Impact Assessment on Electric Vehicles (EVs)

The mobility megatrend of the 2020s

Customer version | Swiss edition

Zürcher Kantonalbank

Summary

Demand for battery electric vehicles (BEVs) is at a new all-time high, driven by surging fuel prices and government phase-out targets for internal combustion engine vehicles (ICEVs), among other things.

The cost of batteries fell by 90% between 2010 and 2021 but further reductions are at risk due to skyrocketing raw material costs and uncertainty in technological developments.

Automobile original equipment manufacturers (OEMs) must commit significant investment to the challenging transition from an ICEV into a BEV value chain, while servicing both ICEV customers and BEV customers. High investments could harm short and medium-term profitability.

In EV batteries, investment opportunities with a most favourable risk-reward can be found in vertically integrated, large players that have significant economies of scale, cost advantages and security of supply as well as the experience and knowledge to keep up with technological developments.

For automobile OEMs, it is advisable to fundamentally analyse OEMs and suppliers to identify companies that have a superior BEV strategy, BEV model pipeline and adequate change management to preserve margin leadership.

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Analyzed regions: Global
Sectors: Industrials, automobiles & components, speciality chemicals
Theme: Mobility
Sub-Theme: Private transport

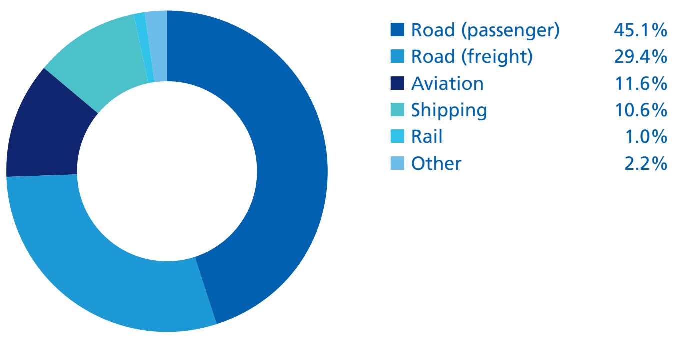
1 Problem description – decarbonising private transport

The year 2020 was special in many ways. The outbreak of the Covid-19 pandemic led to a major slowdown of the economy during the first half of the year and a partial shutdown of social life. The manufacturing of goods was curtailed, largely because of huge uncertainty, leading to a drop in demand for energy. Lockdowns and far-reaching measures such as social distancing led to less travelling (business and leisure alike).

Consequently, global CO_2 emissions fell for the first time in many years, from 33.4 gigatons (Gt) CO_2 in 2019 to 31.5 Gt CO_2 in 2020.

The partial rebound of the global economy and travel in 2021, however, leads to a projected global CO_2 emission increase of 1.5 Gt CO_2 to 33 Gt CO_2, which almost brings back emissions to the 2019 level. Data from the International Energy Agency (IEA) shows that almost one quarter (24%) of global CO_2 emissions can be attributed to the transport sector. Considering different modes of transportation, 45% of the 8.2 Gt CO_2 from transport are emitted by passenger vehicles, 29% by freight vehicles, 12% by aviation, and 11% by shipping (Figure 1). Road transportation, both passenger and freight, are thus the greatest lever to reduce emissions.

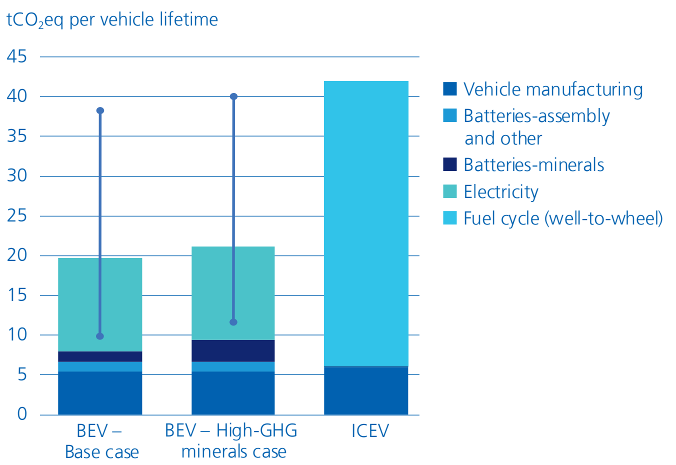
Figure 1: Global CO_2 emissions from transport by type in 2020



Source: IEA and the International Council on Clean Transportation, ICCT

Traditional internal combustion engine vehicles (ICEVs), which still made up ~93% of global passenger vehicle sales in 2021, have lifecycle emissions of ~42 tCO_2eq according to the IEA (Figure 2). This environmental footprint compares to lifecycle emissions of ~21 tCO_2eq for battery electric vehicles (BEVs) in a base case and ~22 tCO_2eq for BEVs in a high-greenhouse gas (GHG) minerals case.[1] Of course, the lifecycle emissions of BEVs largely vary according to how the electricity used in the vehicles was generated. However, a global comparison of average grid carbon intensity shows that BEVs are roughly half as emissions intensive as ICEVs over their lifetime. The lower lifecycle emissions of BEVs make them the preferred option for decarbonising transport. Note that this study does not account for the various hybrid or fuel cell engines, as it is highly likely that BEVs are going to play the key role in the future, anyway. Section 3 contains more on the growth dynamics of BEVs.

Figure 2: Comparison of the lifecycle emissions of BEVs and ICEVs



Source: IEA

Note: The "high-GHG minerals" case assumes double the GHG emissions intensity for battery minerals (70 $kgCO_2$-eq/kWh compared to 35 $kgCO_2$-eq/kWh in the base case; other assumptions are the same). The values are for a vehicle manufactured using today's manufacturing lines, assuming dynamic global average grid carbon intensity (including transmissions, distribution and charging losses and weighted for mileage decay over a 20-year lifetime). The ranges shown for BEVs represent cases for charging with a static low-carbon (50 gCO_2-eq/kWh) and high-carbon electricity mix (800 gCO_2-eq/kWh). Vehicle assumptions: 200 000 km lifetime mileage; ICE fuel economy 6.8 Lge/100 km; BEV fuel economy 0.19 kWh/km; BEV battery 40 kWh NMC622. NMC622 = nickel-manganese-cobalt in a 6:2:2 ratio. Lge = litre of gasoline equivalent.

[1] Please note that this study solely focuses on BEVs and explicitly excludes plug-in hybrid electric vehicles (PHEVs), mild hybrid electric vehicles (i.e., any automobile that still contains an internal combustion engine), or fuel cell electric vehicles (FCEVs).

2 SDG Identification

Growth in BEVs and EV batteries potentially contribute to achieving the following Sustainable Developments Goals (SDGs):

– Affordable and clean energy (SDG 7 and SDG Target 7.1)
– Decent work and economic growth (SDG 8 and SDG Targets 8.1 & 8.2)
– Sustainable cities and communities (SDG 11 and SDG Target 11.6)
– Responsible consumption and production (SDG 12 and SDG Targets 12.2, 12.4, 12.5, & 12.7)
– Climate action (SDG 13 and SDG Target 13.2)

3 Overview of the topic

This topic has several underlying drivers (section 3.1) that suggest significant economic potential (section 3.2). EV batteries and BEVs, the two key solutions to the challenge of decarbonising road transport, are analysed in depth in sections 3.3 and 3.4.

3.1 Drivers

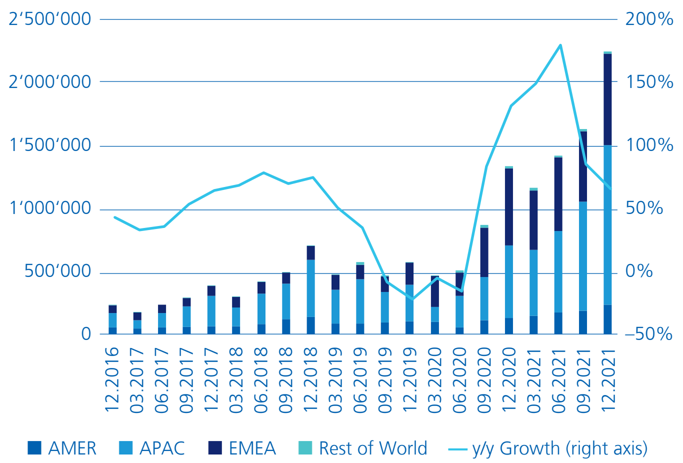
The main drivers are:

– EV demand
– EV subsidies that reduce the total cost of ownership
– EV charging infrastructure
– ICE phase-out targets

3.1.1 EV demand

Customer demand for EVs is probably the single most important driver for EV batteries and components. The increased focus of governments and corporates on the environment led to an unprecedented boom in EV sales in 2020 and 2021. Sales in the fourth quarter of 2020 surpassed the 1 million mark for the first time in history, growing 134% year-on-year. The strong EV sales growth trend continued into 2021 with quarterly sales remaining well above 1 million and year-on-year growth rates at 149%, 183%, and 93% for Q1, Q2, and Q3, respectively. Assuming that this trend will continue – even at a lower level – will result in significant demand for EV batteries and components.

Figure 3: Historic EV sales volume growth by region

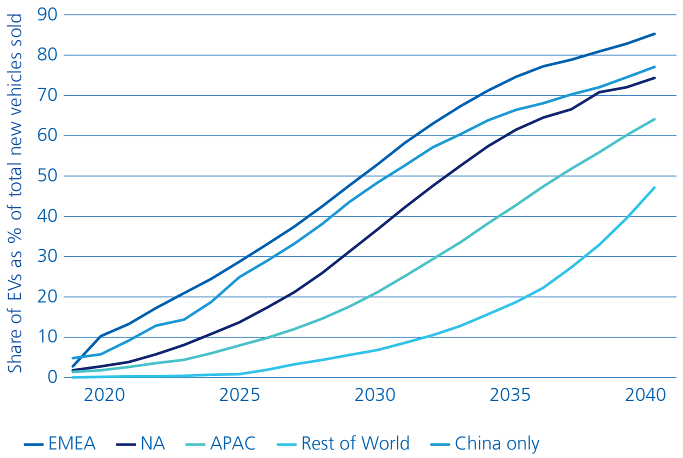


Source: BNEF

Note: Includes BEVs, PHEVs, and FCEVs. Commercial vehicles and low-speed EVs are not included.

Looking at BloombergNEF (BNEF) projections for future EV adoption, it is very likely that Europe and China will remain the uncontested leaders in terms of the highest share of EV sales as a percentage of total passenger vehicles sold (i.e., EV penetration) (Figure 4). Europe took over from China in terms of the lead position for EV penetration in 2020, reached 12% in 2021 and will probably continue to lead in EV penetration. China followed with 10% EV penetration in 2021, while EV penetration in North America (NA) and Asia-Pacific (APAC) will remain rather subdued at least in the coming years and will fail to achieve 20% EV penetration before 2027. EV penetration in the rest of the world, to which many emerging economies are assigned, is projected to remain at extremely low levels and is not expected to achieve double-digit EV penetration rates before 2030.

Figure 4: EV market outlook by region



Source: BNEF

3.1.2 Direct subsidies for BEVs

Subsidies in the form of direct cash reimbursements, scrappage schemes and income tax credits have played a very important role in the acceptance and adoption of BEVs in many regions across the world. They continue to play a role – which only seems logical as they close the price gap between EV and ICE vehicles – but with EV costs dropping further due to manufacturing scale and improvements in technology, this price difference is going to reduce and ultimately disappear. Countries like Singapore, Romania, France and Germany still offered generous subsidies of up to 12,000 EUR to customers buying an EV in 2021. Direct subsidies are an effective but expensive way of making a technology more attractive, especially in the early stages of development. Based on what could be observed with other technologies, it is reasonable to assume that the importance of subsidies will decline as soon as BEVs approach ICE cost parity.

3.1.3 EV charging infrastructure

Another major driver in terms of EVs is the availability of charging infrastructure; this will make BEVs relatively more attractive compared to ICE vehicles, which already benefit from an extensive refuelling network. It is important to note that building the type of refuelling network that many countries have today has also taken quite some time as it has often involved considerable investment and overcoming technical barriers. However, recent statistics show that global EV charging infrastructure is expanding quickly. Newly installed public connectors increased by 42% p.a. between 2015 and 2021 according to BNEF. This figure only accounts for public installations and does not include the growth in privately installed charging infrastructure, which has seen even stronger growth according to BNEF.

3.1.4 Governmental ICE phase-out targets

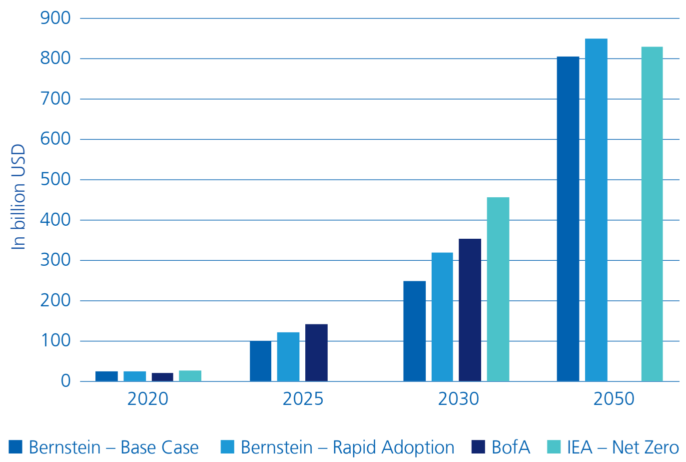
In addition to the EV subsidies described above, governments are starting to increase pressure on the whole automobile industry and its suppliers by implementing phase-out targets for traditional internal combustion engine (ICE) vehicles. In some countries, these phase-out targets have already, or are about to, become law. In other countries, phase-out targets are a rather loose government ambition, but the industry is already quite advanced in terms of EV penetration (as in Norway). Norway is aiming for 100% zero emission vehicle (ZEV) sales by 2025 and is, therefore, clearly a global leader. Other notable European countries such as Denmark, Ireland, France and the United Kingdom will follow suit by 2030, or 2040 at the latest. These phase-out targets move electric mobility to the top of the political agenda and – along with toughening standards for fuel economy and emissions – are very likely to incentivise and boost EV sales.

3.2 Economic potential

Estimates for the size of the total addressable market (TAM) for EV batteries vary quite considerably, depending on the source. The variation in estimates is not very surprising, given that it is still early days for this market, which is growing fast and consists of many moving parts.

In 2020, the yearly TAM was between USD 21 and 26 billion, which was still fairly small (Figure 5). Several preliminary estimates for the full year 2021 point to a growth rate of around 80-90% in 2021 alone, which would mean a TAM of about USD 35-40 billion. Bernstein estimates that the TAM will increase to USD 99 billion (base case) or even USD 121 billion (rapid adoption) by 2025. The Bank of America (BofA) even estimates a TAM of USD 142 billion by 2025, which would be a 5-year growth rate of 576% compared to 2020 levels. By 2030, TAM estimates range from Bernstein's base case of USD 249 billion to the IEA's net zero scenario of USD 456 billion. The compounded annual growth rate (CAGR) between 2020 and 2030 ranges from the least optimistic Bernstein base case scenario of 26% p.a. to the most optimistic IEA net zero scenario of 33% p.a. By 2050, most estimates point to a TAM of >USD 800 billion, which would be almost two-thirds the size of the 2020 TAM for oil, according to the IEA.

Figure 5: Estimated total addressable market (TAM) for EV batteries

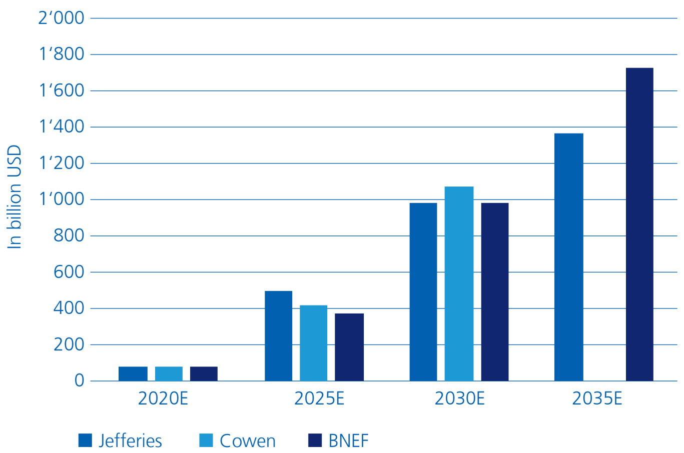


Source: Bernstein, BofA, IEA

Figure 6 shows the total addressable market for BEVs. The estimates were provided by Jefferies, Cowen and BNEF. In 2020, the estimated total addressable market for BEVs was on average approximately USD 73 billion. For 2025, they value the total addressable market to range between USD 493 billion – 371 billion, representing a CAGR of 47.6%, 40.9% and 37.8%, respectively. In the next 5 years until 2030, the total addressable BEV market will double to a range of USD 976 billion – USD 1,063 billion.

The CAGRs for the period 2025E – 2030E are 14.7%, 20.8% and 21.3%, respectively. Therefore, the CAGR is smaller compared to the 2020E – 2025E period, but is still high. According to BNEF, the BEV market will increase to about USD 1,722 billion compared to the total addressable market of USD 1,365 billion forecasted by Jefferies. The CAGRs for the period 2030E – 2035E are 6.9% and 12.0%, respectively.

Figure 6: Total addressable market (TAM) for BEVs



Source: Jefferies, Cowen, BNEF

According to the estimates of Jefferies and BNEF, the total average CAGRs from 2020E – 2035E are 21.9% and 23.3% respectively. The total addressable market forecast for BEVs is characterised by a period of high growth from 2020E – 2030E and a high single-digit to low double-digit growth phase between 2030E and 2035E.

3.3 Key solution – EV batteries

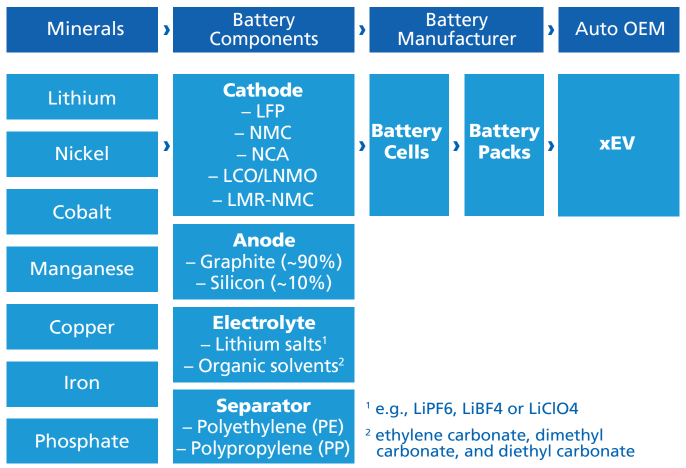
One of the key solutions for decarbonising road transport is EV batteries. Research produced by CLSA and Gartner suggests that lithium-ion batteries (LiBs) – the most common type of EV battery as of today – have just moved on from the "slope of enlightenment" to the "plateau of productivity". An error term is certainly included in this classification and Zürcher Kantonalbank's view is slightly different for the following reasons:

1. LiBs have become significantly cheaper to manufacture over the last 10 years but cost parity with ICEs (and thus wide-spread adoption) is still a couple of years away. This is in contrast to solar and wind energy, which are now the preferred option for new power generation capacity across the world
2. Manufacturers of LiBs are considerably ramping up capacity, which is why there are still higher economies of scale to be achieved (this is also less so for solar and wind, for example)
3. Despite noticeable advancements in battery technology during the past ten years, battery configurations are still evolving at a fast pace (from NMC622 to NMC811 or NCA, for example), showing that there is still significant potential for learning effects

3.3.1 Value chain

The EV battery value chain is very broad, ranging from the extraction and refining of minerals such as cobalt, lithium and copper to the final assembly of the battery packs that end up in BEVs, plug-in hybrid electric vehicles (PHEVs) and even fuel cell electric vehicles (FCEVs, Figure 7). There are only a few players that focus on one of the four parts of the value chain and these are mostly found upstream (i.e., in the materials and battery components business). Most companies within the battery manufacturer and EV OEM space are vertically integrated upstream, at least to a certain extent (i.e., they have some materials or components business for security of supply or, as for the EV OEMs, have their own battery manufacturing business to circumvent the battery manufacturer's margin).

Figure 7: EV battery value chain overview

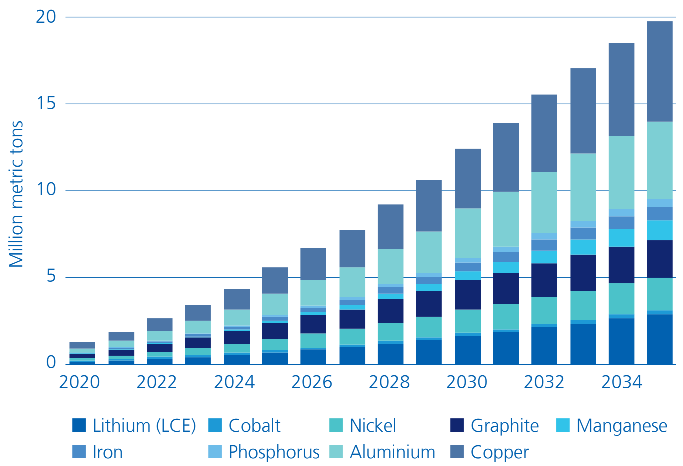


Source: Zürcher Kantonalbank

Minerals

The demand for minerals will expand significantly if demand for BEVs and thus EV batteries grows at the rates described above. There is a lot of uncertainty – as in all long-term forecasts – especially around precisely which metals are going to benefit from a potential EV boom. For example, developments in cathode chemistry over the next few years will heavily influence which materials will be more in demand and which less. Despite this uncertainty, BNEF forecasts that with all that we know about today's market, copper, aluminium, graphite and lithium are most likely to see the strongest pick-up in demand (Figure 8). However, given the scarcity of certain minerals (e.g., nickel or cobalt), it is likely that current extraction and refining capacities are not going to suffice.

Figure 8: Metal demand forecast for lithium-ion batteries



Source: BNEF

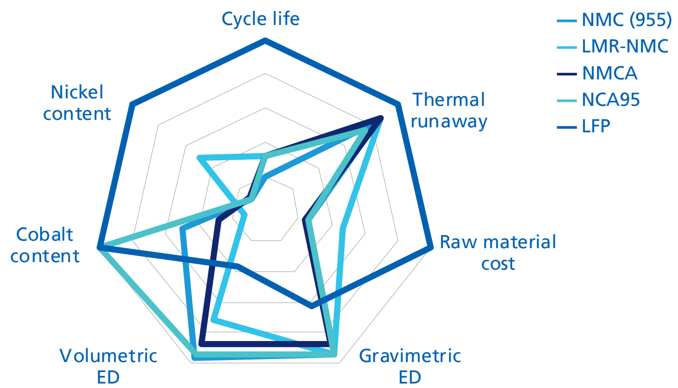
Cathode

Cathode chemistry is much more complicated than anode chemistry, given the various configurations that exist and the many more that manufacturers are currently researching and developing. The main motivation for developing cathode chemistry further is that it is the main determinant of energy density which, in turn, is key for the range of a BEV and thus its economics. That is also the reason why cathode chemistry is the single most important driver for reaching cost parity between BEVs and ICE vehicles. More information on when this state of cost parity could be achieved is included in section 3.4. In Europe and North America, the most popular cathodes are nickel-based (such as Nickel-Manganese-Cobalt (NMC) or Nickel-Cobalt-Aluminium (NCA)). For example, an NMC811 cathode contains 8 parts nickel, 1 part manganese, and 1 part cobalt. Nickel-based cathodes are known for having the highest energy density among the existing lithium-ion cathode chemistries.

However, not a new chemistry but one that saw a potential revival in 2020/21 is lithium ferrophosphate (LFP) (or lithium iron phosphate). LFP's main benefits are (Figure 9):

- Significantly lower material cost (because it contains no nickel, cobalt, or manganese)
- Higher thermal stability (providing more safety regarding battery fires)
- Longer cycle life (providing more charging cycles before capacity declines to a level at which the battery is no longer suitable for EV use)

Figure 9: Performance metrics for cathode chemistries



Source: BNEF

Note: ED stands for energy density. The outer edge of the circle represents a more desirable property. For nickel and cobalt content, the outer edge represents a low content.

At the same time, the primary disadvantage of an LFP cathode compared to nickel-based cathodes is its lower energy density (ED) at cell level. A lower energy density means that the battery cell contains less energy per volumetric (litre) or gravimetric (kilogram) unit which, in the case of an EV, translates into a shorter driving range. LFP has existed for many years but has never really gained ground outside of China. However, there were two important developments in 2020/21 that suggest a revival of the technology globally and a boom in China in the coming years:

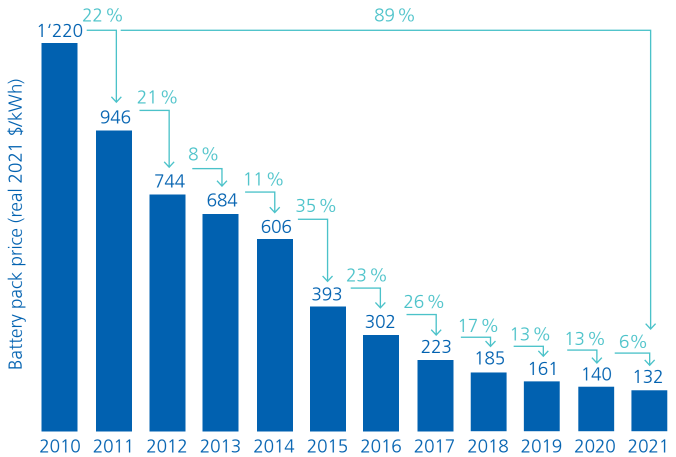
1. Prices for key materials for nickel-based cathodes (mainly nickel and cobalt) have significantly increased, whereas the materials used in LFP cathodes (mainly iron and phosphate) have remained relatively cheap. Therefore, the relative cost advantage (spread) of LFP further increased in the course of 2020/21. LFP cathodes contain 0.67kg of iron and 0.37kg of phosphate, which only made up 2% and 5% of the total cathode raw material costs. In NMC811 batteries, nickel accounts for 47% and cobalt for 18% of the raw material costs. All in all, total raw material costs in LFP are just USD 10 /kWh compared to USD 36 /kWh for NMC811. The significant raw material cost differential increased the spread between the prices paid for LFP and nickel-based cathodes in 2020/21, making LFP cathodes significantly more attractive for EV OEMs cost-wise.

2. Chinese companies such as the two largest LFP manufacturers, CATL and BYD, have significantly improved their battery designs in the last couple of years. Their improved battery design has not only reduced cost but also increased energy density at pack level. For example, CATL calls their new battery design cell-to-pack (CTP) technology, which completely eliminates the modules that usually collect the cells before they are assembled into the battery pack. CTP increases volumetric pack energy density by about 15%. BYD calls its new design blade technology as it uses very long cells, which are inserted into the pack. Blade technology increases volumetric energy density by up to 50%. Guoxuan (Gotion High-Tech) uses a similar battery design called jelly roll to module (JTM) that also increases pack energy density. Ultimately, these technology advancements reduce the gap between LFP and nickel-based batteries in terms of energy density.

3.3.2 Cost structure and development

Battery costs have come down quite significantly since 2010. Today's price of one kilowatt hour (kWh) of battery capacity sits at a record low of USD 132 (Figure 10). Back in 2010, the same kilowatt hour cost USD 1,220. Therefore, battery prices per kWh have fallen by 89% in just 11 years, which translates into double-digit price decreases in most years. The main drivers behind this massive cost reduction were advancements in technology (which increased battery energy density) and increasing economies of scale. Economies of scale are very important in the capital-intensive business of battery manufacturing. After all, building a battery manufacturing facility requires around USD 60 million per gigawatt hour (GWh) of battery capacity for low-cost Chinese manufacturers and up to as much as USD 100-120 million per GWh for European and North American manufacturers.

Figure 10: Changes in volume-weighted average battery pack prices

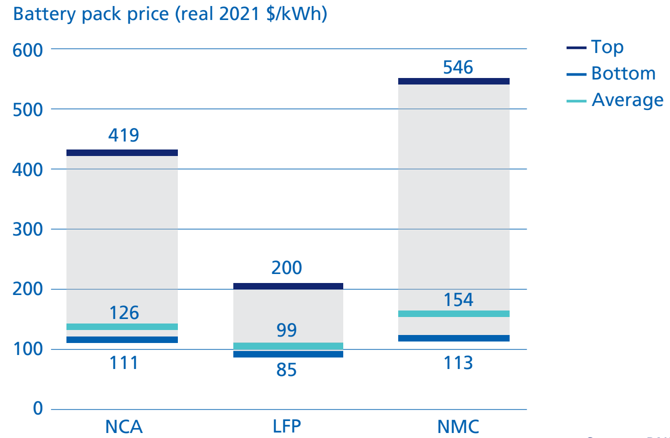


Source: BNEF

Reductions in the cost of the technology will generally make it more attractive, even though decreasing costs can also lead to a margin squeeze if selling prices drop at an even faster pace (for example, due to increased competition). It can be assumed that most BEVs will reach cost parity with ICE vehicles as soon as overall battery pack prices fall below ~USD 100 /kWh. This cost parity could be reached by 2024 or 2025, primarily depending on developments in technology and the prices of raw materials.

The numbers from Figure 10 do not account for the differences in cathode chemistries in terms of battery types. For example, LFP batteries had already achieved a volume-weighted average battery price of ~USD 99 /kWh in 2021 (Figure 11). These relatively lower costs (vs. NCA and NMC batteries) led to a significantly greater adoption of LFP batteries by EV OEMs in 2021. The most famous example of LFP adoption is Tesla (TSLA US), which announced it was moving all its Standard Range Model 3 produced in China in 2020/21 and all Standard Range Model 3 and Model Y ex-China in 2022f to LFP batteries. Tesla also announced it was targeting a 2/3 share for LFP batteries in the next couple of years. While LFP batteries are suitable for shorter-range vehicles (for example, city use), NMC/NCA batteries will still be required for the longer-range, premium vehicles demanded by customers. It is fair to say that advancements in technology and economies of scale should benefit both LFP and nickel-based (NMC/NCA) batteries more or less equally. The benefits of NMC/NCA batteries have already been discussed in section 3.3.1.

Figure 11: Volume-weighted average battery prices by chemistry



Source: BNEF

Note: The light blue line marks the volume-weighted average price, while the dark blue and blue lines represent the highest and lowest prices paid, respectively.

The main driver of the lower cost of LFP batteries is the use of cheaper materials (i.e., iron and phosphate) in the cathode. NMC/NCA batteries use materials that are usually more expensive (especially nickel and cobalt). The cost difference in cathodes in 2020/21 was ~USD 24.5/kWh (USD 10.5/kWh for LFP batteries and ~USD 35/kWh for nickel-based cathodes). A small part of that cost advantage for LFP batteries is offset by the greater use of copper foil (~USD 8-9/kWh) but ultimately, there is still a significant cost advantage of between USD 16 and 29 USD/kWh. For example, this difference can quickly result in a total cost advantage when using LFP batteries of ~USD 2,320 for an electric vehicle with an 80kWh battery.

3.4 Key solution – EV OEMs

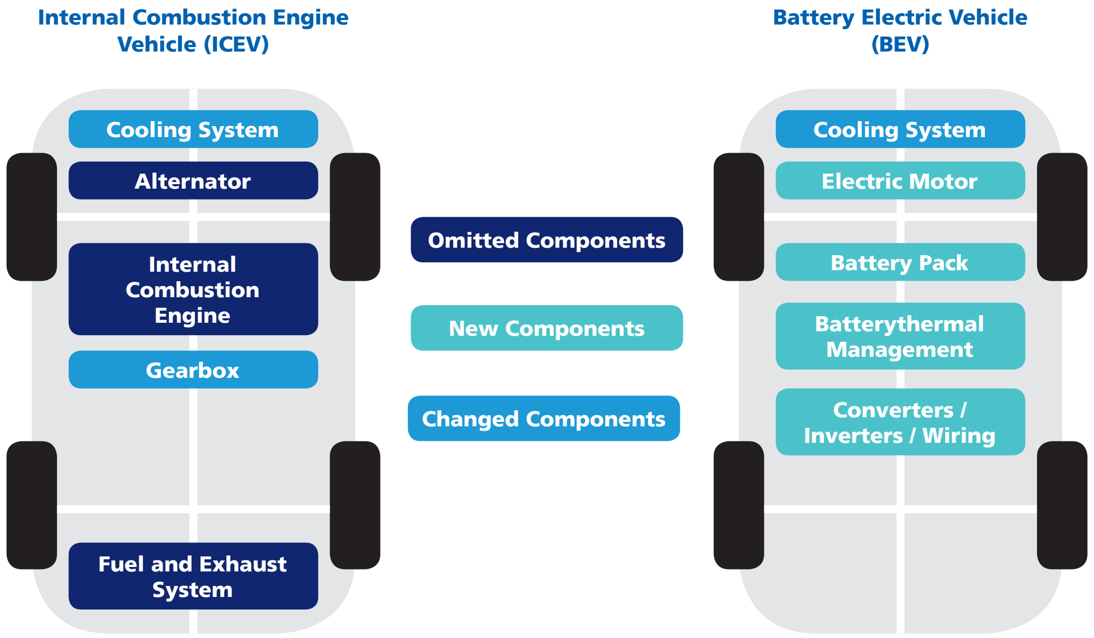
With regard to EV batteries, OEMs, suppliers and BEVs provide a key solution for decarbonising road transport. In section 3.4, we look into the value chain, cost and profitability developments, and the most important barriers to entry, with a special focus on OEMs.

3.4.1 Value chain

The long-term, established value chains of OEMs are in jeopardy because of the transition from an internal combustion engine vehicle (ICEV) value chain to a battery electric vehicle (BEV) value chain. This applies to both OEMs and their suppliers.

The traditional powertrain consists of three parts – the internal combustion engine, the alternator and starter, and thirdly, the fuel and exhaust system (Figure 12). These components are irrelevant for BEV powertrains and are replaced by a battery pack, a battery thermal management system and an electric motor. In addition, the multispeed gearboxes in ICEVs are replaced by simpler, single-speed transmissions due to the fact that the power output of electric motors is more efficient and consistent across a broader range of RPM (revolutions per minute). BEVs also require a cooling system, but the system is changed from one that cools the engine to one that cools the battery, and they require interconnection points and a chassis.

Figure 12: Differences in the production of BEVs vs. ICEVs



Source: BCG, UBS

Power electronic components are added to BEVs. These components include converters and inverters (DC/DC (direct current/direct current), DC/AC (direct current/alternating current), power electronics controllers, power electronics thermal management and high-voltage wiring. To illustrate the shift in components, UBS compared the Chevrolet Bolt's engine to an ordinary internal combustion engine and found that, on the one hand, the internal combustion engine has 113 moving parts compared to just three(!) moving parts in a BEV engine. On the other hand, the value of vehicle components to an OEM is estimated to be 30% higher for a BEV than for a comparable ICEV.

The automotive industry has invested more than 100 years in developing and improving powertrain manufacturing and vehicle assembly. The shift in production to BEVs will have a significant impact on OEMs' value chain, as shown in the next Figure.

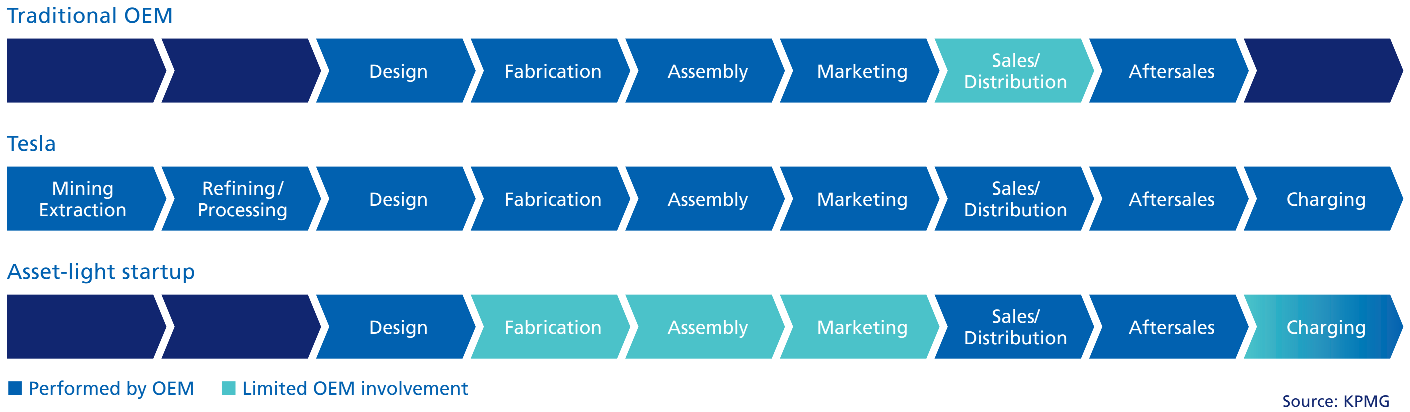
Value chain approaches

The transition into BEV production creates new value chain approaches for OEMs (Figure 13). Traditional OEMs performed the design, fabrication, assembly, marketing and aftersales of ICEVs. Tesla has taken a completely different approach to the value chain. Tesla tries to be as vertically integrated as possible. Besides the traditional OEM value chain, the value chain for Tesla includes the mining/extraction of the raw materials required for batteries, the refining and processing of chips, the software, and even a network of quick charging stations for BEVs.

Stronger vertical integration clearly has benefits regarding efficient investments, more control over product quality, and the planning of production. Elon Musk, founder and CEO of Tesla, said that Tesla's expansion of vertical integration compared to traditional OEMs will give Tesla a competitive advantage and keep Tesla ahead of traditional OEMs. However, the advantages are mitigated by the risks of vertical integration. These risks include significant capital investment, a complex management structure and the possibility of a price disadvantage compared to sourcing parts from suppliers.

Asset-light BEV startups like XPENG, Fiskar, Nio and Rivian differ again from the value chain of a traditional OEM by outsourcing the fabrication, assembly, and marketing of BEVs. Through this approach, the startups are not forced to have significant capital investment in fabrication and

Figure 13: Differences in the production of BEVs vs. ICEVs



Source: KPMG

assembly. Moreover, they outsource the production of BEVs to traditional OEMs or other manufacturers such as the iPhone producer, Foxconn, to benefit from the established, cost-efficient production of vehicles and the long-term partnerships between OEMs and suppliers. Asset-light startups are then only involved in the BEV/ICEV value chain in terms of design, sales/distribution and aftersales. The creation of charging stations is being pursued by some startups, while others intend to adopt the Tesla approach and subsequentially integrate vertically.

Make-versus-buy decisions

Within the BEV value chain and especially the battery and e-motor part, OEMs must evaluate their value chain strategy for make-versus-buy decisions. McKinsey assessed the decision-making process by considering seven factors for an OEM. The factors include organisational focus, internal innovation capabilities, degree of uncertainty, capex and economic issues, production speed, external constraints, and the desire for production control (Figure 14).

Figure 14: Recommendations for OEM buy – make approach

Battery pack and Battery Management-System	Battery module	Battery cells	E-motor and Inverter	Software developement and integration
Make if production volume > 50'000/year	Make if production volume > 100'000/year	Make if production volume > 500'000/year	Buy	Make

Source: McKinsey

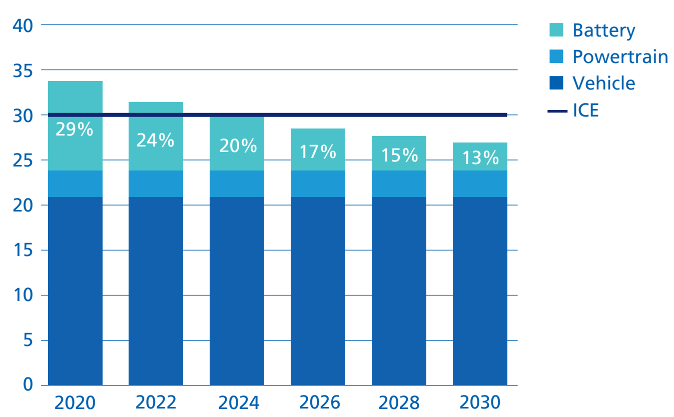
Overall, it can be concluded that control and external constraints clearly favour a "make" approach, while organisational focus and uncertainty regarding demand and technological progress favour a "buy" approach. The other categories show mixed results, depending on the battery and e-motor components. It is recommended that battery packs and battery management systems (BMS) be manufactured in-house for production volumes of more than 50,000 BEVs per year, battery modules for production volumes of more than 100,000 BEVs per year, and battery cells for production volumes of more than 500,000 BEVs per year. In addition, software development and integration for e-motor powertrains should be carried out in-house. Both e-motor components and inverter components should be bought from suppliers, clearly representing a shift for traditional OEMs, where ICEV engine development was one of the key focuses.

3.4.2 Cost developments

As mentioned earlier, many parts are eliminated and replaced in an ICEV compared to a BEV when transitioning from a conventional powertrain to an electrified powertrain. One would assume the fewer the parts, the lower the cost, but reality shows that mid-range BEVs are currently 30% to 50% more expensive than ICEVs. In fact, most OEMs today do not make a profit when selling BEVs.

BNEF estimates there will be a price parity between BEVs and ICEVs in nearly all segments and countries in the 2020s (Figure 15). In 2019, McKinsey expected a price parity in 2025, while BNEF (2022) anticipates that a price parity can be reached as soon as 2023 in Europe for the medium and large vehicle segment, in the U.S. for the large and SUV segment, in China for the medium segment and in South Korea for the SUV segment. This shows the great conversion efforts of OEMs towards BEVs and the technological progress that has led to battery cost reductions. Furthermore, due to improved fuel economy and pollution reduction technologies that must be added to vehicle designs, the manufacturing costs of ICEVs are expected to increase between 2022 and 2025. OEMs can additionally reduce BEV production costs by improving battery efficiency (requiring less battery capacity), improving power electronics and e-motors through integration and scale, and by reducing indirect costs through increases in annual production volumes (> 200,000 units).

Figure 15: BEV price parity



	Year of expected price parity				
Segment	U.S.	Europe	China	Japan	S. Korea
Small	2024	2027	2026	> 2030	2026
Medium	2024	2023	2023	2028	2024
Large	2023	2023	2026	2026	2025
SUV	2023	2024	2028	2025	2023

Source: BNEF

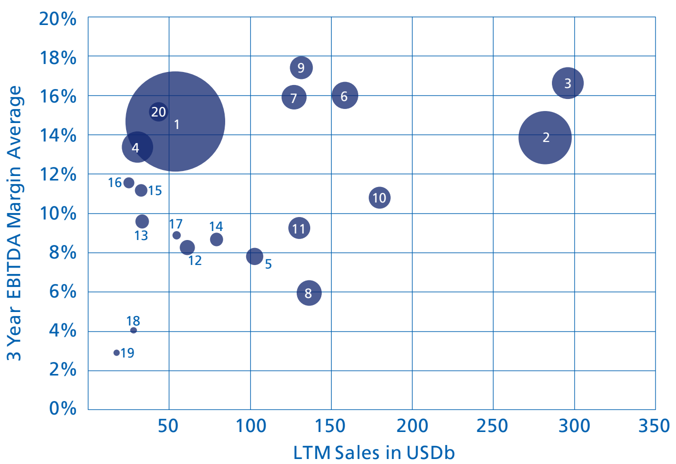
Note: Estimated pre-tax retail prices; the analysis uses data from the EPA, ICCT, FEV, ONRL and IDL.

3.4.3 Profitability developments

As shown in section 3.4.2, it is currently more costly to produce ICEVs than BEVs. This will certainly affect the profitability of OEMs until cost parity between ICEVs and BEVs is achieved.

Figure 16 shows the profitability measured as a 3-year average EBITDA margin and total LTM sales of OEMs. While the figure shows a clear picture of current market cap valuation, it also enables OEMs to be grouped in different clusters based on their sales and profitability. The company with the highest profitability is BMW with an average 3-year EBITDA margin of 17.5%. Other notable companies with high profitability are GM, Volkswagen, and Tesla, with 15.9%, 15.7%, and 14.7%, respectively. Tesla and BYD, two full BEV manufacturers, have an average 3-year EBITDA margin of 13.9% and 13.2% respectively, which is comparable to other OEMs. However, it is not clear how much of the EBITDA is truly from the manufacturing of cars, and how much is from other business fields, given Tesla's full vertical integration approach. A large benefit for Tesla and BYD is that they do not have to turn around production capacities from ICEV production to BEV production.

Figure 16: Bubble chart: profitability and sales



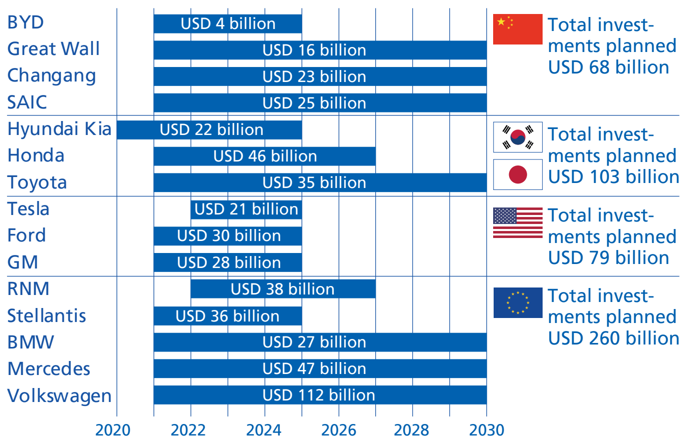
1 TESLA INC
2 TOYOTA MOTOR CORP
3 VOLKSWAGEN AG
4 BYD CO LTD-H
5 HYUNDAI MOTOR CO
6 MERCEDES-BENZ GROUP AG
7 GENERAL MOTORS CO
8 FORD MOTOR CO
9 BAYERISCHE MOTOREN WERKE AG
10 STELLANTIS NV
11 HONDA MOTOR CO LTD
12 KIA CORP
13 TATA MOTORS LTD
14 NISSAN MOTOR CO LTD
15 SUZUKI MOTOR CORP
16 SUBARU CORP
17 RENAULT SA
18 MAZDA MOTOR CORP
19 MITSUBISHI MOTORS CORP
20 VOLVO AB-B SHS

Source: Bloomberg

Note: The size of the bubbles represents the current market capitalisation of the companies.

Figure 17 shows the current EV and battery investment commitments of OEMs. The investments shown are aimed at improving the range and performance of batteries and reducing the cost of electric vehicles, as well as expanding the production of batteries and electric vehicles worldwide. The numbers do not include the investments in additional production capacities by battery companies. Many of these investments are in cooperation with their partners from the automotive industry.

Figure 17: EV & battery investments



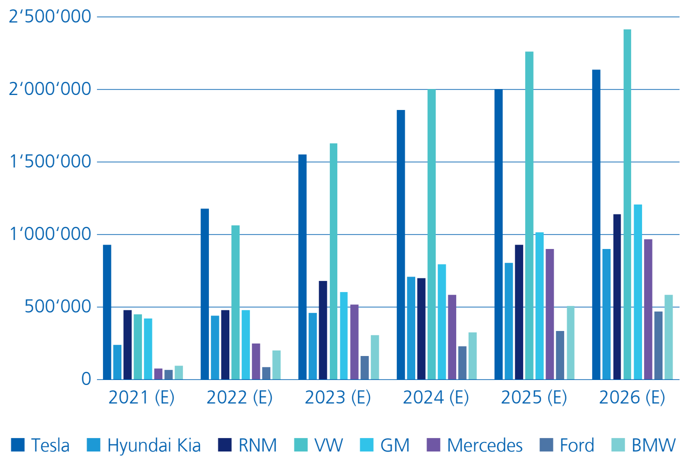
Source: Rhomotion, Reuters, company reports

It can clearly be seen that a restating of investment commitments took place during the Covid-19 pandemic. While announced investments in 2020 amounted to USD 215 billion, OEMs restated their investments of circa USD 485 billion by 2030 as a result of zero carbon mandates in various cities and countries and a higher demand from customers. But the announced investment commitments of OEMs could be a result of a band wagon effect whereby once a few manufacturers announced large EV and battery investments, other OEMs also needed to announce investment strategies to avoid being viewed as being left behind. Volkswagen leads the industry with announced investments of USD 112 billion by 2030, which clearly shows the aggressive rollout plan for BEVs in Europe, North America and Asia. By grouping the OEMs in locations, it can be seen that Europe leads the investments with USD 260 billion by 2030 compared with OEMs in the US (USD 79 billion), Japan/Korea (USD 103 billion) and China (USD 68 billion).

The high level of investment by European OEMs can be interpreted as catch-up investment as several European OEMs clearly missed the BEV trend and now need to recover BEV market share from Tesla and other BEV-only manufacturers.

The large and aggressive BEV push approach from VW can best be seen in Figure 18, which illustrates estimated BEV volumes by OEM until 2026. With the large rollout of roughly 15 new BEV models by 2023, and about 75 by 2025, VW could overtake Tesla as the BEV market leader by 2023. VW is targeting a 20% BEV sales mix by 2025 and wants to achieve the top end of an 8%–9% EBIT margin, which is comparable to current margin levels. Other OEMs that are largely shifting to BEVs are GM, RNM (Renault – Nissan – Mitsubishi) and Mercedes. GM is targeting annual global EV sales of more than 1 million by 2025 and plans to invest approximately USD 28 billion by 2025 so it can scale up faster and attract demand. Another key player will be RNM with total BEV investments in the region of USD 38 billion, 20 new BEV models in 2022, and a targeted BEV sales mix of 20% for the same year. Mercedes, which is also heavily investing in BEVs with around USD 47 billion by 2030, plans 10 new BEV models in 2022, and is targeting a 25% BEV sales mix by 2025. While Volkswagen and RNM can be classified as middle-class OEMs, Mercedes clearly separates itself from other premium OEMs by aggressively investing and entering the BEV market compared to other luxury OEMs like BMW.

Figure 18: BEV volumes by carmaker



Source: Bloomberg, Wood Mackenzie

It also needs to be noted that some large OEMs such as Toyota have a multi-drive approach where they do not focus on just one technology; instead, they are also investing in other technologies such as fuel cells. Toyota currently plans to release 15 new BEV models by 2025 and is aiming for more than 1 million annual global BEV sales by 2030. Compared to other OEMs, Toyota's plans are clearly lagging behind in the market and increasing the risk of arriving late at the BEV market share race.

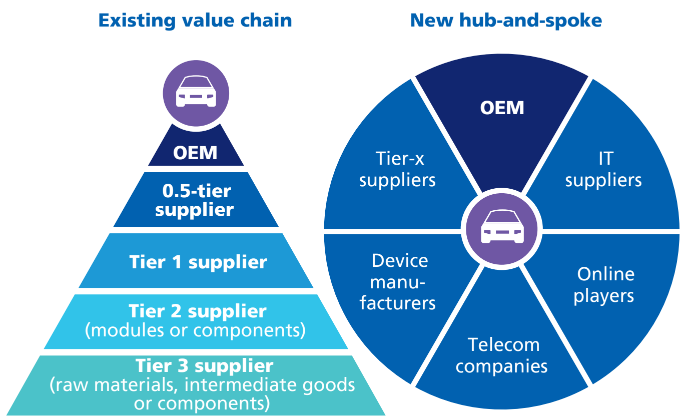
Previously, we discussed the investment, models and sales target for BEVs and OEMs. But the large, announced investments in BEVs will clearly affect near-term profitability. Both Tesla and BYD, who only manufacture BEVs, are evidently leading the market in BEV investments with a 5-year average R&D + capex to sales ratio of 18.5% and 18.2%, respectively. It is assumed that the total capex and R&D spent is invested in the development of BEVs, batteries and other BEV-related fields. In all, the large, announced investments combined with large capex and R&D costs have the potential to hamper short-term profitability. This is further increased by the higher cost of production for BEVs compared to ICEVs for OEMs. For the medium-term, as battery costs are approaching the USD 100/kWh threshold, BEVs will become more profitable than ICEVs.

3.4.4 Most important barriers to entry

Internal combustion engine vehicles have been developed and improved over a period of more than 100 years, especially in terms of manufacturing and assembly. In this period, the production of conventional ICEVs developed a high industrial complexity and is therefore a very high and capex intense barrier to entry. However, by analysing the complete OEM value chain, former strongholds such as aftersales, marketing, and design, which are barriers to entry, are slowly crumbling away and are giving asset-light startups and other companies the opportunity to enter the value chain of OEMs. Asset-light startups and other companies are able to enter the automotive market in various ways. They can be a developer of a BEV while outsourcing the production (i.e., Rivian, Lucid, Fisker, Nio, and Xpeng) or bring new technology to the production process (for example, autonomous driving) or take on single parts of the value chain (for example sales, due to better customer outreach and technical advantages).

The current car manufacturing value chain can best be described as a pyramid shaped value chain, where OEMs are at the apex of the pyramid and in full control of the ICEV value chain. Under the OEMs, there are several tier-x suppliers that provide raw materials, modules, systems and other components. With the transition to a BEV value chain and the integration of diverse technology, the chain will transform into a hub structure where the OEM is not in full responsibility of the value chain and therefore does not fully control the customer relationship.

Figure 19: Current value chain to hub value chain



Source: A.T. Kearney

To date, OEMs have largely been the leaders in automotive technology because of high R&D costs but other global companies with strong R&D teams and global market leadership (such as Google, SAP and Microsoft) are attracted to the future growth opportunities arising from technological advances in the automotive sector that overlap with their business models. While the average value of an automobile is currently 90% hardware and 10% software, it is expected that the share of hardware will plummet to approximately 40%, which will severely affect its profit pool. Software will increase its share to around 40% with 20% content driven, including the apps bridging hardware and software. Margin-wise, software and content providers are expected to achieve the highest margins.

4 Investment risks

The main downside risks inherent to this investment topic are:

- **Overinvestment:** One of the key risks for battery manufacturers is oversupply through overinvestment. However, it is highly likely that this oversupply would be limited to certain regions (for example, China) while other regions could remain rather undersupplied as they are today (such as Europe). Whether the industry is going to see oversupply or undersupply will also depend on the costs of shipping/logistics and other potential barriers (such as patent agreements) to exportation from regions of oversupply to regions of undersupply.
- **EV battery margin squeeze:** Connected to a potential oversupply as well as developments in raw material costs (for example, lithium prices) is the risk of a margin squeeze resulting in reduced profitability for battery manufacturers or other companies in the battery value chain. Oversupply would put pressure on manufacturers' average selling prices (ASP) to secure market share ('price war') and reduce profitability as a result. Higher raw material costs could lead to a margin squeeze if manufacturers are not able to pass on higher costs downstream.
- **Technological disruptions:** A potential threat to established battery and component manufacturers as well as BEV OEMs is posed by technological disruptions such as hydrogen drivetrains, solid-state battery technology and silicon anodes.
- **BEV short-term/mid-term profitability:** As the margins for BEVs are lower when compared to ICEVs and OEMs must invest heavily to transform the current value chain into a BEV-compatible value chain, short-term profitability may well be hampered.
- **Increased competition and lower barriers to entry:** EV transition has lowered the barriers to entry for start-ups. This will increase competition in the BEV market, which will increase the pressure on traditional OEMs.
- **New mobility concepts:** MaaS (Mobility as a Service) concepts will additionally put pressure on traditional OEMs, since they are in a follower position that will require large investments in automated driving and artificial intelligence to increase scale.
- **Parallel production structures:** The transition from ICEVs to BEVs forces many OEMs to operate parallel production structures to build up BEV production and meet current ICEV demand. Parallel production will lead to higher costs and may result in production deficiencies.

5 Conclusion

The BEV value chain offers plenty of opportunities but – given potentially disruptive developments and competing solutions on the horizon – not without significant downside risks. If commercialised, solid-state battery technology could prove to be a real game changer by offering a significantly increased energy density (resulting in considerably lower costs in kWh/USD terms). In EV batteries, investment opportunities with the most favourable risk-reward can be found in vertically integrated, large players that have significant economies of scale, cost advantages, security of supply and experience as well as the knowledge to keep up with technological developments.

The traditional value chain of OEMs is in jeopardy. As demand for BEVs and regulatory changes increases, OEMs are entering the BEV market. The BEV OEM market comprises traditional players as well as asset-light startups that profit from a lower barrier to entry. As additional investments are required when turning ICEV production into a BEV production, short-term and medium-term profitability will be hampered. This is fostered by the larger production costs of BEVs compared to ICEVs. High double-digit growth rates in the BEV market will also attract investors. However, OEMs have to be cautious when investing, due to the short-term and medium-term profitability risk. It is advisable to fundamentally analyse OEMs and suppliers to identify companies that offer an attractive risk-reward in the BEV market.