reason for this is the lack of cell production. Italy is again in last place due to its very small model range. A significant increase in production is not expected until 2022.

Market – China leads the way; only the Japanese market is declining

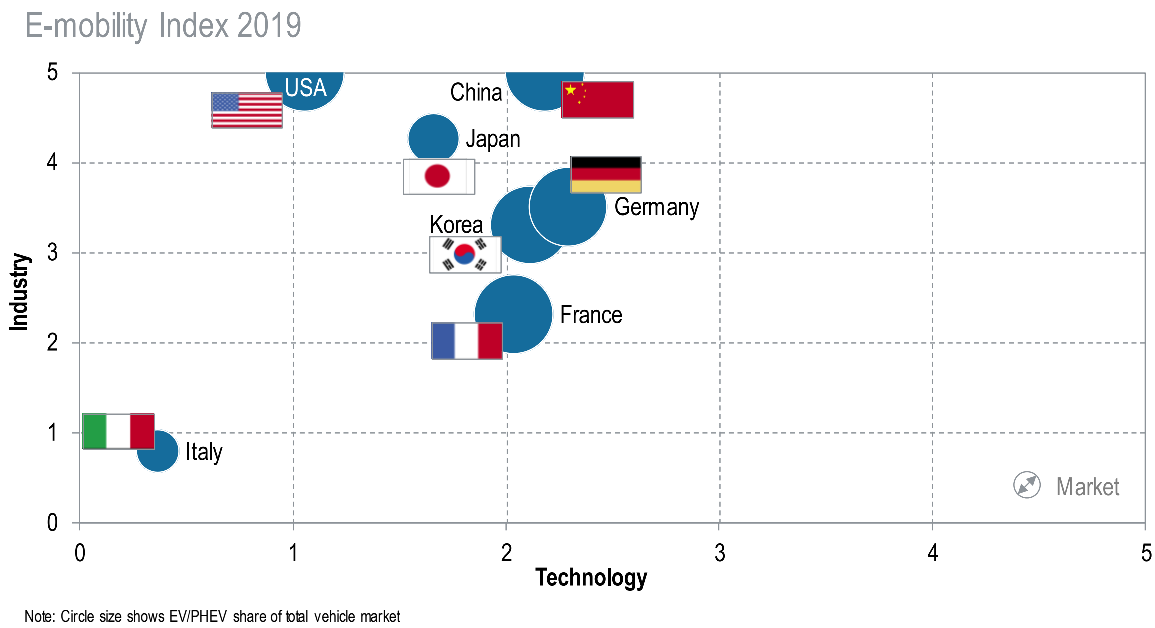
In terms of market development, sales figures for battery and plug-in hybrid electric vehicles rise significantly in all countries except Japan (Fig. 8) in the period Q3 2018 - Q2 2019. For the first time ever, the share of partially or fully electrified vehicles in all new Chinese registrations exceeded the five percent mark. Compared to the previous period (2018), Chinese sales are growing at approximately 160 percent.

France, South Korea, the US and Germany exceeded the two percent mark of the xEV sales ratio for the first time. France is ranked second ahead of a strongly growing South Korean market (+189%). USA ranks fourth with an increase in sales share of over
2.3 percent of all newly registered vehicles, ranks fifth.

After stagnation in 2017 and strong growth in 2018, the Japanese market is experiencing another downturn. The number of newly registered EV and PHEV has fallen by 14 percent, corresponding to a market share below 1.0 percent. The e-mobility Index includes only BEVs and PHEVs, while the Japanese market is focused on HEVs (hybrid electric vehicles). Japan is thus in sixth place, ahead only of Italy. Although Italy has growth of
40 percent compared to last year, it still lags far behind the other nations in terms of the absolute number of new registrations and the market share of BEVs and PHEVs.

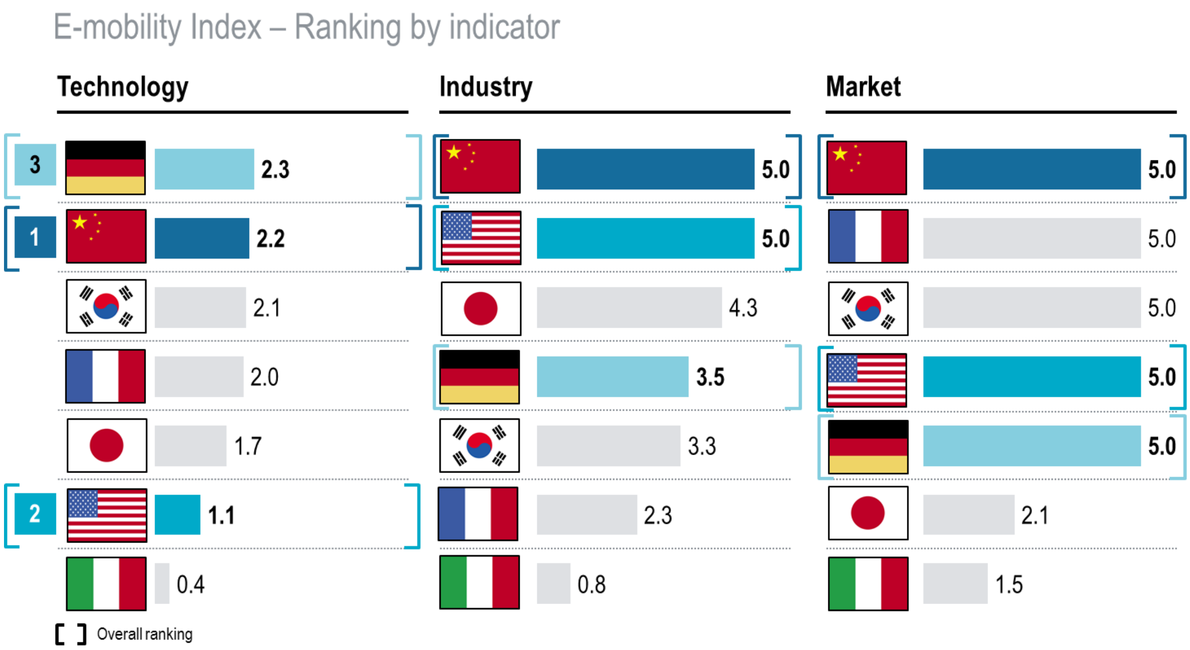
Figure 3 shows the development of the individual indicators over time.

Fig. 1: China takes sole lead. USA falls back slightly but maintains second place ahead of Germany



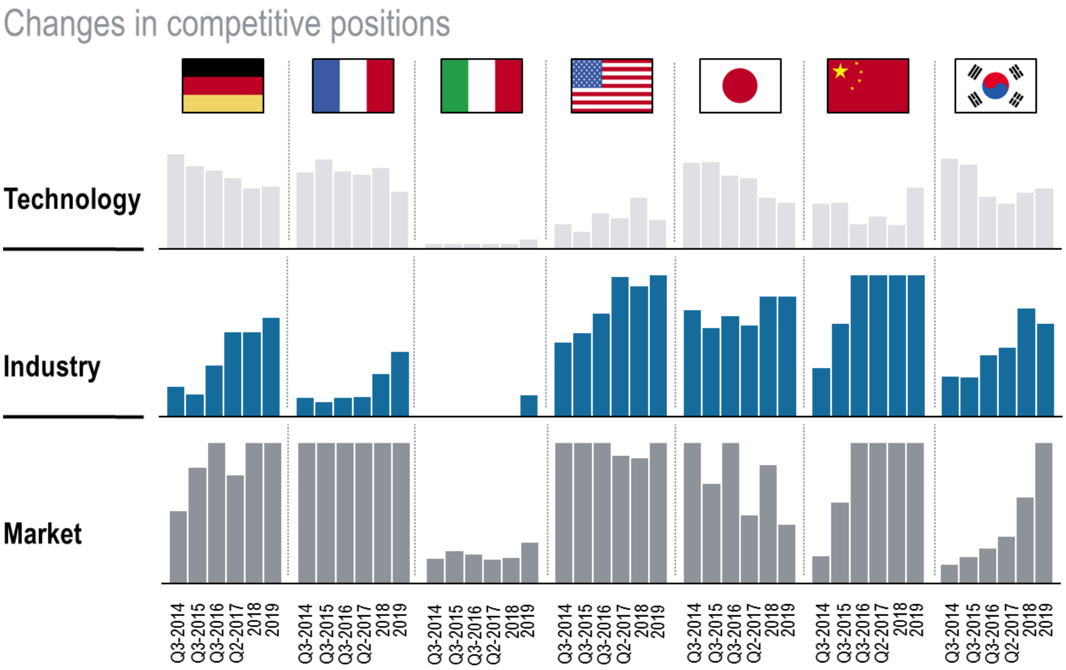
Source: fka; Roland Berger

Fig. 2: Germany regains lead in technology from France. China is catching up quickly and moves up to second place; Korea defends third place. China remains the leader in terms of industry and market



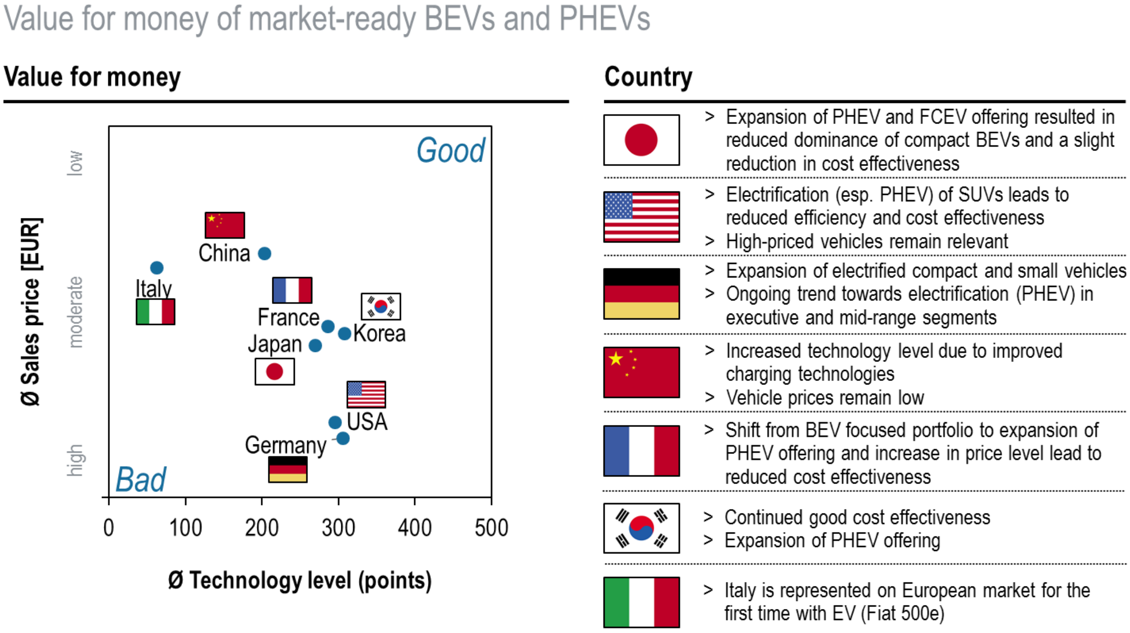
Source: fka; Roland Berger

Fig. 3: Changes in competitive positions of leading automotive nations by indicator



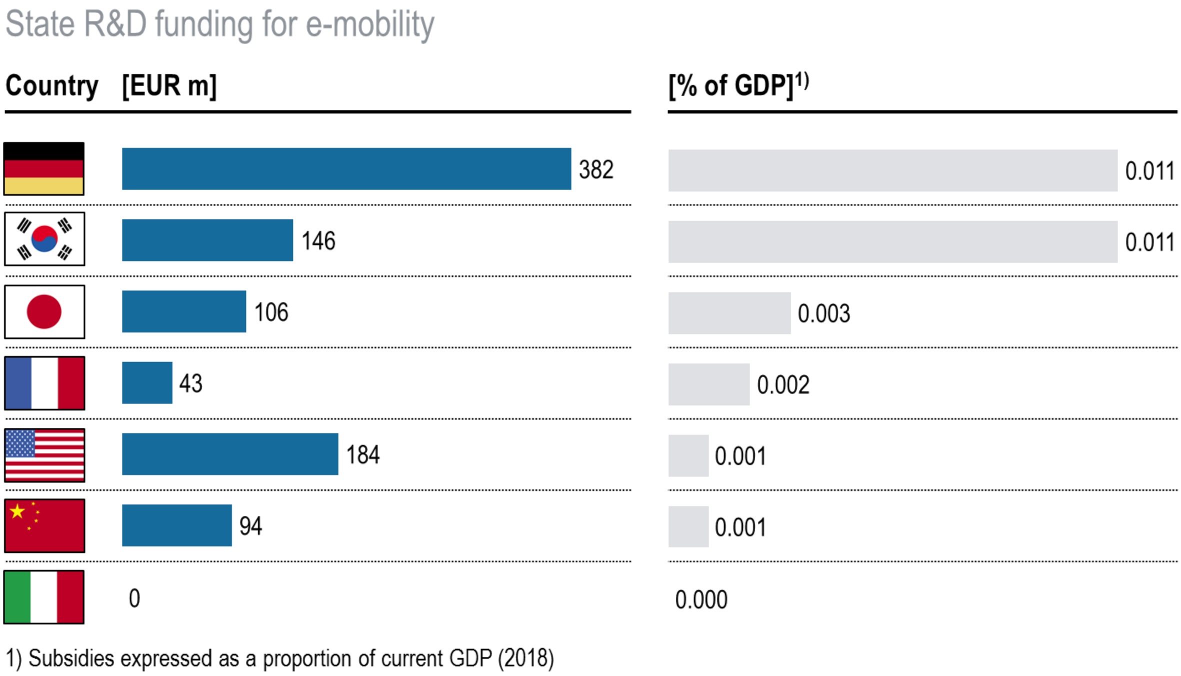
Source: fka; Roland Berger

Fig. 4: High-priced models still important in Germany and the USA. Korea and France lead in terms of value for money. Italy launches series vehicle on the European EV market for first time



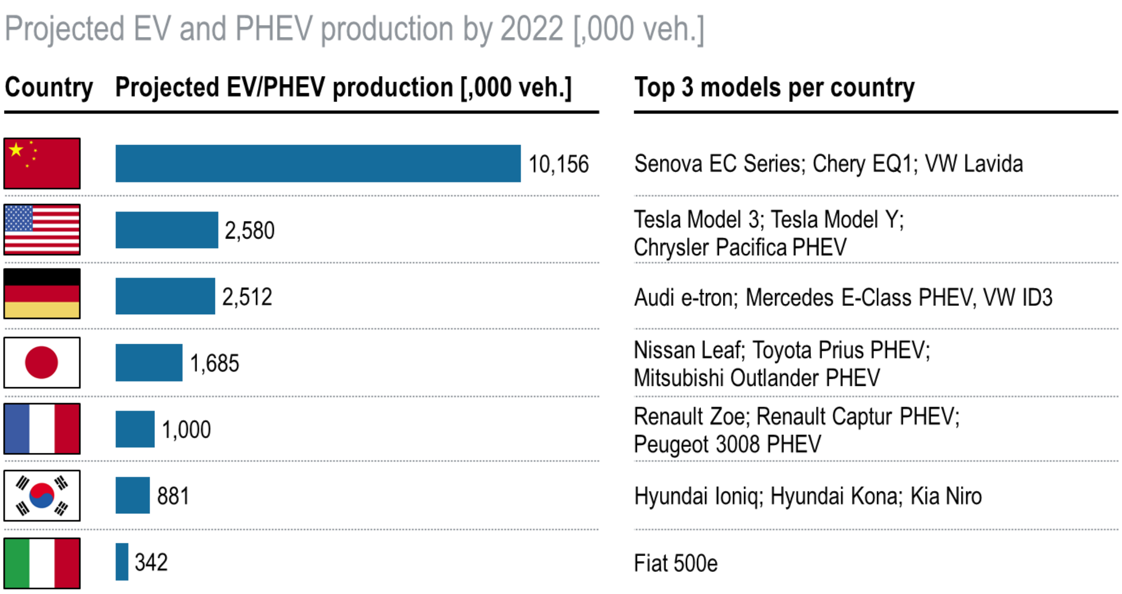
Source: fka; Roland Berger

Fig. 5: R&D funding in France is in sharp decline. Japan strongly increases subsidies. Germany, South Korea and USA stable



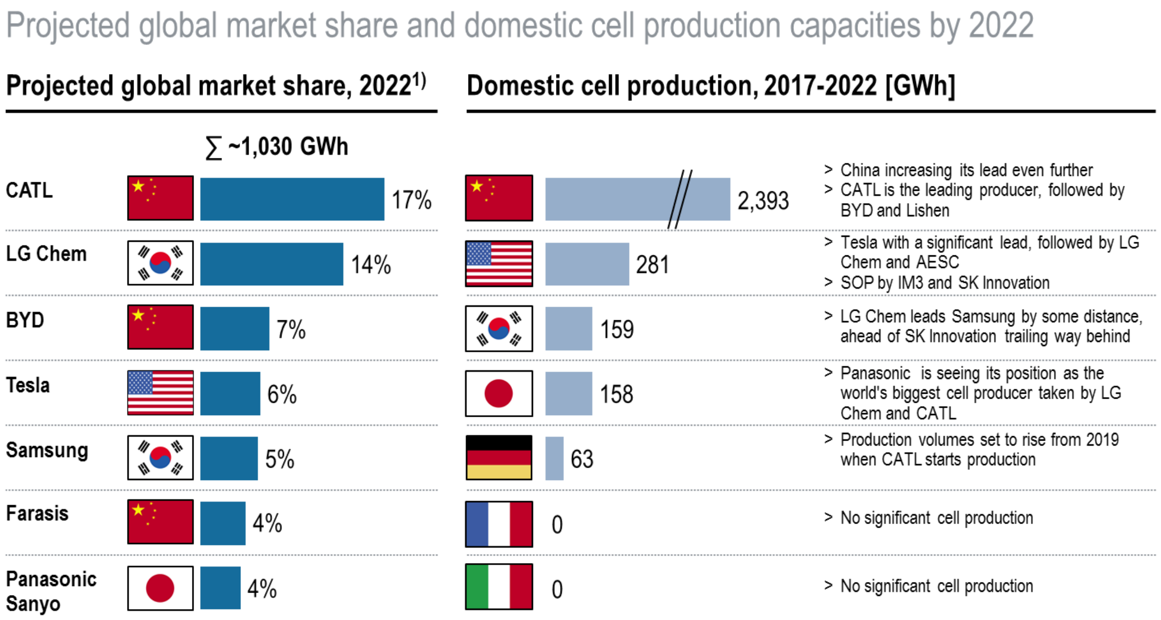
Source: fka; Roland Berger

Fig. 6: China retains a clear lead in EV/PHEV production. Reduced growth in USA but it maintains second place, Germany catches up



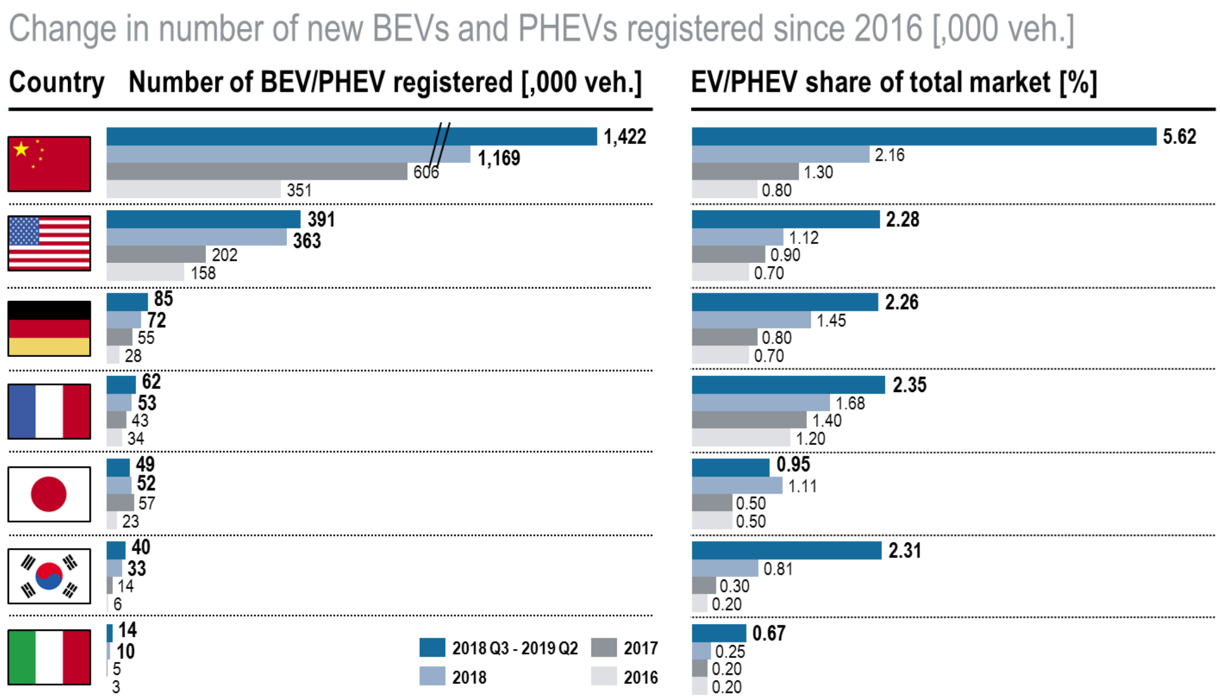
Source: fka; Roland Berger

Fig. 7: China establishes itself as the frontrunner in battery production. USA moves up to second place



Source: Benchmark Minerals; Roland Berger

Fig. 8: EV sales growing in all countries except Japan. China retains clear lead in market for electrified vehicles



Source: fka; Roland Berger

3. Spotlight on the European E-mobility industry

China has dominated the key dimensions for electrifying the automotive powertrain for years, from xEV sales volume to growth of charging infrastructure and production capacity for battery cells. But as Europe approaches its first evaluation point for CO2 emission reductions in 2021, it is time to take stock and review what the European automotive industry must do to catch up.

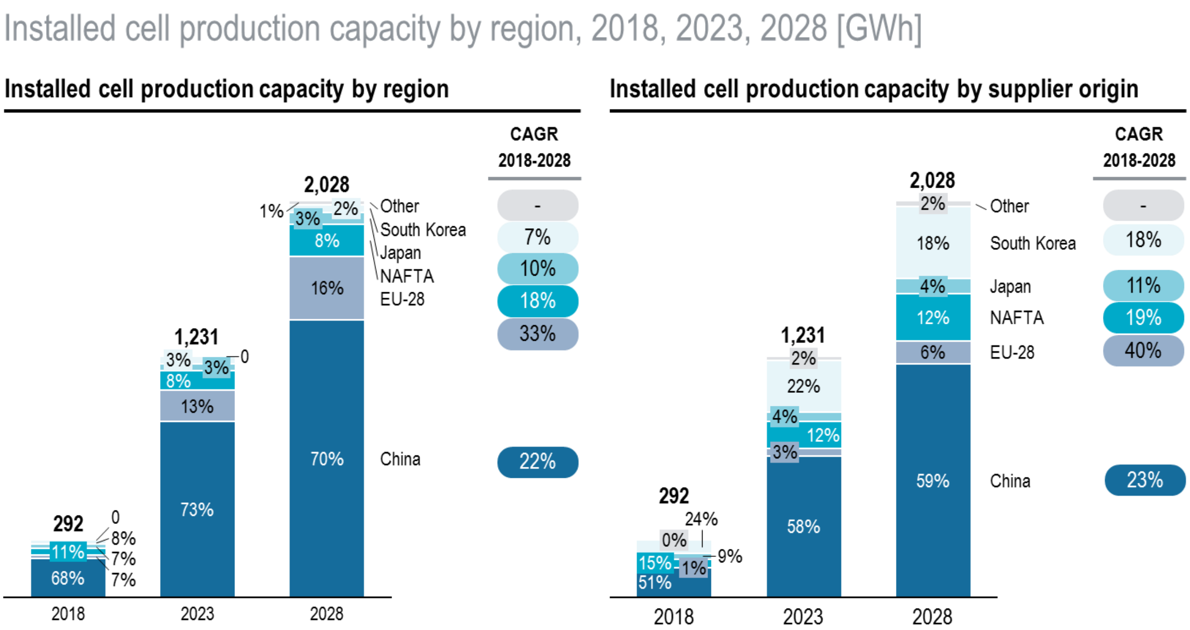
For example, can the Europeans (and the Americans) make up the ground they have lost to their Asian competitors? And does the current situation of under investment and low market dynamics perhaps even offer new and previously unconsidered opportunities?

The answers are not straightforward. But in this chapter, we discuss three key industry challenges that highlight the multiple issues that need to be addressed if the European automotive industry is to become a leader in electrical powertrains.

3.1 Strengthening Europe´s weak position in the battery value chain

Unsurprisingly, Asian players dominate the global market for battery cell production, both in installed and planned production capacity (Fig. 9). Even most of the existing and planned production capacities in Europe are owned and operated by companies with a non-European origin, like LG Chem in Wroclaw (Poland), CATL in Erfurt (Germany) or most recently announced Tesla in Brandenburg (Germany). So, where does this leave European players?

Fig. 9: Asian players dominate the market for battery cell production, and are even expanding their footprint to Europe



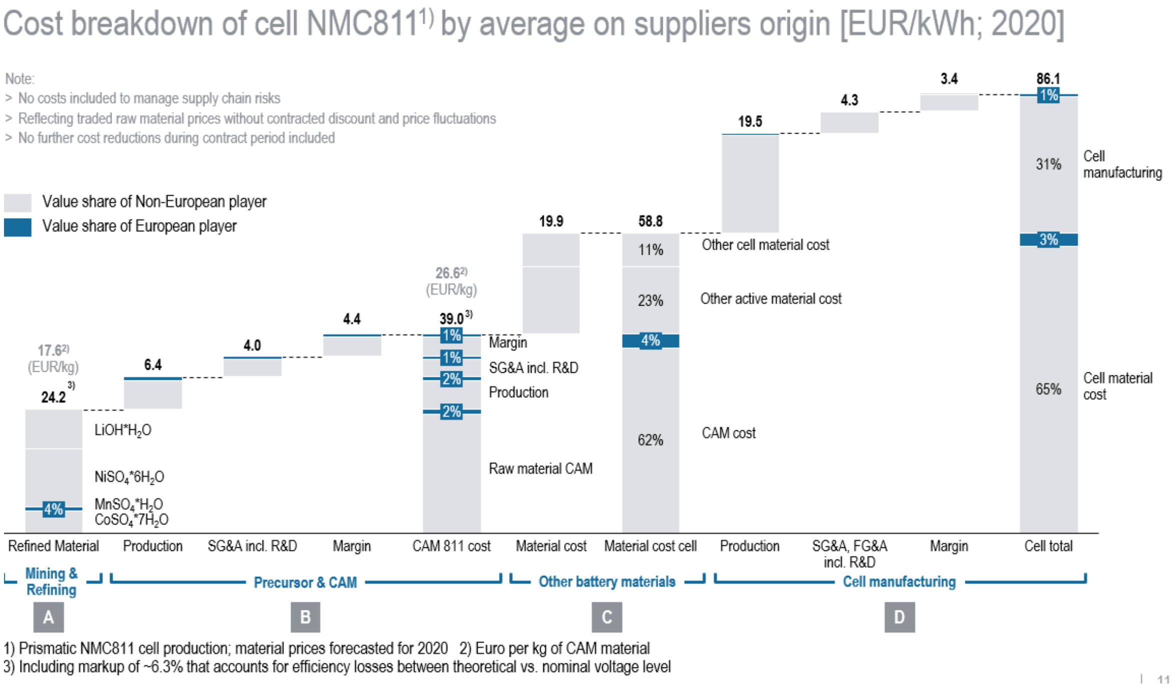
Source: Benchmark Minerals; Roland Berger

Currently, companies with a European origin play only a minor role along the battery value chain and are not represented at all in cell production. Their overall market share is expected to fall to just ~4% at cell level by 2020 (Fig. 10).

Some 70% of cell costs are heavily dependent on material costs, of which cathode active materials are the most important. But the active material market is heavily dominated by Chinese, Korean and Japanese industry players, as is the cell production market.

Northvolt seems to be the most promising European player at the moment. But it is not yet producing cells for automotive applications, and even after SOP will only play a minor role compared to the Giga factories of Asian market leaders such as CATL and LG Chem.

Fig. 10: The market share of European players along the battery value chain expected to play only a minor role until 2020



Source: Roland Berger "Total LiB Value Chain Cost Model"

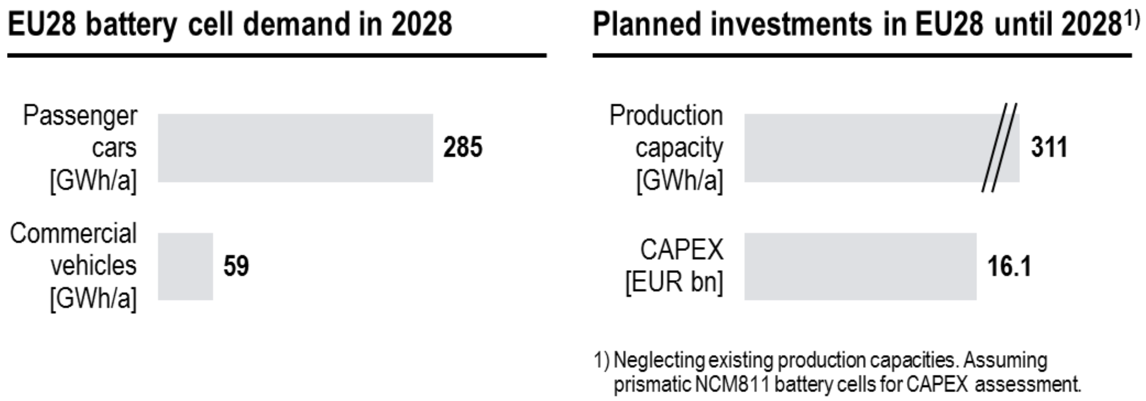
Conclusion and recommendations

The battery cell production market is characterized by very high market entry barriers in regards of technology and process know-how. Large scale production facilities also require significant investment.

As a result, European players are unlikely to successfully enter the market on their own or play a significant role in the production of state-of-the-art lithium-ion battery cells. The market is expected to remain heavily dominated by a relatively small number of Asian players.

However, the level of investment required to cover the expected increase in production capacity over the next decade poses a major challenge to the established cell manufacturers (Fig. 11). European OEMs and suppliers with a chemical background should therefore position themselves as investment partners willing to share risks and CAPEX. This will enable them to increase their control over the battery cell value chain.

Fig. 11: The investment required to cover the expected increase in battery cell demand over the next decade poses a major challenge



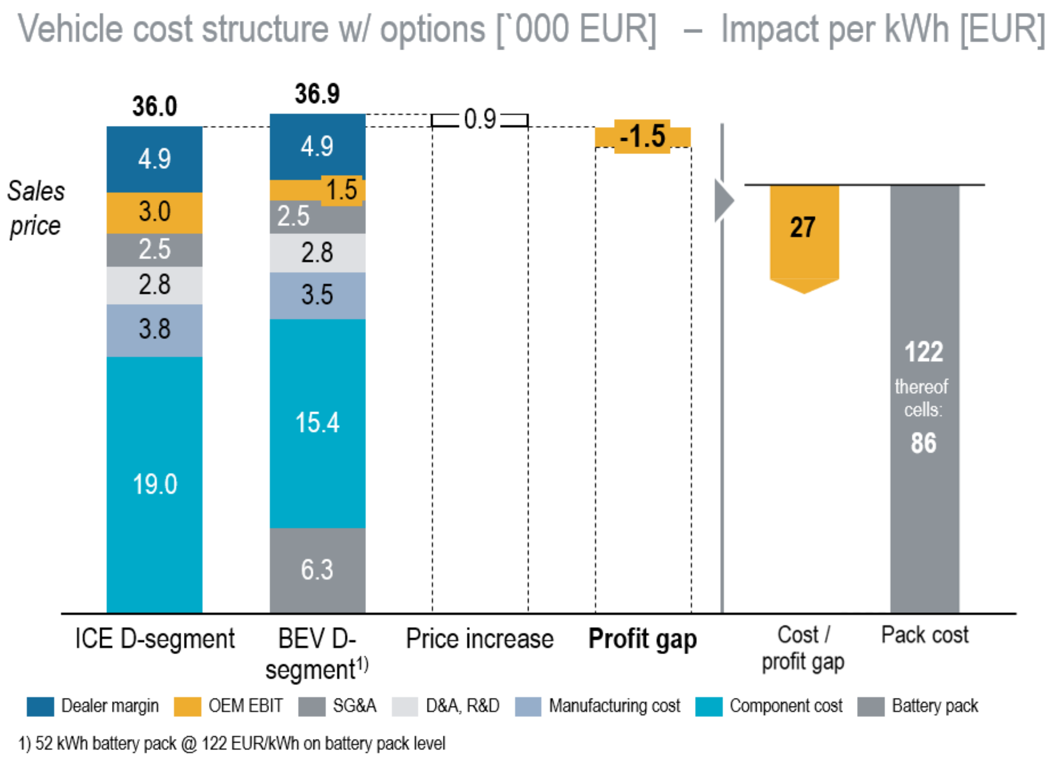
Source: Research; Expert interviews; Roland Berger "LiB Market Model"

3.2 Closing the profitability gap between battery electric and combustion engine vehicles

Under current business models, BEVs are not as profitable as conventional, internal-combustion engine (ICE) vehicles as customers are unwilling to pay a price premium for them. Despite this, OEMs are artificially limiting the price difference between the two types to boost BEV sales, even though it means sacrificing margin to avoid fleet emission penalty fees (Fig. 12).

To ensure profitability, OEMs and battery suppliers need to focus on closing the profit gap between ICE and BEV. But OEMs are caught in a price-cost trap: their current profitability, and that of cell suppliers, is not sufficient to raise the cash needed to finance the expected growth of electric vehicles. Instead, new business models are needed.

Fig. 12: To achieve BEV profits that are similar to those of ICE vehicles, OEMs' pack costs need to go down by 25-30 EUR / kWh, or additional profits need to be generated



Source: UBS; Roland Berger "Battery Cost Model"

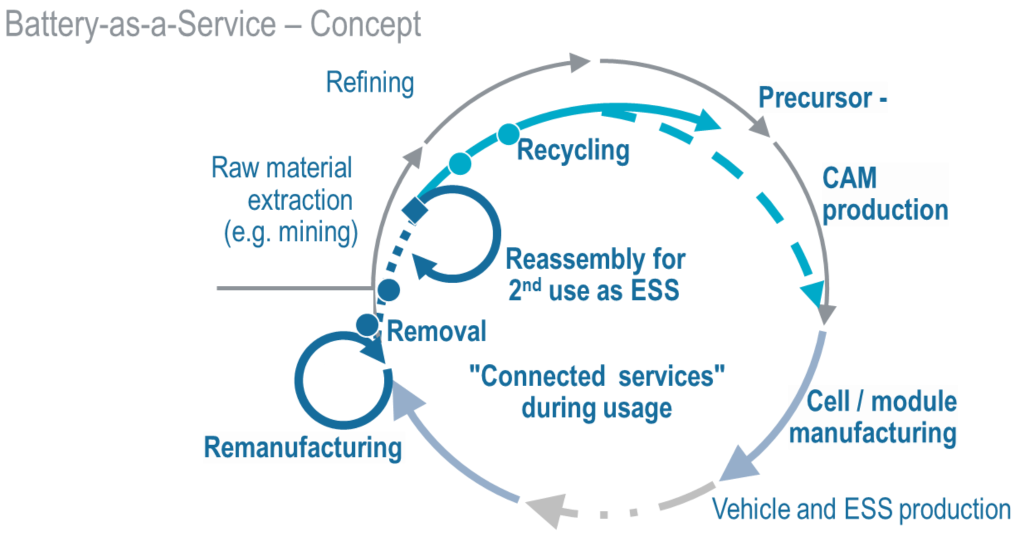
Integrated value chain approaches, in particular the battery-as-a-service (BaaS) concept, show the potential to close the profit gap. BaaS uses a circular economy model to maximize asset utilization, connecting the transport and energy sector (Fig. 13 and 14).

An integrated value chain starts by offering customers battery leasing to reduce their upfront costs and tap into expenditure previously used to buy conventional fuel. The battery is accessible to third parties and connected to cloud services, significantly increasing the overall value pool for stakeholders. Once used, the battery can be given
a second life and utilized in financial or battery-related cloud services, giving rise to further use cases.

There are a growing number of examples of integrated value chain approaches involving BaaS. For instance, Proterra, a US electric-bus maker, and Japanese investor Mitsui are cooperating on a bus battery leasing scheme to lower entry costs for transit customers. The 12-year leases will cut the upfront costs of Proterra's zero-emission eBus to roughly the same price as a diesel or CNG bus. The batteries can be easily swapped or repurposed for a second-life use.

In addition, German engineer Bosch just launched its "battery in the cloud" service to manage and monitor the battery life of electric vehicles. It gathers real-time data on metrics such as charging speed, number of charge cycles, stress from rapid acceleration and deceleration, and ambient temperature to offer user recommendations. For example, could the driver be driving more efficiently, and when will the car need a maintenance check? The system shows the potential to reduce battery wear and tear by up to 20%. Carsharing firm Didi is set to be the first client, with plans to launch Bosch's solution across its fleet of electric vehicles in the city of Xiamen, China.

Fig. 13: Battery-as-a-service (BaaS) maximizes asset utilization using a circular economy approach and connecting the transport and the energy sector



Source: Roland Berger

Fig. 14: Integrated value chain approaches can generate much higher profits to distribute among stakeholders

Integrated value chain creation – Selected approaches and profit potentials

	Battery leasing	Cloud services	Refurbishment	Energy storage systems	Recycling
Description	> Offer a **battery leasing** option at monthly fee > Battery **returns to OEM** after leasing	> **Battery-related cloud services** to increase life time and enable predictive maintenance	> **Refurbish** used batteries **by replacing modules** with insufficient capacity	> **Integrate** used batteries in industrial and residential **energy storage systems**	> **Recycle batteries** to extract **raw materials** as well as **precursor** material
Profit opportunities[1]	22.1 EUR/kWh	25.3 EUR/kWh	2.7 EUR/kWh	5.0 EUR/kWh	4.8 EUR/kWh

∑ 60 EUR/kWh

1) Initial battery pack price: 133.19 EUR/kWh; Leasing period: 12 years; Battery pack price after remanufacturing: 59.93 EUR/kWh; SoH after first life: 80%; SoH after 2nd life ESS: 65%. Example hypothetical, to be optimized with respect of regional market situation

Source: Roland Berger

Conclusion and recommendations

To overcome the profitability gap between BEV and ICE vehicles, OEMs need new business models. These should ensure higher profits for all players involved in the battery value chain and reduce costs for customers by integrating the transport and energy sector in a circular economy.

As a prerequisite, technical requirements must be minimized and harmonized to allow for modular designs. This will enable second-life applications and cut costs. In addition, new business models will require a shift from the belief that OEM-supplier relationships are always zero-sum games. Instead, they should become closer and long-term cooperative approaches with “win-win outputs”.

3.3 Developing complementary zero-emission technologies

In the past few years it has become clear that OEMs are backing partial battery electric powertrains as the best way to achieve future emission targets. But they are also hedging their bets. While discussing strategic options to set battery electric technology as the only zero emission technology, OEMs also remain open to other battery electric powertrain options, such as fuel cells (FCEVs).

One reason for this two-pronged approach is that although BEV technology is ready for mass production, it still needs to overcome several hurdles. The key challenges are the high investments required to build recharging infrastructure; balancing energy sources and the electric grid; and the weight, refueling time and range of BEVs.

Fuel cell technology avoids most of these problems. It offers shorter refueling times, longer ranges and potentially limitless fuel and storage in the form of hydrogen. But to date the technology remains niche, especially when it comes to FCEV sales in Europe.

The situation is better in Asia, where the market drivers of FC technology itself, cost structure and competitiveness ad hydrogen fueling infrastructure are more advanced.
A new generation of FCEVs, including the Hyundai Nexo and Toyota Mirai, is proving the technology works. These vehicles show key improvements in critical areas such as cell packaging, energy density of the membrane electrode assembly and the use of platinum and modular systems.

Even so, production volumes remain low compared to those of BEVs. Only small series of up to 30,000 units have so far been announced. But this may change as market leaders such as Hyundai and Toyota open up their technology to other OEMs, for example Toyota is working with BMW and Hyundai with Audi.

Despite only small investments so far, we expect that the commercialization of fuel cell technology will gather pace. Long-haul trucks, buses and transportation mobility machines such as forklifts are likely growth areas.

Conclusion and recommendations

Fuel cell technology offers various appealing opportunities for OEMs and suppliers, particularly those who already have a foot in the commercial vehicle market. The fact that access to the technology is comparably good adds to the appeal. In addition, fuel cell technology remains an attractive option for players who are not yet well established in the EV powertrain market.

4. Methodology

To compile our ranking, we compared the relative competitive position of individual automotive nations against that of others using three key indicators:

> **Technology:** The current status of technological development in vehicles made by indigenous OEMs, and the support for vehicle development provided by national subsidy programs

> **Industry:** The regional value added in the automotive industry, by national vehicle, system and component production

> **Market:** The size of the national market for electric vehicles based on current customer demand

Roland Berger and fka weighted the individual indicators (value range 0-5) and combined them to form the E-mobility Index (Fig. 15). The Index allows the comparison of the competitive positions of the world's seven leading automotive nations (Germany, France, Italy, the US, Japan, China and South Korea), assessing their individual automotive markets on the basis of uniform global standards. The Index also reveals the extent to which individual nations are benefitting from the market that e-mobility is creating. The criteria applied are assessed as described below:

Technology

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

> National e-mobility R&D programs. Only research grants and subsidies are taken into account (not credit programs for manufacturing, budgets for purchase incentives, etc.)

Industry

> Cumulative national vehicle production (passenger cars, light commercial vehicles) for the period 2017-2022, taking into account BEVs and PHEVs

> Cumulative national battery cell production (GWh) for the period 2017-2022

In the 2019 Index, the measurement threshold for national battery cell production was adjusted to reflect increasing cell production for the first time. The adjustment was necessary in order to implement an indicator assessment in the value range of 0-5. While in the 2018 Index the highest rating of 5.0 was awarded for countries that produced at least 75 GWh in the period 2016-2021, this threshold for the period 2017-2022 is 250 GWh in the 2019 Index. The higher threshold reduces countries' industry values compared to previous editions of the Index.

Market

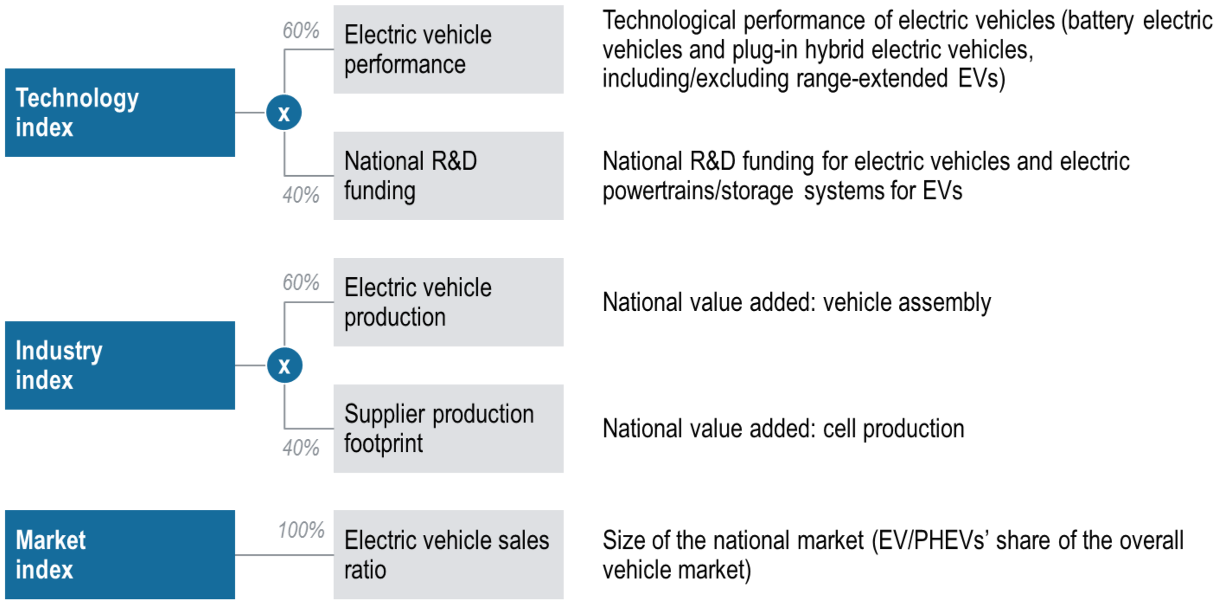
> Electric vehicles' current share of the overall vehicle market (Q3 2018 – Q2 2019)

The 2018 Index was the first to include projections for 2021, while the 2019 Index is the first to include projections for 2022. The additional volume is reflected in higher scores for industry in all markets. However, this does not affect the shifts between markets, and the E-mobility Index's comparability with previous indices is not compromised.

The measurement threshold for the market indicator was also modified in the Q2 2017 index for the first time. In the 2019 Index, the measurement threshold was once again adjusted to reflect increasing market penetration of BEV and PHEV vehicles. The adjustment was necessary in order to implement an assessment in the value range of 0-5. While in the 2018 Index the highest rating of 5.0 was awarded for countries with
a minimum EV/PHEV market share of 1.3 percent, this threshold for the 2019 Index was increased to a market share of at least 2.25 percent. The higher threshold reduces countries' market values compared to previous editions of the Index.

The technology indicator was updated in the Q4 2016 E-mobility Index. Individual aspects of the methodology used to measure technological performance (safety features, active safety) were adjusted, while on-board charging technology was added as a new criterion. Overall, these adjustments alter the level of the technology indicator compared to previous editions of the Index. The new charging technology criterion also results in shifts between individual countries.

Fig. 15: The E-mobility Index compares the automotive nations based on three parameters



Source: fka; Roland Berger

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