Powered by UBS Evidence Lab

Q-Series
UBS Evidence Lab Electric Car Teardown – Disruption Ahead?

Equities

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1 electric car teardown, 6 pivotal questions, 39 UBS analysts providing answers

We tore down the Chevy Bolt, the world's first mass-market electric vehicle (EV) with a range well above 200 miles. We gained key insights to understanding the content and profitability of EVs, especially Tesla's upcoming Model 3. Our findings expand beyond the autos industry to include technology, capital goods, chemicals and commodities.

$4.6k cheaper than we thought – EVs to be profitable sooner, incl. Model 3

We found that the EV powertrain is $4.6k cheaper to produce than we thought and there is more cost reduction potential left. Consumer cost of ownership (TCO) parity vis-à-vis combustion engine (ICE) cars can be reached from 2018 (first in EU), creating an inflection point for demand. We raise our 2025E EV sales by ~50% to 14.2m, or 14% of global car sales. We estimate GM loses $7.4k (EBIT) with every Bolt sold today, mainly due to the lack of scale. Because of many similarities between the Bolt and Tesla's long-awaited Model 3, we estimate Tesla incurs an EBIT loss of $2.8k per vehicle in its base version, but will break even at an ASP of $41k – a level most likely to be exceeded. We generally expect the profitability of premium EVs to be higher than in the mass segment. Once TCO parity is reached, mass-brand EVs should also turn profitable.

Widespread impact on auto sector, technology, chemicals, cap goods and more

For OEMs, earlier cost parity means earlier and more visible returns on the current high R&D. Furthermore, the contribution of EVs to CO_2 fleet targets, particularly in Europe, will remove a key cost burden. For our tier-1 supplier coverage, the teardown delivered two takeaways: (1) LG, a new entrant in automotive, has ~56% content in the Chevy Bolt, whereas "traditional" tier-1 suppliers only exist outside the electric powertrain. (2) Our detailed analysis of moving and wearing parts has shown that the highly lucrative spare parts business should shrink by ~60% in the end-game of a 100%-EV world, which is decades away. EVs are an opportunity for tech companies because the electronics content in the Bolt is $4k higher than in an ICE car, excluding the battery. Commodities-wise, we detected the highest deviation in weight shares between the Bolt and ICE car in copper, aluminium, battery active materials and rare earths.

Stocks positively and negatively impacted by the theme

A comprehensive list of stocks positively or negatively impacted in autos (OEMs and suppliers), chemicals, batteries, tech, and capital goods can be found on page 59.

Executive summary

Tearing down the world's first mass-market electric car

We are more convinced than ever that electric cars are about to reach the tipping point in the penetration curve in the next few years. This new generation of electric cars has far-reaching implications for the global autos industry, but also for many other sectors, such as capital goods, chemicals, mining, technology, and energy. The only way to better understand these implications was to tear down the first vehicle of its kind, piece by piece. So, that is what we did. We tore down the Chevrolet Bolt, which we consider the world's first *real* mass-segment electric vehicle (EV). The Bolt combines a $37k price tag ($30k including US government subsidies) with an EPA-estimated range of 238 miles on a single charge, which surpasses competitors by at least 30% in this price segment. Moreover, the Bolt has a price tag and range similar to the upcoming Tesla Model 3, which is Tesla's long-awaited entry into the mass market.

238-mile range

$37k price tag

Figure 1: UBS Research and UBS Evidence Lab have gone the extra mile

Source: UBS

UBS's Q-Series products reflect our effort to aggressively anticipate and answer key investment questions, to help drive better investment recommendations. Q-Series is a trademark of UBS AG.

Figure 2: Pivotal questions we can answer thanks to the teardown

Pivotal questions	Our answers	For details …
Q: When will EVs reach consumer cost parity, and what will be the impact on EV sales?	- Europe is first in 2018E but still at a loss for the OEMs; true cost parity (5% OEM margin) is reached in 2023E. - Raising forecasts by ~50% to 14% global sales penetration (30% in Europe) by 2025E.	*Click here*
Q: What is different in an EV like the Chevy Bolt, compared to an equivalent ICE car?	- Much less mechanical complexity, far fewer moving and wearing parts. - EV powertrain $9k more expensive today, going down to $4k by 2025E.	*Click here*
Q: How profitable are EVs like the Bolt and the upcoming Tesla Model 3?	- Bolt: $7k EBIT loss per car 2017E, going to $6k profit in 2025E, holding price stable. - Tesla Model 3: $2,800 loss per car today on base version, but well-equipped versions should be profitable. We estimate $41k is the break-even point.	*Click here*
Q: What is the impact on the auto industry?	- OEMs: EVs become profitable sooner; more CO_2 benefit, particularly for EU OEMs. Finco risk is the key downside. - LG as a new entrant has ~56% content share in the Bolt. - Mixed picture for "traditional" tier-1 suppliers and long-term threat in aftermarket.	*Click here*
Q: How are global commodities markets influenced by the shift to EVs?	- Highest impact on markets for aluminium, copper, battery active materials, rare earths (all positive) and platinum group metals (negative). - Largely no impact on steel demand.	*Click here*
Q: How much more electronics and semi content is in an EV, and who is set to benefit?	- $3k more electr(on)ic content (ex battery). - EV powertrain contains c$580 of semiconductor content compared to an ICE car at $60-90. - Electronics powerhouses and semi suppliers likely to grab substantial market share. - Shift to EVs is one of the two structural trends driving up semi content (along with autonomous driving). Autos to be one of the fastest-growing markets for semis.	*Click here*

Source: UBS estimates

Note: This Q-Series focuses on the differences between an EV and ICE car. Stay tuned for further teardown research about tech content outside the powertrain.

Q: When will EVs reach consumer cost parity, and what will be the impact on EV sales?

- **Surprise finding #1:** In the Bolt's powertrain, costs are $3k lower for the battery and $2k lower for the other modules versus our previous expectations. This means TCO parity between EVs and ICE is reached 2-3 years earlier.

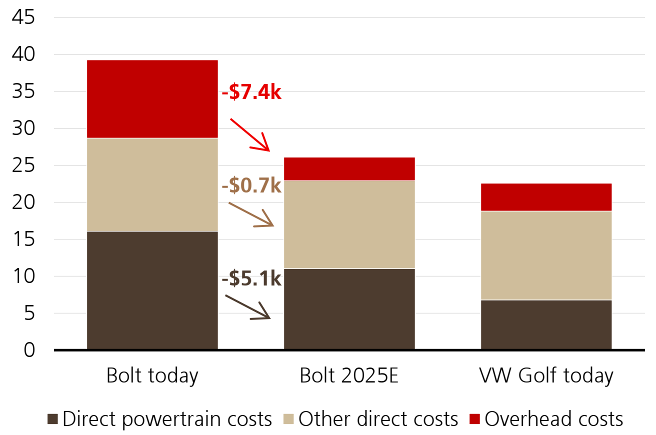
- The battery pack, which is the largest cost item in the Bolt, is likely to become 36% cheaper by 2025E, from ~$12.5k today to ~$8.0k. Therefore, the cost difference (not the retail price difference) between the Bolt and the VW Golf, which we consider an equivalent ICE car, appears set to shrink to $2.3k.

- On a total cost-of-ownership basis (TCO), which also factors in the Bolt's lower energy and maintenance costs (the latter is even lower than we thought), *true* TCO parity (*true* meaning the OEM makes a 5% EBIT margin) should be reached in Europe in 2023E, and in China in 2026E ex subsidies, 2-3 years earlier than previously expected.

$5k cheaper

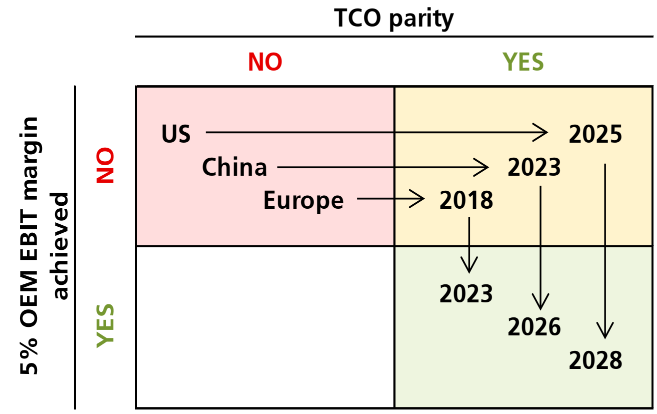
TCO parity 2-3 years earlier

Figure 3: Cost breakdown ($ per car) – Bolt versus Golf



Source: UBS estimates

Figure 4: TCO analysis

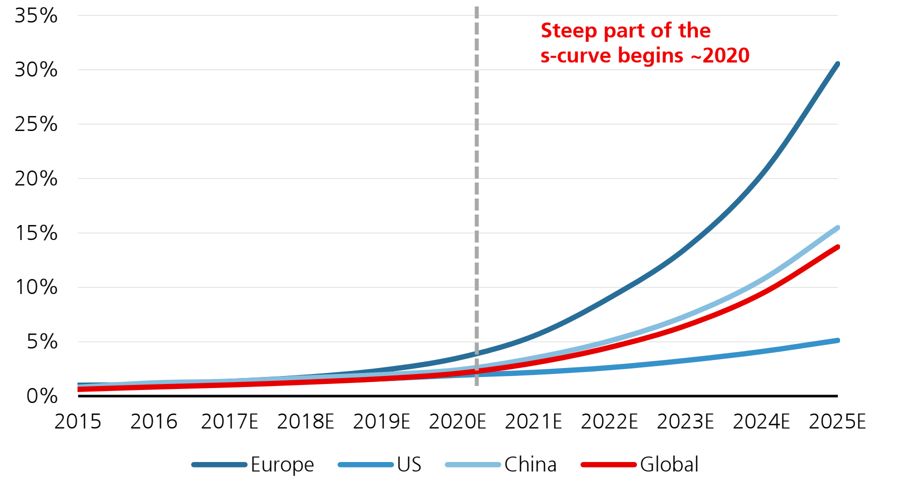


Source: UBS estimates

As a consequence of earlier-than-expected cost parity, we raise our EV sales penetration forecasts. We now forecast 3.1m EVs sold in 2021E (battery-electric cars and plug-in hybrids) and 14.2m sold in 2025E, instead of 2.5m and 9.7m previously. In our updated global market model, the share of EVs in global annual new car sales is now 3% in 2021E and 14% in 2025E. The difference with our old forecast mainly stems from Europe, where we now expect 30% EV sales in the mix in 2025E. While the new numbers appear aggressive at first glance, they are in sync with the findings from our ~10k consumer-strong UBS Evidence Lab survey and are not contradicted by availability of battery raw materials and required investments in electricity infrastructure. We have also raised our forecasts for Japan and the US, albeit from a low base. The US is likely to lag due to worse consumer economics (lower fuel prices). We see upside risk to our US forecasts in the event of a return to a more benign political environment at the federal level or rapidly rising gasoline prices.

Electric car sales: 30% in Europe 14% globally in 2025E

Figure 5: Raising our global EV forecasts – steep part of s-curve getting closer



Source: UBS estimates

Q: What is different in the Chevy Bolt, compared to an equivalent combustion engine car?

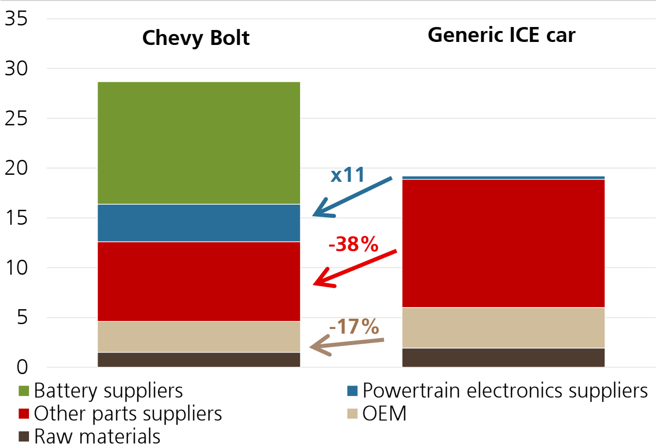
- **Surprise finding #2:** Some 56% of the vehicle content comes from outside the traditional auto supply chain.
- By value created, the share of tier-1 suppliers from outside the traditional auto supply chain reaches a remarkable ~56% (14% excluding the battery). In the case of the Bolt, the entire electric powertrain and infotainment modules are supplied by LG. This comes at the expense of "traditional" tier-1 suppliers.
- Mechanical complexity is much lower, whereas electronic complexity is higher. We counted 24 moving parts in the Bolt's powertrain, versus 149 in the Golf. The powertrain electronics content is $4k higher on the tier-1 level, motor included.

56% LG content

24 versus 149 moving parts

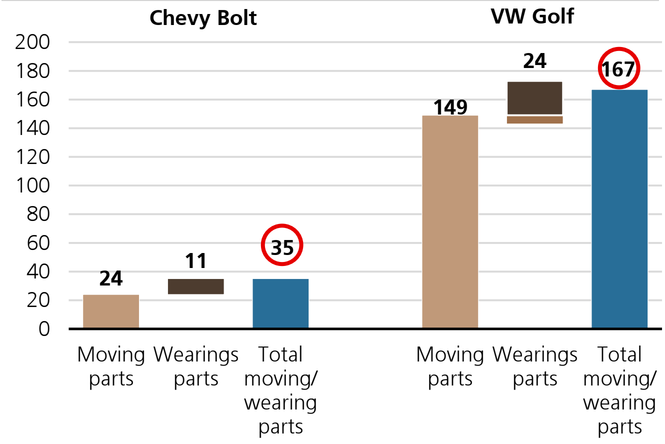
+$4k electronics

Figure 6: Vehicle content on tier-1 level by sub-sector ($k)



Source: UBS estimates

Figure 7: Number of parts in the powertrain



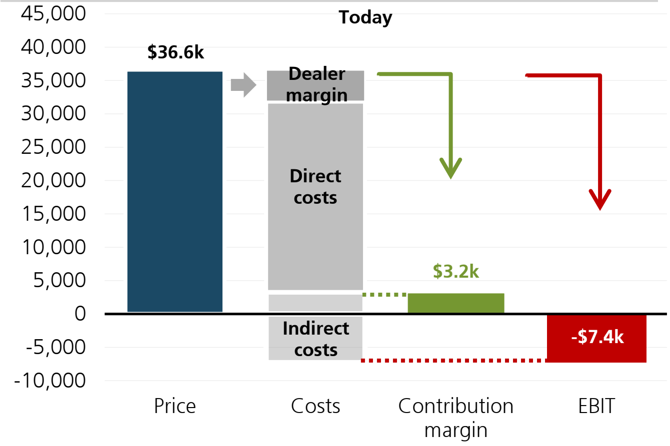
Source: UBS estimates

Q: How profitable are EVs like the Bolt and the upcoming Tesla Model 3?

- **Surprise finding #3:** The Model 3 will require an ASP of ~$41k to break even, on our calculations. This is only ~$6k above the expected base price, and very likely to be exceeded.

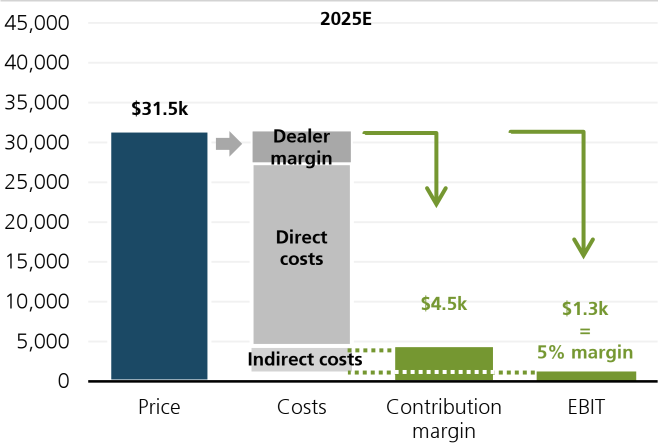
- We estimate that GM loses ~7$k per vehicle at the EBIT level, but the contribution margin (selling price less variable production costs) is in positive territory at ~$3k. Based on our component costs forecasts, the EBIT per vehicle can improve to $1.3k (5% EBIT margin) by 2025E, assuming that the lion's share of the cost savings need to be passed on to the consumer in order to reach TCO parity.

Figure 8: How much money does GM lose with a Bolt today (EBIT/contribution margin in $)...



Source: UBS estimates

Figure 9: ...and how will it evolve until 2025E?

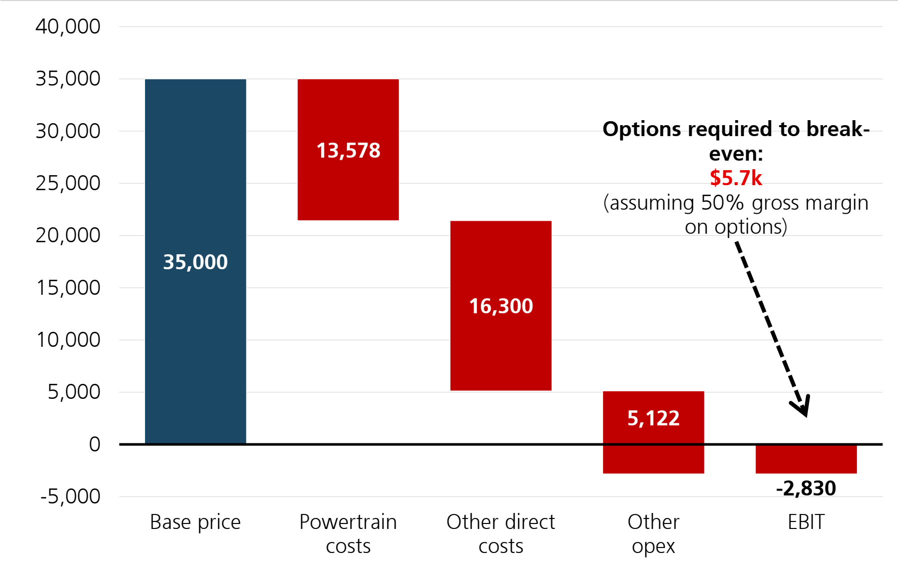


Source: UBS estimates

- The findings on the Bolt enable us to assess the profitability of the long-awaited Model 3, Tesla's entry into the mass segment. We estimate that Tesla will require an achieved selling price of ~$41k for the upcoming Model 3 to break even at the EBIT level. This is ~$6k above the estimated base price of $35k. As Tesla buyers are likely to order well-equipped versions (margins on the options should be ~50%), the required ~$41k threshold is likely to be well exceeded, in our view.

$41k break-even price for Model 3

Figure 10: What will be the break-even selling price ($) for the Tesla Model 3?



Source: UBS estimates

Q: What is the impact on the auto industry?

- **Surprise finding #4:** The transition to EVs could be better than feared for OEMs from a return and CO_2 cost perspective, but there are potentially more risks for "traditional" tier-1 suppliers. This is contrary to the consensual view that suppliers are better positioned to master the transition to EVs.

- **OEMs:** EV manufacturing costs are likely to be lower than previously expected, which means: (1) profitability for OEMs can be better; and (2) volumes can grow faster, leading to better economies of scale and a faster return on current high investments. The positive contribution of EVs to CO_2 fleet targets, in particular in Europe, is another key positive. The flipside is elevated residual value risk for OEMs with own fincos, as well as lower contribution from the highly profitable aftermarket (10-15% of EBIT today).

EVs profitable sooner

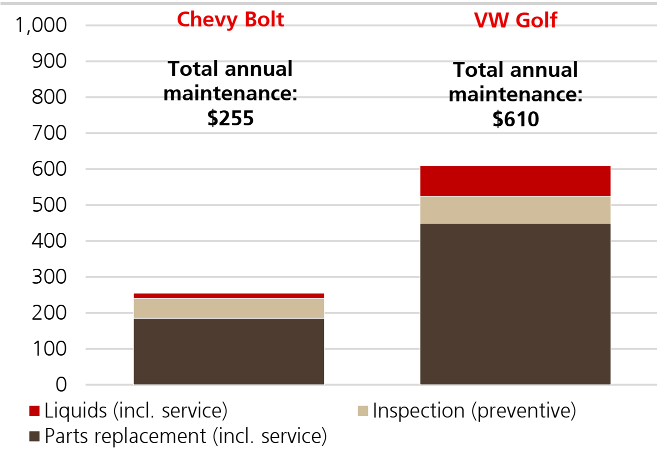
- **"Traditional" tier-1 suppliers:** Better EV economics and higher growth induces better and earlier returns on high current EV-related investments. However, the content per vehicle will likely decline due to the higher content share of non-traditional suppliers (but there will be a large variance among individual players). Some suppliers will have to write down some divisions or product lines, mostly related to emissions. Also, revenues from the lucrative spare parts business, which accounts for ~20% of EBIT, are likely to drop by ~60% in the long term in an EV world. However, this scenario is several decades away. We expect more M&A activity in the supplier space.

Threat of new entrants

- **Aftermarket:** The Bolt is almost maintenance-free. Not only do fewer parts need to be replaced over the car's life, it also does not require a regular change of fluids, such as engine oil. On our analysis, the after-sales revenue pool could drop by ~60% or >$400 per vehicle per year. This should pose a major challenge for dealerships, which typically generate >40% of their gross profit pool in service and maintenance.

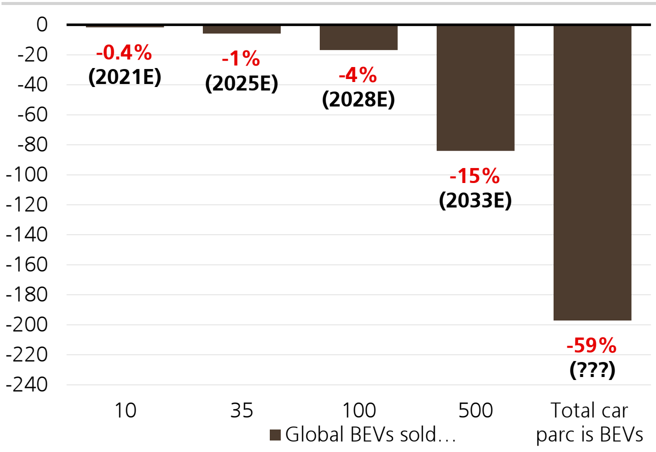
~60% decline in aftermarket

Figure 11: The Bolt has ~60% lower after-sales costs ($)



Source: UBS estimates

Figure 12: Aftermarket revenues ($bn) to drop by ~60%



Source: UBS estimates

Q: How are global commodity markets influenced by the shift to EVs?

- **Surprise finding #5:** The Bolt's body and chassis are fairly conventional in terms of the commodities used. It has, however, a 70% higher aluminium content (we expect an even higher aluminium share in premium EVs). We have not found any carbon fibre-reinforced polymers. The Bolt's total weight is 22%

higher than that of the VW Golf, mainly due to the battery. The key differences between the Bolt and the Golf are the following:

Less steel, more aluminium

- **Steel, aluminium, copper:** There is 7% less steel in the Bolt, but meaningfully more aluminium and copper. If all passenger vehicles sold were electric, the incremental decline in steel demand would be marginal in the context of the global steel market, while aluminium demand would increase by 13% and copper demand by 21%, compared to today's market size (based on the Bolt).

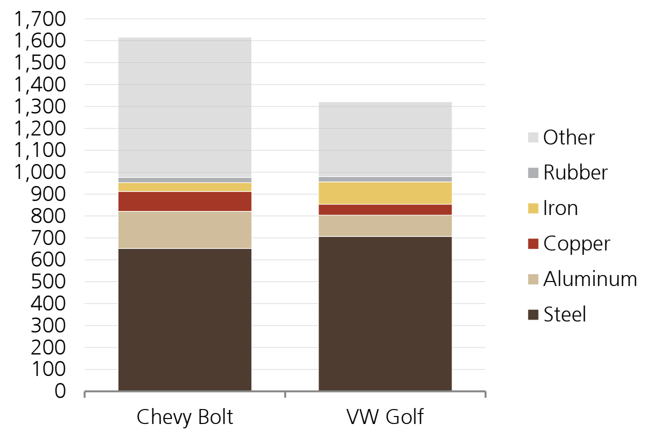
Battery materials boom

- **Battery active materials:** Commodity markets in the lithium battery supply chain would be most disrupted by a rapid increase in EV penetration, in particular lithium, cobalt and graphite. But only cobalt faces the issue of limited reserves, whereas for the other materials, current production capacity is the only bottleneck. New cell generations, however, will use less cobalt.

Neodymium, platinum

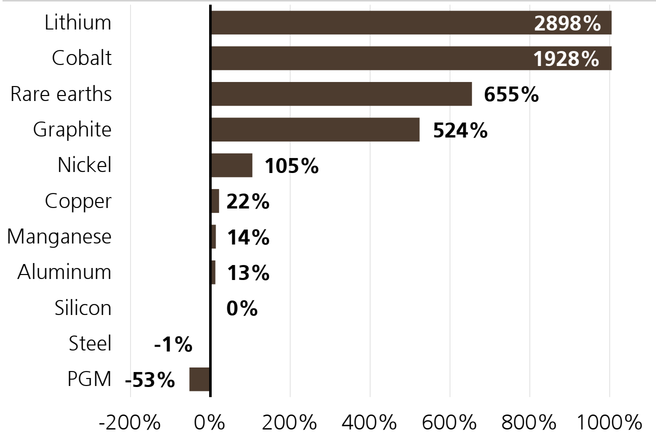
- **Rare earths, other:** The market for rare earths, neodymium in particular, could face demand shocks in case of a rapidly evolving EV market. The material is used in the e-motor magnets. There is only one obvious loser among global commodities in a 100% EV world: platinum group metals, which are used in ICE emission treatment solutions.

Figure 13: Weight of key commodities – Bolt versus Golf



Source: UBS estimates

Figure 14: Incremental commodity demand in a 100% EV world (% of today's global production)



Source: UBS estimates

Q: How much more electronics and semi content is in an EV, and who is set to benefit?

6-10x more semi content

- **Surprise finding #6:** We estimate that the Bolt EV powertrain has $580 semiconductor content, or 6-10x more than an average equivalent ICE car, such as the VW Golf.

- We estimate that, in an ICE, the powertrain electronics can range from as much as $60 to $90, implying a significant step-up, even for a relatively low-end mass-market EV. At this point, we are only focusing on the powertrain; however, we did also tear down the infotainment/connectivity/ADAS components, which will be analysed in separate research.

Summarizing the impact by sector

EVs will have a strong fundamental impact on many sectors. UBS global sector teams have contributed their analysis based on the findings from the teardown. Further, they have highlighted the stocks most positively or negatively exposed.

Figure 15: Sector map – impact from EVs at a glance

EV impact on …	Revenue growth	EBIT margin	ROIC	Valua-tion	Sector impact & UBS positively/negatively impacted by the theme
Auto OEMs	→	↘	→	→	**Sector impact:** Better EV profitability, CO_2 tailwinds, more Finco risk **Positively impacted:** Daimler, Volkswagen, Renault, GM **Negatively impacted:** FCA, PSA, Subaru
Auto suppliers	→	↘	↘	→	**Sector impact:** Top line impact varies, risk of content loss to new entrants, aftermarket risk **Positively impacted:** Valeo, Delphi, Conti, Hyundai Mobis **Negatively impacted:** Schaeffler, Faurecia, Tenneco
Battery producers	↗	↗	→	→	**Sector impact:** Strong top-line growth to drive EBIT break-even in 2018/19 **Positively impacted:** LG Chem, Samsung SDI **Positively impacted but priced in:** Panasonic
Capital goods	Varies widely by company				**Sector impact:** Mixed. Auto capex winners but some players lose content (bearings) **Positively impacted:** Siemens, Atlas Copco, Hexagon, GKN **Negatively impacted:** SKF, Rheinmetall, Sandvik, Kennametal
Chemicals	→	→	↘	→	**Sector impact:** EV winners in battery value chain; ICE losers (catalyst materials) **Positively impacted:** Umicore, LG Chem, Asahi Kasei, Sumitomo Chem, Albemarle, Sika **Negatively impacted:** Johnson Matthey, BASF, Clariant, EMS Chemie
LG companies	↗	→	→	→	**Sector impact:** 56% content in the Bolt from LG Group as automotive new entrant **Positively impacted:** LG Chem, LG Display **Positively impacted but priced in:** LG Electronics
Commodities	↗	↗	→	↗	**Sector impact:** Positive for most commodities **Positively impacted:** Lithium, cobalt, graphite, nickel, rare earths **Negatively impacted:** Platinum and palladium
Semicon-ductors	↗	↗	↗	→	**Sector impact:** Electric and autonomous cars as a key growth driver **Positively impacted:** Most autos semis – we favour Infineon, Texas Instruments **Positively impacted but priced in:** Melexis, STMicro

Source: UBS estimates

** UBS Evidence Lab provides our research analysts with rigorous primary research. The team conducts representative surveys of key sector decision-makers, mines the Internet, systematically collects observable data, and pulls information from other innovative sources. It applies a variety of advanced analytic techniques to derive insights from the data collected. This valuable resource supplies UBS analysts with differentiated information to support their forecasts and recommendations—in turn enhancing our ability to serve the needs of our clients.*

For this report, UBS Evidence Lab entered an exclusive partnership with Munro & Associates. The Auburn Hills, Michigan based firm is specialized in teardown benchmarking and accurate costing in the automotive industry. The project included a teardown of all electric powertrain-related parts and components – in essence, everything that's different compared to a combustion engine car. Furthermore, Munro tore down the modules related to connectivity / HMI and ADAS (advanced driver assistance systems).

The Munro cost estimates reflect the cost an automaker would pay a supplier. Generally, these costs are calculated by estimating the raw material costs, the amortization of parts tooling, and estimating labour costs and applying an industry standard mark-up for supplier overhead and profit. To create its estimates, Munro looks for numerous variables, including materials and material comparisons, process, machinery, tooling, labour (modelled by region of production), geography, competition, and logistics.

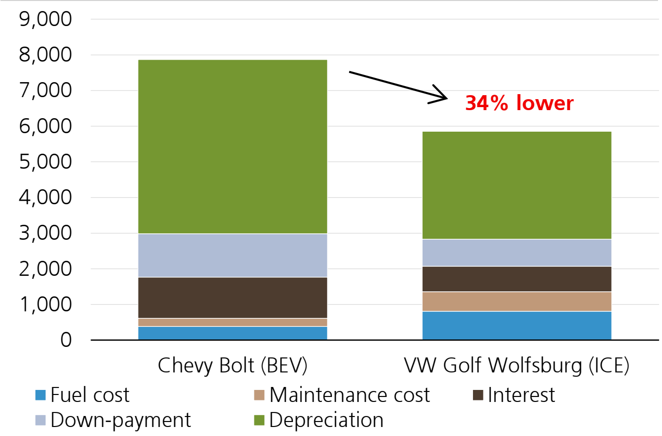
We would like to thank the Munro team for its excellent collaboration and enthusiasm throughout the project.

Q: When will EVs reach consumer cost parity, and what's the impact on sales?

TCO parity already almost reached in Europe today

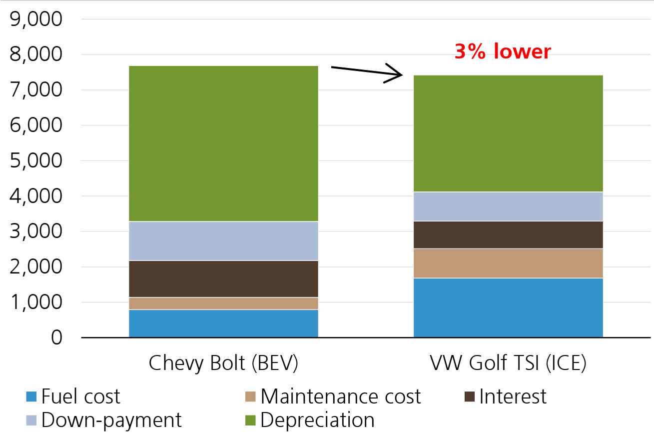
Because of lower vehicle component and also maintenance costs than previously expected, total cost of ownership (TCO) parity to consumers between EVs and ICE cars is reached earlier than modelled in last year's Q-Series *What is the Powertrain of the Future?*. The charts below illustrate cost of ownership today in the US and Europe. It can be seen that thanks to higher fuel prices, TCO parity in Europe has almost been reached already today, whereas the Golf is significantly cheaper in the US. The detailed assumptions and maths are shown in the appendix of this report.

Figure 16: TCO analysis Bolt vs. Golf – US (2017 - $)



Source: UBS estimates

Figure 17: TCO analysis Bolt vs. Golf – Europe (2017 - €)

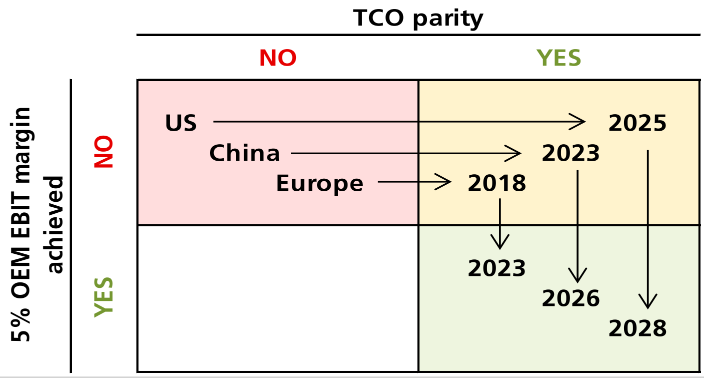


Source: UBS estimates

In the next few years, most if not all cost savings will need to be passed on to consumers until consumer TCO parity is reached. TCO parity occurs first in Europe in 2018E, then in China in 2023E, and in the US in 2025E, excluding any EV purchase incentives or other subsidies. The *true* cost parity, by when the OEM makes money with an EV, is a few more years out. Assuming that TCO parity is achieved, further savings will end up in the OEM's pocket until a 5% EBIT margin level is reached (which we consider a normal over-the-cycle margin for this vehicle type). Such an EBIT margin level should be met in Europe in 2023E and in China in 2026E. However, it would take ~10 years to achieve such a profitability level in the US, unless fuel prices surge or EV subsidies continue to exist for such a long period.

***True* cost parity to be reached by 2023E in Europe and 2026E in China**

Figure 18: TCO parity matrix – Chevy Bolt vs. VW Golf by region



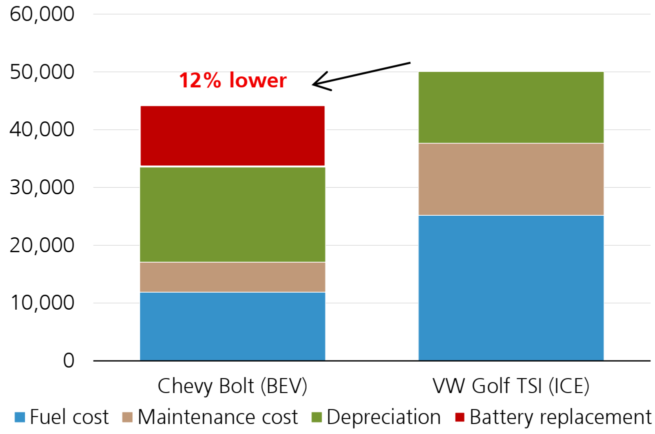
Source: UBS estimates

Note: The TCO analysis is based on a 3-year lease (longer periods lead to better EV economics due to energy/ maintenance cost advantage), annual mileage of 9,000 miles and 50% residual value after 3 years. See the detailed maths in the appendix.

What if the battery needs to be replaced during the life of the vehicle? This is not our base case, because user data of latest-generation EVs show limited battery degradation even after 150k miles (240k km). Nonetheless, we alternatively look at the TCO over the life of the vehicle (150k miles driven) assuming one battery replacement. It can be seen that in spite of high costs of the battery replacement (UBSe: $11,700 at 2025 costs – includes ~100% aftermarket surcharge), TCO for the EV vis-à-vis the ICE car become even better. This is because the energy cost advantage of EVs plays out over a longer time period. Residual value risk is removed if the vehicle is owned for 15 years. Also, we would highlight that there is a significant chance of gearbox or engine failure in the ICE car over the vehicle's life, which is *not* included in our analysis.

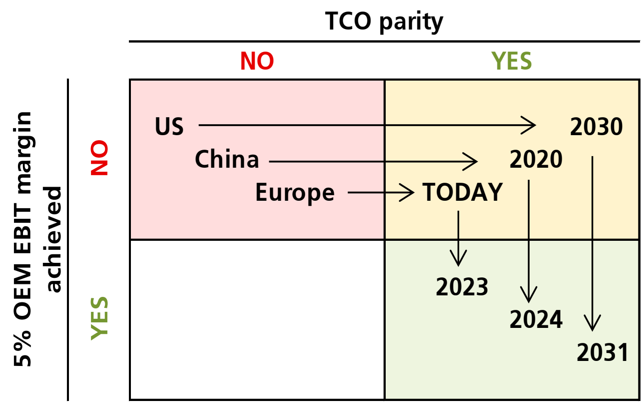
Comparing TCO over vehicle lifetime improves the EV economics, even with battery replacement

Figure 19: Stress test – 15-year lifecycle TCO if battery needs replacement (Europe, €) at 2017 vehicle price and 2025 battery replacement costs



Source: UBS estimates

Figure 20: Stress test – TCO parity matrix (15-year lifecycle, including battery replacement in 2025)



Source: UBS estimates

14% global EV penetration in 2025; 30% in Europe

TCO parity is the main prerequisite for rising EV sales. As TCO parity can be reached earlier than we anticipated previously, we are raising our global EV sales forecasts. We believe that extrapolating near-term trends results in a drastic under-estimation of what will happen to the powertrain mix once the TCO inflection point has been reached. We expect the steep part of the penetration s-curve to begin ~2020, with Europe and China leading. Our forecasts include plug-in hybrids (PHEVs). We assume that in 2017, about 40% of all EVs sold will be PHEVs and 60% battery-electric (BEVs). Over time, as BEVs become more competitive vis-à-vis PHEVs, we expect the PHEV share to drop below 20% by 2025.

We raise our EV penetration forecasts ~50% to 14% globally and 30% in Europe in 2025

In our updated base case scenario, we expect 14.2m EVs to be sold in 2025. This represents 13.7% of global car sales by then. We previously assumed only 9.7m EV sales or 9% of total car sales. The main difference to our old forecast is the higher penetration in Europe, where EV economics appear even more favourable after 2020. In Europe, we now expect an EV share of 30% in 2025, up from 1% today. But we have also raised our estimates for Japan and the US, albeit from a very low base. Estimates for China remain broadly unchanged. With a 2025E view, we remain ~45% below the government target of 8.8m new-energy vehicles (25% BEV and PHEV out of 35m new car sales), mainly due to unclear political support medium-term.

Our raised forecasts for Europe may appear very aggressive at first glance, but:

- EVs are likely to replace **diesel** cars, which currently have ~45% share in Europe. Cost of ownership is a key (yet fading) argument in favour of diesel in Europe – and this is exactly what should play out in favour of EVs after 2020. We expect the European diesel share to drop to ~7% by then. Political action is taken against diesel cars in some major European cities, including driving bans on days with high pollution. This political debate also bodes well for EVs.

- EVs will become the cheapest option for OEMs to meet **post-2020 CO_2 targets in Europe**. Therefore, marketing and consumer education, as well as investments into charging infrastructure, are likely to intensify.

- Findings from our recent **UBS Evidence Lab survey** (~10k participants, 6 largest car markets) about price, cost and range expectations for EVs support our thesis that EVs can become mainstream in the next few years.

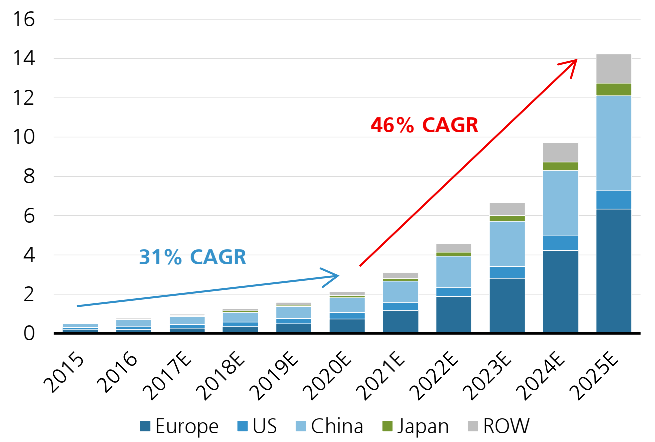
Our near-term estimates between now and 2020 are broadly unchanged on a global basis.

Figure 21: UBS EV forecast by region ('000 units)

EV sales (BEV + PHEV)	2015	2016	2017E	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E
Europe	**186**	**207**	**269**	**349**	**489**	**733**	**1,173**	**1,877**	**2,815**	**4,223**	**6,335**
growth y/y		*11%*	*30%*	*30%*	*40%*	*55%*	*60%*	*60%*	*50%*	*50%*	*50%*
% of new car sales	*1.0%*	*1.1%*	*1.4%*	*1.7%*	*2.4%*	*3.5%*	*5.5%*	*9.1%*	*13.6%*	*20.4%*	*30.6%*
US	**116**	**159**	**191**	**229**	**275**	**330**	**396**	**475**	**594**	**742**	**928**
growth y/y		*37%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*25%*	*25%*	*25%*
% of new car sales	*0.7%*	*0.9%*	*1.1%*	*1.3%*	*1.6%*	*1.9%*	*2.2%*	*2.6%*	*3.3%*	*4.1%*	*5.1%*
China	**206**	**336**	**403**	**504**	**605**	**756**	**1,096**	**1,589**	**2,305**	**3,342**	**4,846**
growth y/y		*63%*	*20%*	*25%*	*20%*	*25%*	*45%*	*45%*	*45%*	*45%*	*45%*
% of new car sales	*0.8%*	*1.2%*	*1.4%*	*1.7%*	*2.0%*	*2.4%*	*3.5%*	*5.1%*	*7.4%*	*10.7%*	*15.5%*
Japan	**25**	**25**	**47**	**66**	**80**	**103**	**145**	**203**	**284**	**426**	**638**
growth y/y		*-2%*	*90%*	*40%*	*20%*	*30%*	*40%*	*40%*	*40%*	*50%*	*50%*
% of new car sales	*0.5%*	*0.5%*	*1.0%*	*1.4%*	*1.7%*	*2.2%*	*3.0%*	*4.2%*	*5.9%*	*8.9%*	*13.3%*
ROW	**15**	**51**	**71**	**100**	**140**	**195**	**293**	**440**	**659**	**989**	**1,484**
growth y/y		*239%*	*40%*	*40%*	*40%*	*40%*	*50%*	*50%*	*50%*	*50%*	*50%*
% of new car sales	*0.1%*	*0.2%*	*0.3%*	*0.4%*	*0.5%*	*0.7%*	*1.1%*	*1.6%*	*2.4%*	*3.5%*	*5.2%*
Total	**549**	**777**	**981**	**1,248**	**1,588**	**2,118**	**3,103**	**4,584**	**6,657**	**9,722**	**14,230**
% of global PV sales	*0.6%*	*0.8%*	*1.0%*	*1.3%*	*1.6%*	*2.1%*	*3.1%*	*4.5%*	*6.5%*	*9.4%*	*13.7%*

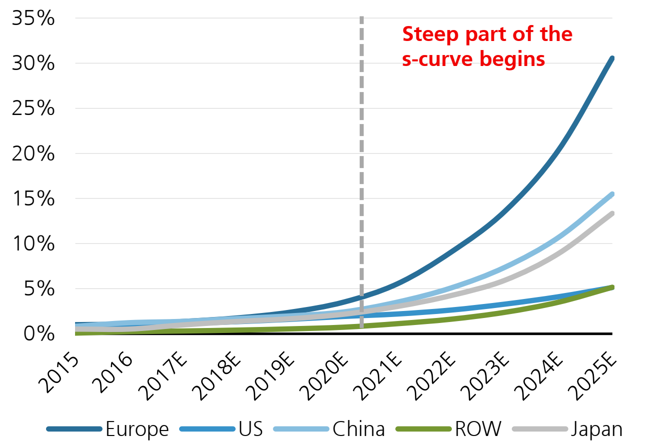
Source: UBS; IHS, ACEA, CAAM, Fourin, EV-Sales, Inside-Evs of historical figures

Figure 22: EV sales by region (m units)



Source: UBS estimates

Figure 23: EV share by region (% of total car sales)



Source: UBS estimates

We also run upside and downside scenarios for EV penetration.

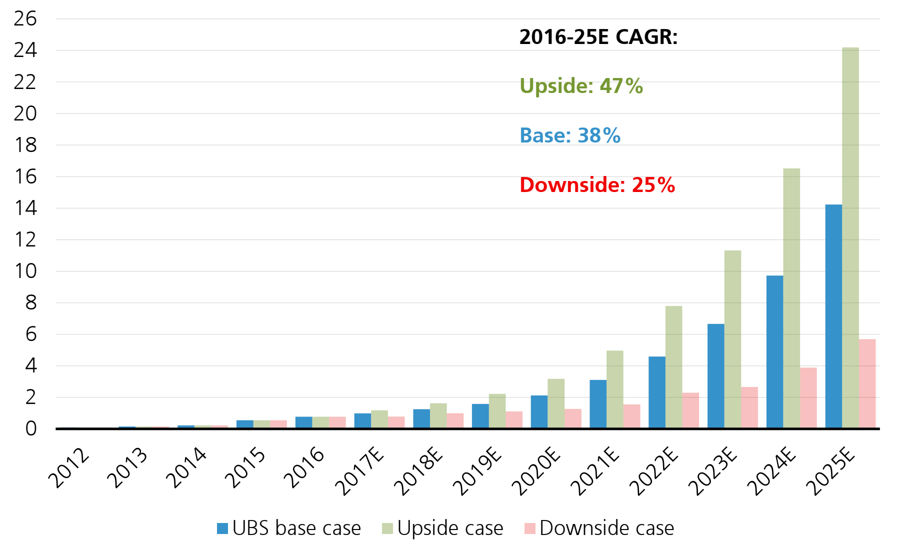
- **Upside scenario:** We forecast 24.2m EVs sold in 2025, or 23% of global car sales. This would imply that EVs become the dominant powertrain in Europe and China by then – a scenario that would most likely only materialize with sustained strong political support and rising fuel prices. Why not even higher? Because cost parity in the US is highly unlikely to be reached before 2025 without subsidies, EV economics in EM are still inferior to ICE cars, and CO_2 regulation is of subordinated importance. Also, battery production capacity and the number of charge points need to grow at the same pace to support such high EV sales growth, which may represent potential bottlenecks in some regions.

Upside: 23% EV penetration by 2025E

- **Downside scenario:** We forecast 5.7m EVs sold in 2025, or 5.5% of global car sales. This scenario discounts a low-to-zero political support level, sustained low gasoline prices and a slower-than-expected consumer response to EVs (TCO concept is not well understood as consumers are focused on vehicle selling prices only).

Downside: 5.5% EV penetration by 2025E

Figure 24: UBS base, upside and downside EV penetration scenarios (m units)



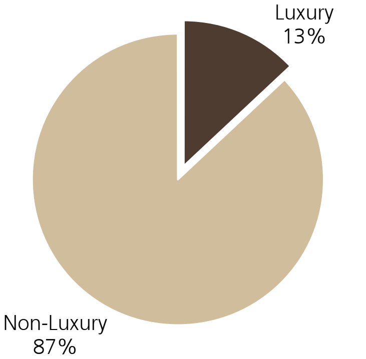
Source: UBS estimates

Why we still remain relatively cautious about EVs in the US

With low gas prices and likely easing fuel economy regulations, the economics of pure EVs remains challenging. There also remain challenges around infrastructure and significant uncertainty around consumer behaviour. However, the economics are more compelling in luxury as the luxury powertrain is more costly and luxury customers are willing to pay a premium for the rapid acceleration, quietness, and avoidance of gas stations as part of their daily routines. That said, the range limitation and longer charging times may imply EVs will be an ideal second car with an ICE available for longer trips. With ~13% of industry sales in luxury, this would imply ~40% of luxury sales will be EVs by 2025E. This is very consistent with expected EV launches from Mercedes, Audi, Porsche, and BMW.

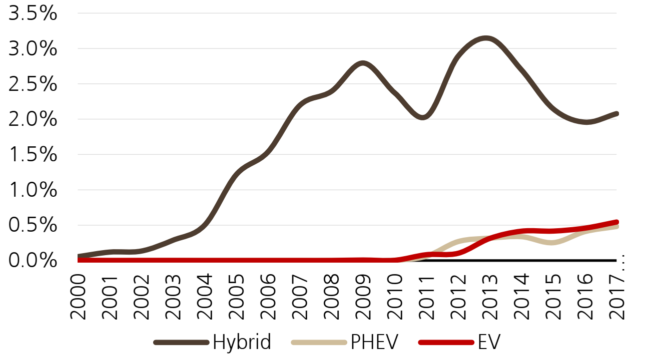
Low gas prices challenge EV economics in the US

Figure 25: US Luxury Mix 2016



Source: Wards

Figure 26: Hybrid, PHEV, and EV Mix



Source: Wards

Stress-testing our forecasts

We have sanity-checked our new forecasts against the following:

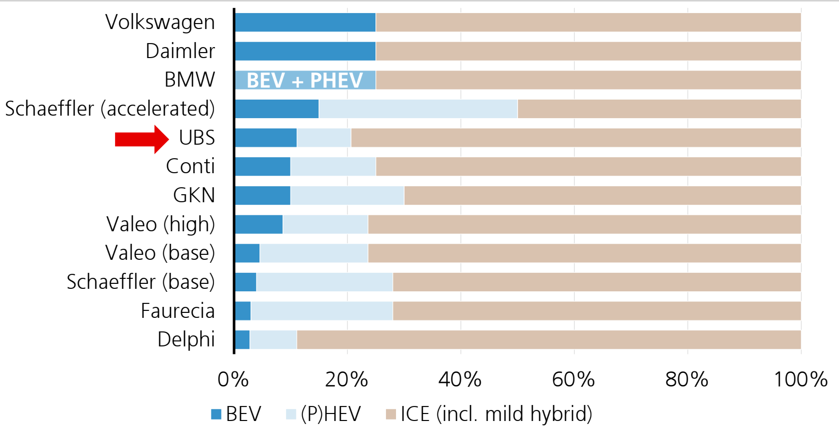
- EV sales and production forecasts of **major OEMs and tier-1 suppliers**
- Availability of **battery raw materials and cell production capacity**
- Availability of charging and power generation infrastructure, particularly in **Europe**
- Findings from our recent **UBS Evidence Lab survey** (~10k participants, 6 largest car markets) about stance towards EVs

What are OEMs and key suppliers saying about the powertrain mix?

OEMs and suppliers have dramatically increased their EV targets over the past 12 months. Volkswagen, the world's largest carmaker, now believes it will have 20-25% battery-electric vehicles in its sales mix in 2025 (excluding plug-in hybrids), and Daimler expects 15-25% BEVs in its mix – both are well above our estimates. Leading suppliers, such as Continental, are also turning more optimistic on EVs. These announcements go hand in hand with rising R&D and capex budgets that facilitate these new targets. We don't believe that powertrain and vehicle assembly capacity will be a bottleneck, because to a large degree, existing capacities will be upgraded or re-tooled to produce EVs in the same plants as today.

OEMs EV targets are already above our forecasts; suppliers are turning more optimistic

Figure 27: 2025 powertrain mix forecasts (suppliers, UBS) and targets (OEMs)

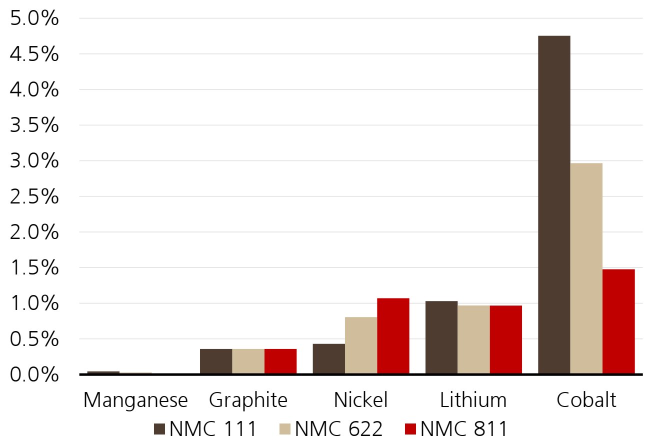


Source: Company disclosures, UBS estimates

Battery raw mats availability and cell production capacity

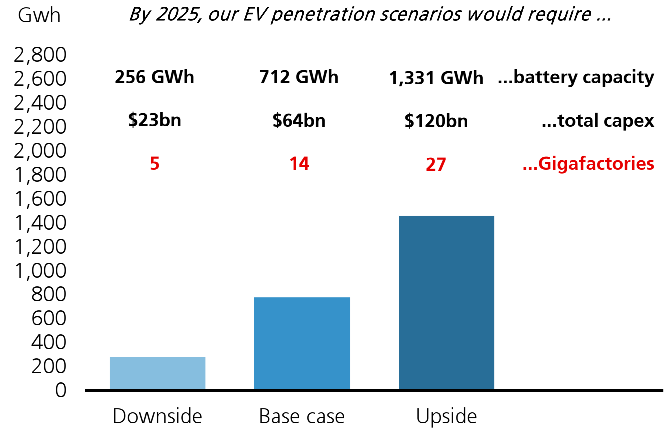
Can battery demand be met from a raw materials and production capacity point of view? The analysis below shows (1) the incremental demand for lithium, nickel, cobalt, graphite and manganese and how the respective commodity markets would be affected and (2) the required investments in cell production capacity.

Figure 28: NMC battery raw mats demand 2025E in % of proven reserves – NMC 811 likely mainstream after 2020



Source: UBS estimates

Figure 29: 16 Tesla Gigafactories required to meet 2025E battery cell demand – ambitious yet possible



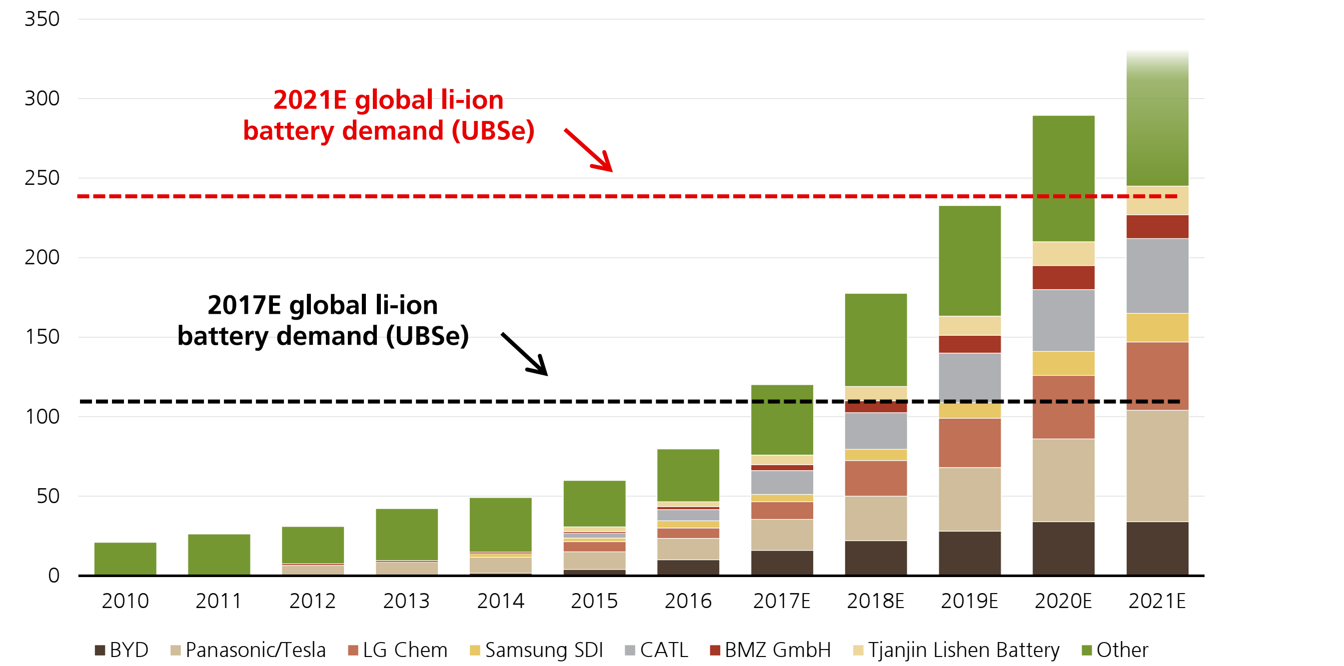
Source: UBS estimates

Our stress-test shows global raw mat reserves are not a bottleneck; the supply chain might be

In a 2025 world with 14.2m EVs sold (our base case), Cobalt would be the material with the highest depletion ratio, of 5% p.a. of proven reserves. In last year's Q-Series, we covered the commodities space in great depth. We believe that raw mats are not a bottleneck as such, but the supply chain needs significant investment to increase the output in the required order of magnitude. However, we would emphasize that (1) the use of cobalt will be significantly lower in future NMC cell generations on a per-kWh basis. In the 8:1:1 NMC battery cell, which is expected to enter mass production around 2021, the use of cobalt declines by 69% per kWh, compared to the 1:1:1 materials mix today. (2) The chance of a break-through in battery chemistry in the long term is significant, ie, the commodity depletion rates cannot be extrapolated beyond 2025.

In terms of battery cell capacity, the equivalent of 14 Gigafactories would be required globally to meet expected 2025 cell demand in our base-case scenario. This equates to $64bn total investments, applying the cost/GWh ratio of the first Gigafactory. Tesla managed to build a green-field (actually, it's located in a desert) Gigafactory within three years. The Korean battery suppliers are investing heavily in new capacity already today, and so are the Chinese suppliers.

Figure 30: Li-ion battery cell production capacity plans in line with EV sales forecast for the next five years – limited visibility on post-2020 plants at this point (GWh)



Source: UBS

Note: Includes non-automotive li-ion demand

Charging and power infrastructure in Europe

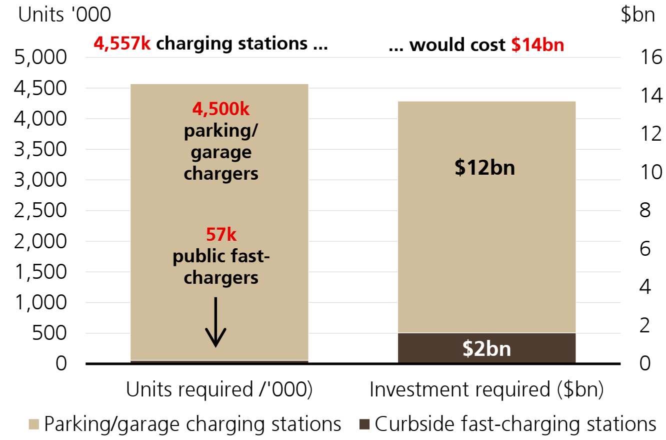
Our EV forecast would require $14bn charging infrastructure capex by 2025…

What's the required investment in charging infrastructure and power generation capacity, with a particular focus on Europe? We estimate that $14bn investments into charging infrastructure will meet requirements for 19m EVs on European roads in 2025. The infrastructure will be a mix of high-performance chargers alongside major motorways and lower-performance curb-side charging facilities, as well as home chargers. We think the need for high-performance chargers is over-estimated by many people, because only a fraction of miles driven during the year requires long-distance charging. In our UBS Evidence Lab survey, 81% of respondents said that they do two or less trips a year with a driving distance of >300 miles.

…and no incremental power generation capacity in Europe

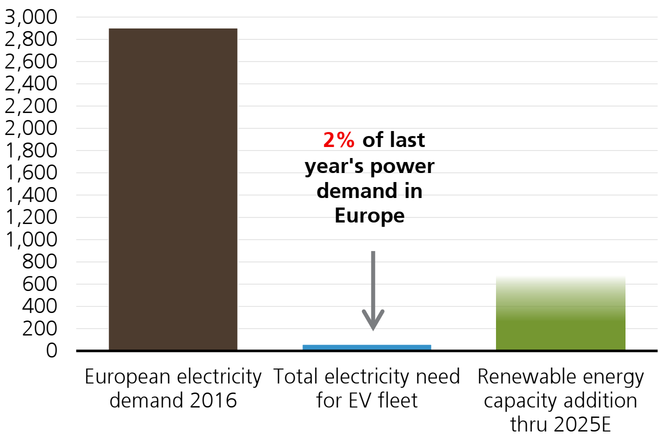
On the power generation side, most European power markets are currently oversupplied and power demand keeps shrinking by ~1% p.a. on energy efficiency measures. In a world of 19m EVs on European roads in 2025E with an average electricity consumption of 20 kWh per 100 km (conservative), the incremental power demand from EVs would be ~67 TWh (terawatt-hours) or 2% of Western European electricity demand. In light of the projected decrease in electricity demand excluding cars, we believe that the entire incremental demand can be met with existing production capacity. Furthermore, Western European countries currently add about ~30 TWh in new renewables capacity every year, which means that incremental supply for electric cars should mainly stem from CO_2-free sources.

Figure 31: Required investment in charging infrastructure in Europe



Source: UBS estimates

Figure 32: EV Impact on European power demand (2025)



Source: UBS estimates

How does our raised EV sales forecast square with our UBS Evidence Lab survey?

In September 2016, we published an in-depth report about likely consumer adoption of EVs. We conducted a survey with 10k consumers in the six largest car markets globally. In our view, some key findings of the survey support our increased forecast, particularly for Europe where TCO parity should be reached first:

UBS Evidence Lab: 55% of Europeans would be ready to pay a premium for an EV…

(1) The survey results show that today's high purchase price is the #1 reason why many people are unlikely to buy an EV today. However, when asked "if two cars had the same features, but one a gas or diesel vehicle, whereas the other was an all-electric vehicle, how much would you expect to pay for the all-electric vehicle?", **about 55% of European respondents would be ready to pay a higher purchase price for an EV vis-à-vis an ICE car, and about 30% are prepared to pay a 20% or even higher premium**. The actual price difference in 2025 will likely shrink to below 20%, and this ignores the running cost advantage the EV has. As the price premium narrows, the key reason for consumers not to buy an EV fades and eventually disappears. Hence, our 30% EV sales penetration forecast for Europe in 2025 is well below the share of survey respondents who, at least theoretically, would be ready to pay a higher price for the EV. Of course, the theoretical nature of this question makes it only one piece in the mosaic that influenced our EV sales forecast.

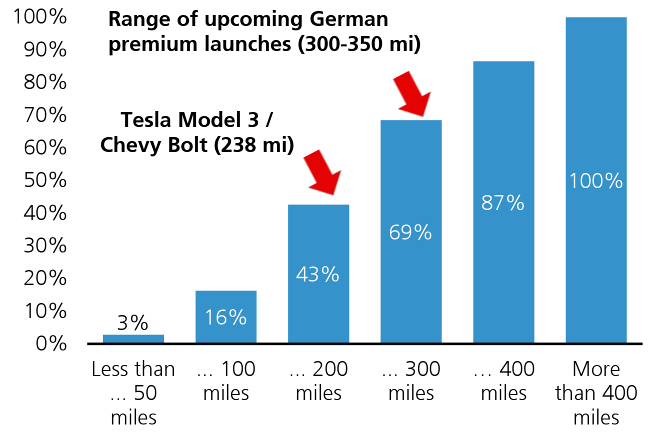
…two-thirds consider 480 km range sufficient…

(2) **Two-thirds of consumers consider 300 miles / 480 km range on a single charge as sufficient**, which will be met by upcoming product launches (in particular in premium);

…and over half of those with >$150k household income are likely to consider buying an EV

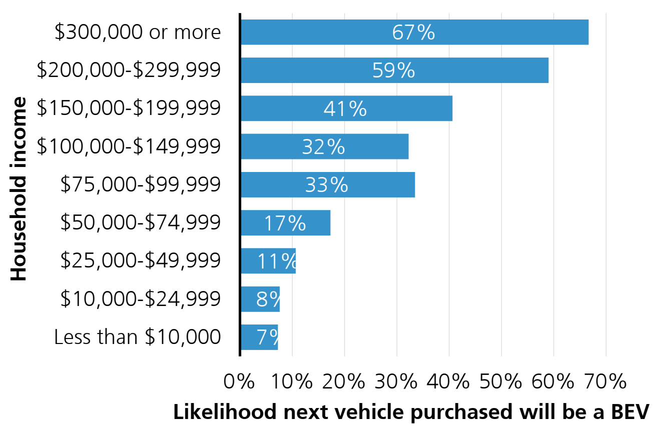
(3) **52% of respondents in the >$150k household income bracket are likely to consider buying an EV, which bodes well for premium brands.** Europe is the market with the highest premium brand share globally, about 22%. Overall, about 33% of European consumers said they are either likely to or uncertain about whether they would consider buying an EV. This result needs to be seen against the background of a very limited awareness / education level about EVs, due to the lack of models in the market at the time of the survey. We expect awareness and interest in EVs to increase on the back of numerous upcoming product launches over the years 2018-20, both in premium and mass (VW, Mercedes, Tesla, Audi…)

Figure 33: Acceptable minimum range for a single charge



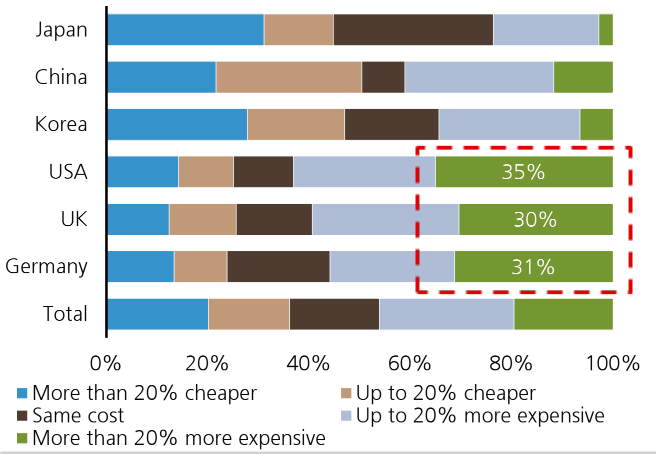
Source: UBS Evidence Lab

Figure 34: Likelihood to purchase BEV by household income ($/year)



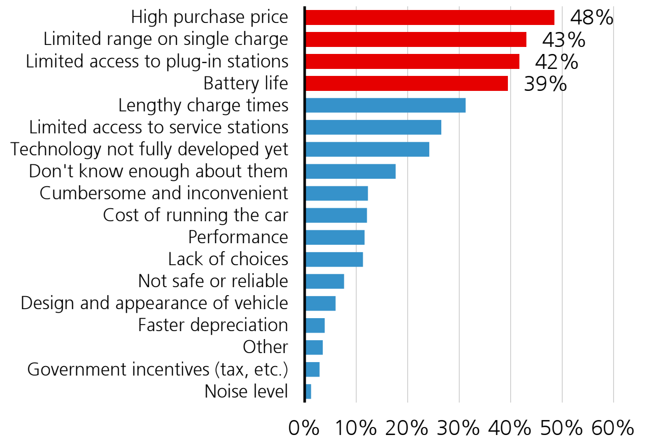
Source: UBS Evidence Lab

Figure 35: Consumers' expectations for price of BEV vs. a similar ICE car



Source: UBS Evidence Lab

Figure 36: Key concerns of consumers about BEVs



Source: UBS Evidence Lab

Q: What is different in the Chevy Bolt, compared to an equivalent ICE car?

Summary of results

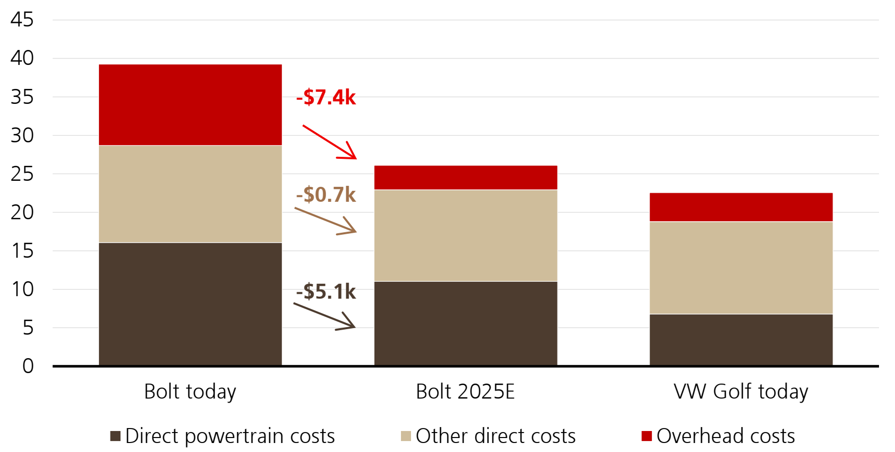
Below, we provide an overview of estimated component costs for the Bolt today and estimated costs in 2025 based on Munro expertise, in comparison to the Volkswagen Golf, Europe's top-selling ICE car with key features comparable to the Bolt. We have factored in our estimates for future battery pack costs based on our own extensive research.

Key conclusions about costs:

Munro's more optimistic cost estimates suggest OEMs and suppliers will be profitable sooner…

- Munro findings are **more optimistic** than our previous assumptions, which means that EVs should (1) be **more profitable for OEMs and suppliers** and (2) **reach the break-even in cost of ownership earlier** than anticipated. **Powertrain-specific costs** according to the teardown experts are $2.8k lower than our hypothesis, excluding the battery. It also turned out that the **battery pack** is $2.5k cheaper than our previous estimate (the battery *cell* costs were announced by GM).
- On our forecasts, the difference in **direct production costs** between the Bolt and the Golf will **shrink from $9.5k today to $2.7k in 2025.** A "second-generation" Bolt in 2025 is likely to be ~20% cheaper to manufacture than the first generation. And thanks to likely higher volumes, there is also better fixed cost absorption (R&D, SG&A etc). **Hence, the all-in cost difference should shrink from $16.5k today to $2.3k in 2025.**
- Battery cell and pack costs are the most important driver, but there is also further savings potential in the other powertrain components, which are ignored by the Street, in our view.

Figure 37: All-in cost comparison between the Bolt and Golf ($k)



Source: UBS

Further, our teardown analysis found that the Bolt has **$3k higher electronics content** than the Golf (measured at tier-1 supplier level including the e-motor), instead of $4.5k ICE powertrain content from "traditional" tier-1 suppliers. In terms of **commodities**, the most remarkable differences between both vehicle types are in the use of aluminium, copper, active battery materials, rare earths (all higher in the Bolt) and platinum group metals (don't exist in the Bolt). The use of steel is fairly similar, and more expensive light-weight materials, such as carbon fiber based materials, are not found in the Bolt.

Differences in vehicle architecture and powertrain

The Bolt has more interior space than the VW Golf with smaller external dimensions

Our focus of the teardown is on the powertrain, which is totally different between these two vehicles. But the vehicle platforms are also quite different. The Bolt, in spite of an overall shorter length, has a longer wheelbase than the Golf. This is for two reasons: (1) The Bolt's battery is underfloor between the axles. In order to fit as much battery capacity as possible, the wheelbase needs to be long. (2) A longer wheelbase maximizes interior space. The Bolt has 1% more passenger volume than the Golf and more legroom for both front and rear passengers, in spite of being 8 cm shorter. The main reason is the shorter front "engine" compartment. The e-motor and electronics require much less space than the combustion engine. The VW Golf is built on the so-called "MQB" platform, a German abbreviation for "modular transverse (engine) toolkit". This is Volkswagen Group's state-of-the-art modular platform for almost all new non-premium cars.

Figure 38: Chevrolet Bolt cutaway

Source: GM

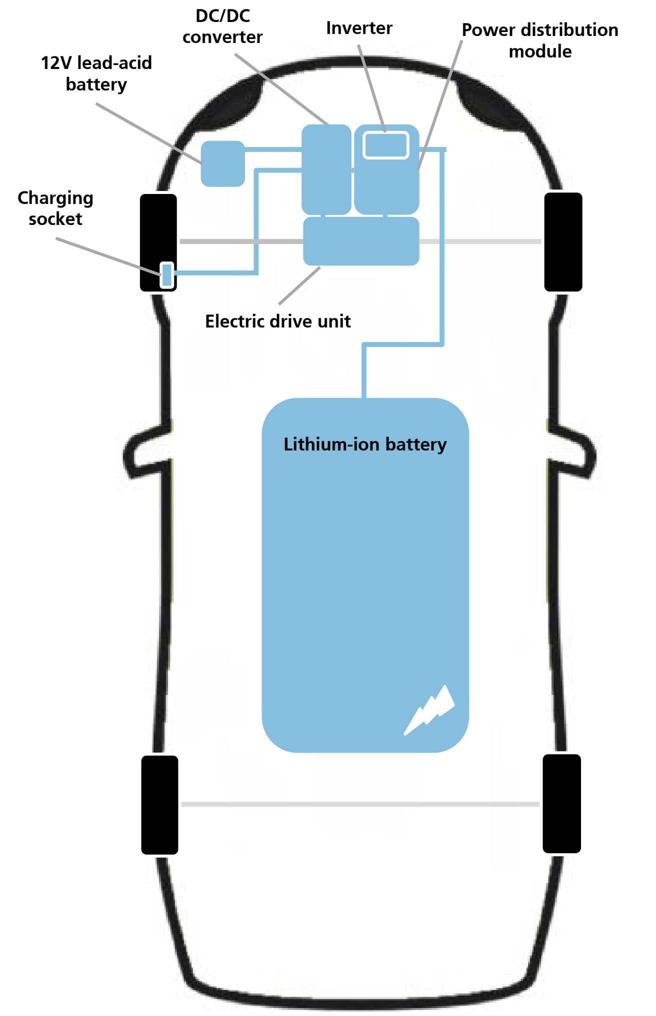
Figure 39: VW Golf cutaway

Source: Volkswagen

Zooming into the powertrain, the following schematic illustrations show the key differences between the Bolt and the Golf.

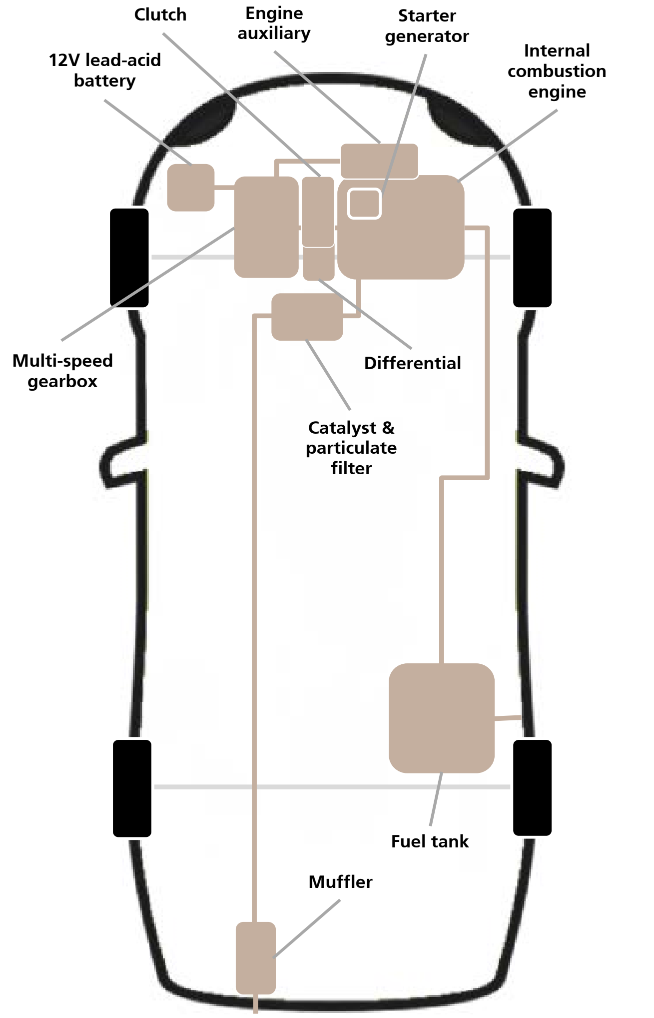
- The **Bolt** carries the e-motor (front-wheel drive), power electronics and charging equipment under the short front hood. The battery resides between the axles. There is a small **single-speed transmission** integrated into the e-motor unit.
- The **Golf** has a transversely mounted 4-cylinder gasoline engine (front-wheel drive). The version we use for this comparison has a **6-speed automatic transmission**.

Figure 40: Chevy Bolt powertrain



Source: UBS

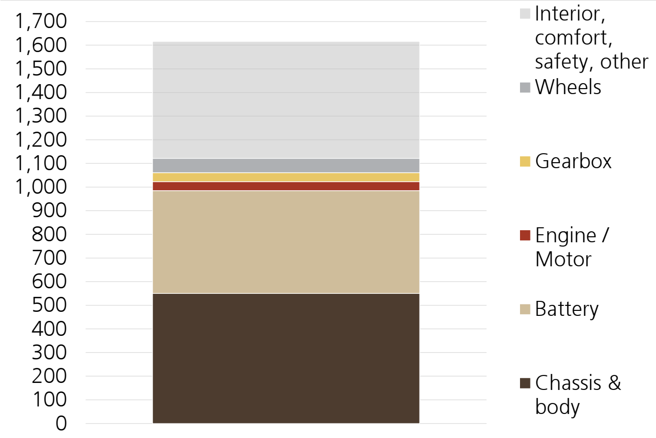
Figure 41: VW Golf powertrain



Source: UBS

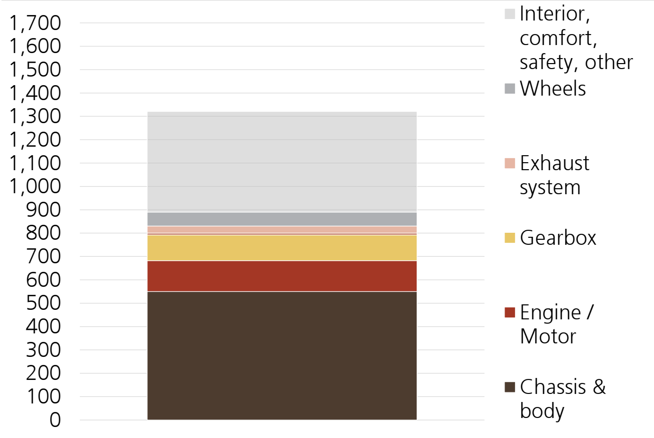
Differences in commodity weights

Figure 42: Chevy Bolt curb weight breakdown



Source: General Motors, UBS estimates

Figure 43: VW Golf curb weight breakdown

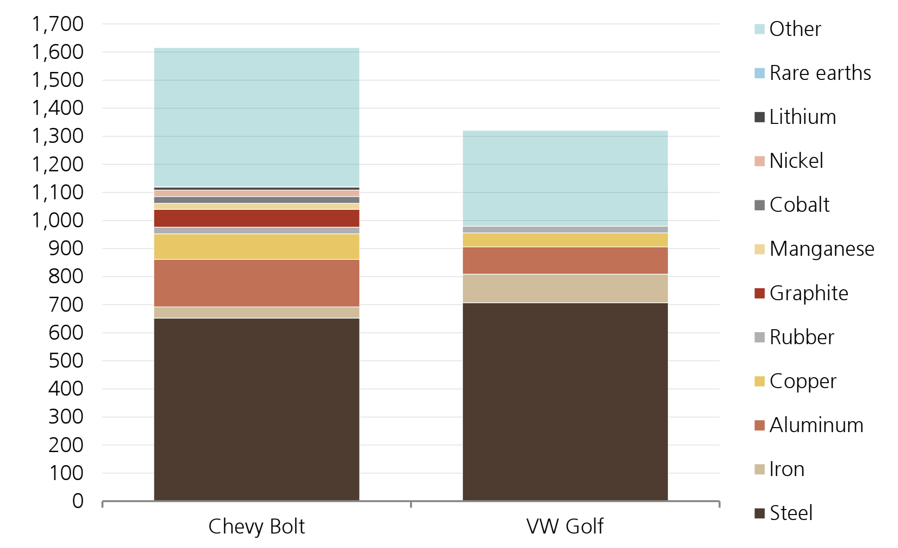


Source: Volkswagen, UBS estimates

The Bolt is 22% heavier than the Golf. The main reason is the battery pack. But what are the main differences in terms of the commodity weight share? In the Bolt, we have found (compared to the Golf):

- ~70% **more** aluminium
- ~80% **more** copper
- ~7% **less** steel
- ~60% **less** iron
- 100% **less** precious metals
- ~140 kg of "active" materials in the battery cells (Nickel, Cobalt, Lithium, Manganese, Graphite)
- ~1 kg of rare earths in the e-motor, in particular neodymium and dysprosium
- the same amount of rubber

Figure 44: Chevy Bolt vs. VW Golf commodity mix (kg)



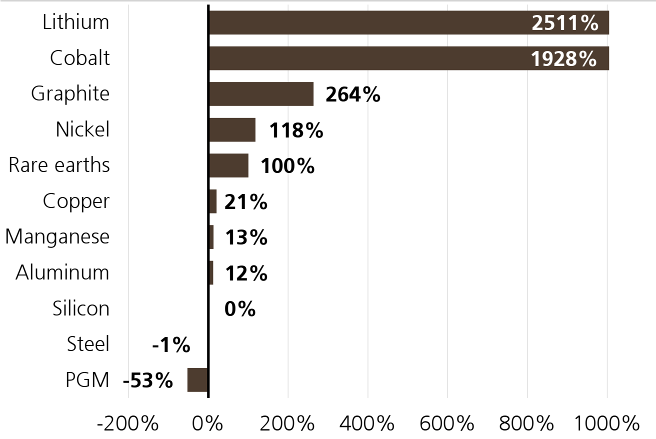
Source: UBS estimates

The shift to EVs should impact aluminium, copper, precious metals, rare earths and active battery materials most

Consequently, the shift to electric cars is likely to have a significant impact on the markets for aluminium, copper, precious metals, rare earths and the active battery materials. As a scenario analysis, the following graph shows how the respective commodity markets would be influenced if 100% of all vehicles sold globally would be Chevrolet Bolts, instead of today's vehicle sales mix. We put the incremental commodity demand (or lack thereof) in a 100% Bolt world in relation to the size of the respective commodity markets today. Lithium, cobalt, rare earths and graphite markets would be most disrupted on the positive side, and platinum group metals, which are used in catalysts, on the negative side. Not shown in the chart below is the use of plastics materials. We expect a moderately higher use of plastics (polymers- or polyester-based), for example for the upper cover of the battery pack.

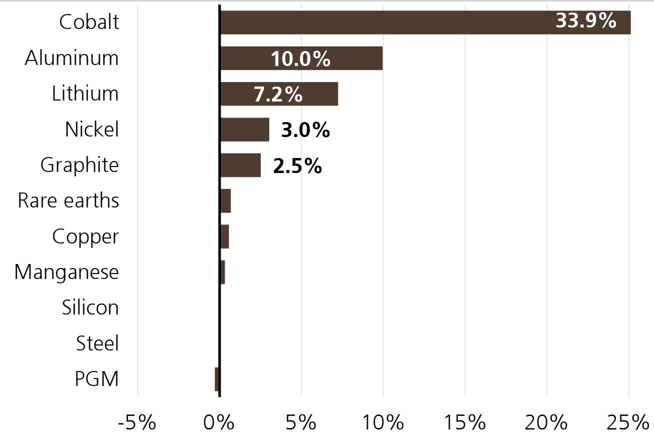
It is also worth highlighting that the battery active materials use is based on the Bolt's battery chemistry today. Future cell generations are likely to use significantly less cobalt and manganese, ie, the charts below would over-estimate the long-term impact. Please refer to the battery section for more details.

Figure 45: In a 100% EV world, demand for commodities would change by… (in % of global market today)



Source: UBS

Figure 46: In a 100% EV world, incremental annual commodity demand would deplete reserves by…



Source: UBS

As EVs become mass-market thanks to decreasing battery costs, we don't expect a higher use of more expensive 'exotic' light-weight materials, such as carbon fibre reinforced plastics. Lower costs and higher energy density (and hereby lower weight) will greatly reduce the need to spend additional money on light-weight materials for body and chassis.

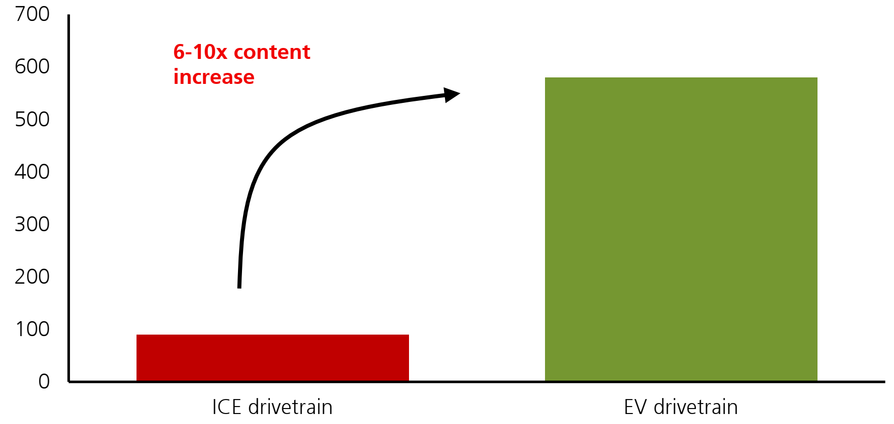
Differences in electronics / semiconductor content

We estimate that the Bolt EV powertrain has ~$580 semiconductor content, or 6-10x more than an average equivalent ICE car such as the Golf. We estimate that in an ICE the powertrain electronics can range from as much as $60 to $90 meaning that at ~$580 for a relatively low-end mass-market car, EV is a significant step up. At this point we are only focusing on the powertrain. We did also tear down the infotainment / connectivity / ADAS components, but these will be analysed in separate research.

The Bolt has ~$580 of semiconductor content on our estimates, 6-10x more than an ICE

Where are the main differences? We plan to carry out further in-depth analysis on the breakdown on the semi content side, but at a high level, in a traditional ICE powertrain, the main semiconductor content is in the engine control unit (ECU) and the sensors that feed it information. In an EV powertrain, there are numerous new components that contain a mix of power electronics (modules used to convert back and forth between AC & DC and between different voltages of DC) along with many 32-bit microcontrollers used to manage different subsystems (e.g. battery, charger module). The most prevalent suppliers in the teardown of the Bolt are Infineon (power electronics including the inverter/converter IGBT), NXP/Freescale for the higher value 32-bit components and STMicro for an ASIC supplied to LG Chem for battery management.

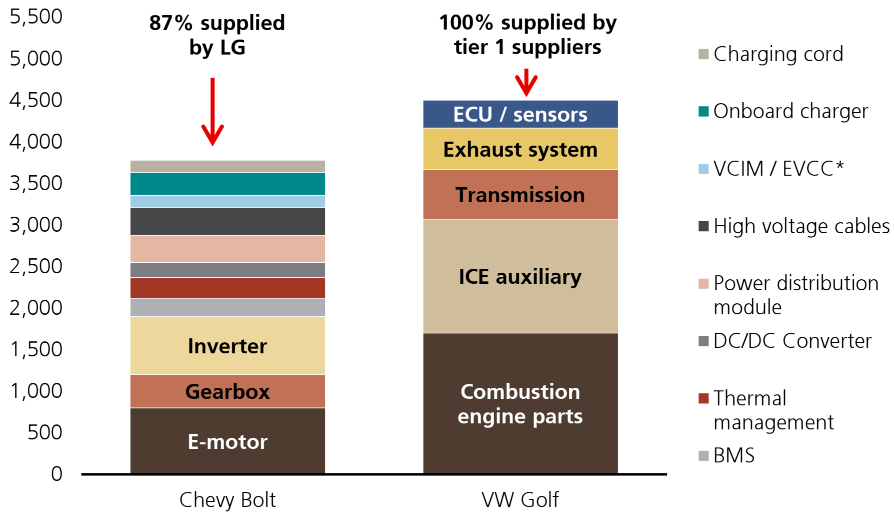
Figure 47: Semiconductor powertrain content increase in an EV



Source: UBS

At ~$3,800, the Bolt's powertrain excluding the battery pack is 16% less expensive than the Golf's full powertrain, on our estimates. In a nutshell, the lion's share of mechanical content gets replaced by electr(on)ical content.

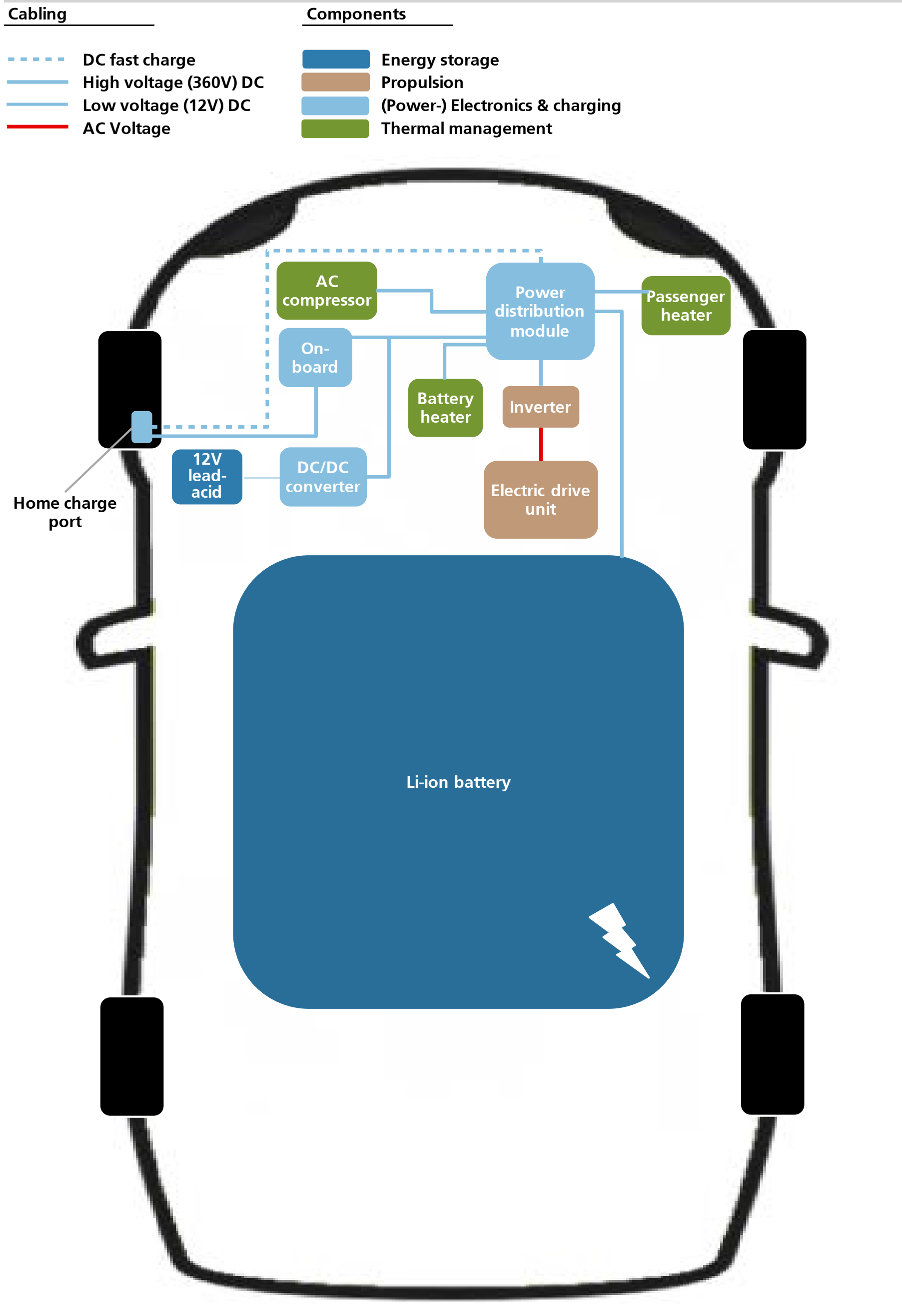
Figure 48: Powertrain components – Bolt vs. Golf ($)



Source: UBS estimates
* VCIM = Vehicle interface control module
** EVCC = Electric vehicle communication controller

Deep-dive into the Bolt's electric powertrain

Figure 49: Chevy Bolt Powertrain overview



Source: UBS

Figure 50: Chevy Bolt powertrain modules

Component	Price today ($)	Price 2025E ($)	Change %	Function
Li-ion battery pack	**11,500-12,522**	**8,000**	**-30-36%**	**Entire battery pack including housing, thermal control, internal wiring, emergency switch and battery management system**
Li-ion battery cell	*8,700*	*5,400*	*-31%*	*Stores up to 60kWh of electric power, $145/kWh*
Battery management system (BMS)	*150-222*	*200*	*up to -10%*	*Monitors the voltage output of each cell group and temperature of the pack*
Battery thermal management	*100*	*90*	*-10%*	*Heats and cools battery in order to keep operating temperature within desired range; glycol/water based*
All other pack content	*2,550-3,500*	*2,310*	*-9-34%*	*Module frames, internal wiring, cooling plates, steel pack case, plastics cover, emergency switch, safety relays, pack assembly*
Thermal management	250	225	-10%	Controls temperature of electronics and cabin via liquid-based cooling/heating loops
Power distribution module (PDM)	250-328	295	*up to -10%*	Takes in DC from battery or charging system and distributes it to the inverter, DC/DC converter and electric heating system
Inverter / converter	697-700	523	-25%	Takes in DC from the PDM and converts it to 3-phase AC for the e-motor
Electric drive module	1,200-1,550	1,080	-10-30%	150kW permanent-magnet e-motor takes in AC from the inverter to turn a drive shaft via magnetic power; a single-speed gearbox is used to translate rotational speed down to final drive ratio
DC/DC converter	150-179	134	-11-25%	Takes in 360V DC from PDM and converts to 12V DC for low-power systems in the vehicle
Electric Vehicle Communication Controller (EVCC)	51	46	-10%	Supports communication between the vehicle and charger for fast charging
Vehicle Interface Control Module (VCIM)	93-100	84	-10%	Functions like a data storage and distribution centre, controlling and monitoring operations between inter-reporting modules; maintains diagnostic information related to the electric propulsion system
High voltage cables	335	302	-10%	Connects the various electronics modules, the e-motor and the battery
On-board charger	273-598	205	-25-66%	Charges the battery pack by converting AC from the charging cord to DC. High end of range represents fast charging (paid option in our Bolt vehicle)
Charging cord	150	135	-10%	Allows the customer to charge the car using a standard 120V AC outlet. Rated to withstand 10,000 mating cycles. With 1 mating cycle per day, the theoretical lifespan is approx. 27.4 years
Total	**14,949-16,763**	**10,416**	**-30-38%**	

Source: UBS estimates. Note: Estimates highlighted in blue are Munro estimates, which we use as basis for further modelling purposes in this report

Number of moving and wearing parts

A combustion engine has many shortcomings vis-à-vis an e-motor, which have to be dealt with through complex technical solutions. The only reason why electric cars have not become mainstream yet, is energy storage, i.e. the battery. The e-motor is superior to the ICE: less mechanical complexity and fewer moving / wearing parts, stronger and linear torque, shorter response time, no local emissions, wider usable rpm range, no "cold start" issues, no energy-consuming idle running and the capability of regenerative braking to recover kinetic energy. Additional components, such as a complex gearbox, a clutch, a starter generator, a start-stop system, and emissions after-treatment are required to address the shortcomings of the combustion engine. The Bolt's powertrain is much simpler than the Golf's from a mechanical point of view:

The e-motor is significantly less complex than the combustion engine

- The e-motor itself is much less complex than the combustion engine. Bearings aside, there are only **three moving parts**. Modern e-motors are brushless, ie, maintenance-free. The Golf's 4-cylinder engine has **113 moving parts**. On top, spark plugs need to be replaced and engine oil needs to be changed regularly.

The e-motor has three moving parts vs. the combustion engine's 113

- The combustion engine has a limited usable rotation range, between c800-6,000 rpm. Also, its torque is not constant over the usable rpm range (unlike the e-motor). Therefore, a complex gearbox and clutch (or torque converter) are needed. The Golf's 6-speed automatic transmission has **27 moving parts.** Gearboxes and clutches also wear. After mileage of 150k kilometres, gearbox replacements begin to rise significantly. In contrast, the Bolt has a very simple single-speed gearbox with only **four gear wheels**. We expect no maintenance or replacement to be required over the life of the car.

The e-motor generates usable torque over the rpm range; the combustion engine needs a complex transmission

- Stating the obvious: A combustion engine produces emissions and more heat than the e-motor due to worse energy conversion efficiency. This requires complex after-treatment with ever-increasing regulatory standards (catalysts, particulate filters, mufflers, etc). Emissions after-treatment components wear down.

The e-motor's energy efficiency is far superior

Figure 51: Comparing the number of moving and wearing parts

Chevrolet Bolt	Parts	VW Golf
24	**(1) Moving parts**	**149**
3	… in engine	113
12	… in gearbox	27
9	… other	9
11	**(2) Wearing parts**	**24**
0	**(3) Moving & wearing parts**	**6**
35	**(1) + (2) - (3) Total moving and wearing parts**	**167**

Source: UBS

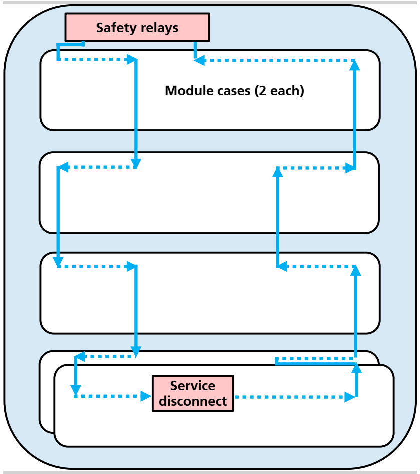
Battery pack

Need-to-knows

The Bolt's battery pack is supplied by **LG Chem**. It is a latest-generation NMC (Nickel Manganese Cobalt) battery with a usable capacity of 60kWh, which provides an EPA-rated range of 238 miles / 384 km. It weighs 436 kg, out of which 300 kg relate to the battery cells. Of the total weight, 26% is contributed by the packaging and cooling (steel, aluminium and iron), and about 68% by the "active" materials in the battery cells. Other key features:

- 288 LG battery cells in pouch format, with 96 cells connected in series (adding up to a voltage of 365V) and three strings of cells in parallel. The cells house in 10 module cases.
- The battery cell frames and the heating/cooling plates are made of aluminium, whereas the battery pack protection case is made of steel.
- The battery management system, which sits on top of the battery modules in the rear, is assembled by LG Innotek and designed by LG Chem.
- The battery pack is equipped with two disconnect methods, one if a system fault occurs, and another manual emergency disconnect under the rear seat.

Figure 52: Bolt battery layout



Source: UBS

Figure 53: Chevrolet Bolt key battery specifications

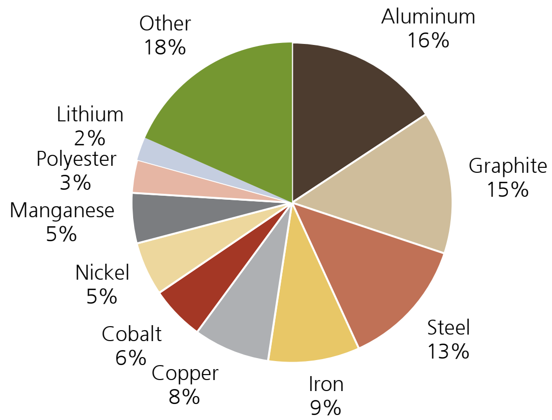
Li-ion cell technology	Nickel-manganese-cobalt (NMC)
Cell format	Pouch
Capacity	60 kWh
EPA-rated range	238 miles
Number of cells	288 cells
Charge times	
Basic (Level 1) - standard 120V residential cord	~60 hours / home
Fast (Level 2) - 240V fast-charging cord	~9.5 hours / home + public
Super-fast (Level 3) - public DC fast-charging	~1.5 hours / public
Cost today	$209 / kWh = $12,522
… cell	$145 / kWh = $8,700
… pack	$64 / kWh = $3,822
Cost 2025 (UBSe)	$133 / kWh = $8,000
--> Cost digression	-36%
Pack weight	436 kg
… cell material	300 kg
… cell frame and cooling plate	54 kg
… protection case	71 kg
… other	10 kg

Source: General Motors, UBS

Figure 54: Chevy Bolt battery pack

Source: UBS

Figure 55: Battery pack commodity breakdown (weight)



Source: UBS

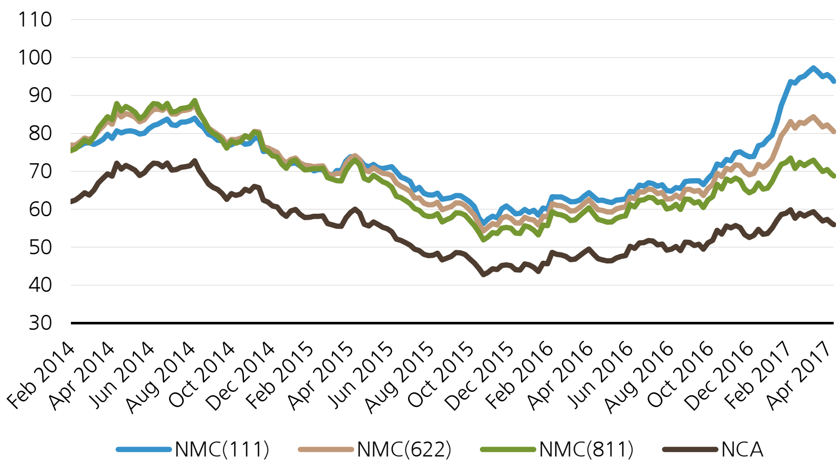
Technology

The chemistry used in the NMC cathodes is the state-of-the-art 1:1:1 ratio between Nickel, Manganese and Cobalt. The same chemistry is also used by Samsung SDI. Panasonic's cylindrical NCA technology (Nickel Cobalt Aluminium) is mainly used by Tesla.

Next gen NMC cells will reduce the share of expensive cobalt and manganese

The upcoming next generation of NMC cells (expected for 2018) will use a different materials mix: The ratio is expected to be 6:2:2, which means the share of cheaper Nickel is set to increase while the share of more expensive cobalt and manganese should drop. With a 2021 view, the cathode materials mix is expected to be optimized further to 8:1:1. At the same time, the energy density is expected to be further improved by ~20% for every new generation. This will lower not just the bill of materials per kWh, but also the costs for the module / pack assembly on a per kWh basis.

Figure 56: Commodity cost by cell generation ($/kWh)



Source: UBS. Note: Calculations are based on today's energy density. Positive impact from higher energy density will reduce BOM further.

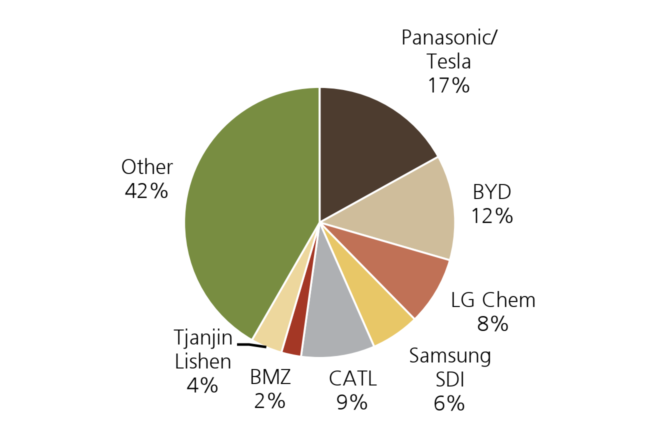
The battery management system is responsible for monitoring the voltage output from each battery module and the temperature of the pack. The module consists of various electronic components from a range of sub-suppliers.

Competitive landscape

EV battery supply to non-Chinese OEMs is quite concentrated: LG Chem, Samsung SDI and Panasonic are the leading players. There are several Chinese battery makers that predominantly supply the domestic carmakers – BYD is the largest player. Most of the Chinese supply is based on the LFP (Lithium Metal Phosphor) technology – a chemistry that industry experts see little further optimisation potential in. We doubt OEMs will commit large sums of money into own battery cell manufacturing due to the high capital intensity and the lack of technological edge, at least for the foreseeable future.

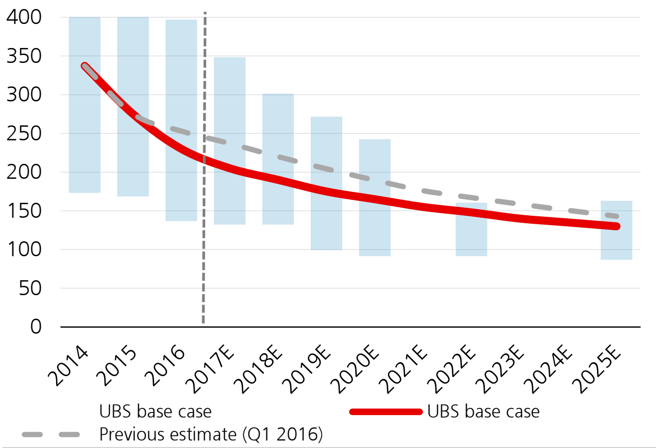
LG Chem, Samsung SDI and Panasonic dominate the non-Chinese market

Figure 57: EV battery cell producer capacity share 2016



Source: Company data, UBS

Figure 58: EV battery pack costs ($/kWh)



Source: UBS, various. Note: See source of external estimates in the appendix.

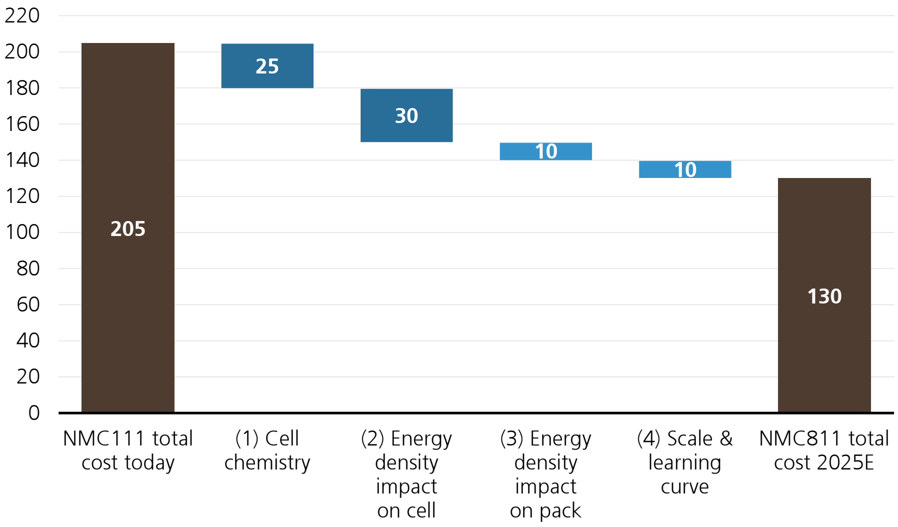
We over-estimated battery pack costs; $130/kWh by 2025E realistic

GM pays $145/kWh for the battery cells, i.e. $8,700 in total, and Munro estimate a $3,600 mark-up for the battery pack. The mark-up includes all materials, wiring/connectors, cooling plate, emergency switch and assembly. The battery management module comes on top of this and is estimated to cost $222 by Munro. Hence, total pack costs are $12,522 or $209/kWh. Our Asian tech team, who cover LG Chem and Samsung SDI, believe that this estimate is at the high end. They estimate that the total pack costs in the Bolt could be as low as $11,500 today.

The Bolt's battery pack is estimated to cost $192-209/kWh

We continue to expect a drop in cell costs to $90/kWh with a 2025 view, resulting in pack costs of $130/kWh (our previous forecast was $145/kWh). The following chart provides a breakdown of estimated costs today and in the future. The reduction of battery pack costs is the key driver of BEV economics. The projected reduction in the pack cost implies a reduction in total vehicle manufacturing costs by $4,500 or ~12% of the Bolt's price tag today.

Figure 59: Battery pack cost bridge 2017-2025E in detail ($/kWh)



Source: UBS estimates

$25/kWh from material weight changes in the cell

(1) The **shift from NMC 111 to NMC 811**, which battery suppliers expect to achieve as early as 2020-21, contributes **$25/kWh**. This is because of the lower weight share of the expensive commodities, Cobalt above all. We have not factored in any further optimisation in the chemistry mix after that, even though in the "normal" cycle of 2-3 years for the next cell generation, another step is quite likely by 2025.

$30/kWh from higher energy density

(2) Every new cell generation has an increase in energy density by ~20%. LG publicly stated that it expects an increase in energy density by 30-40% by 2020. We (highly conservatively) assume an increase in energy density by 25% on a 2025 view, in order to reflect a potential slowdown in the decline rate. As the commodity use per kWh also declines accordingly, the **contribution from higher energy density is $30/kWh**.

$10/kWh from lower pack assembly cost per kWh

(3) The higher energy density of the cells also has a **positive impact on pack assembly cost on a per kWh basis**, because the assembly steps remain the same and the use of materials is not affected (if anything, it goes down because of smaller battery size). This item delivers **savings of $10/kWh**.

$10/kWh from scale and learning curve effects

(4) Finally, **economies of scale and the learning curve in cell and pack assembly** should bring further savings. In today's $3,600 pack mark-up, only ~25% relates to materials used. This points to high fixed costs in a sub-scale production environment. We assume a contribution from economies of scale of $10/kWh.

Our forecasts lie within the range of various industry experts. **Key risks to our forecasts** would include changes in **commodity prices**, **timing of the delivery of new NMC generations** and the **magnitude of economies of scale**, given the risks to EV demand forecasts over such a long period.

Electric motor (drive unit)

Need-to-knows

The Chevy Bolt uses a permanent-magnet synchronous motor supplied by **LG Electronics** and engineered by GM. The one-speed transmission (7.05:1 final drive ratio) houses in the same module, also known as drive unit. The regenerative braking function is accomplished via the e-motor being utilized as a generator and the inverter/converter converting the generated AC in to DC for the battery, i.e. no additional mechanical equipment is required.

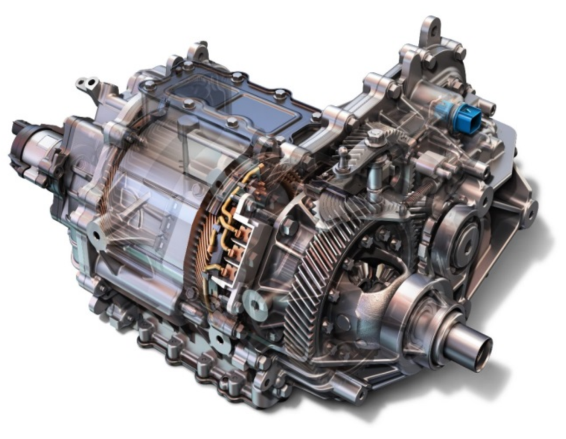
The Bolt's e-motor is designed by GM and manufactured by LG Electronics

Figure 60: Chevrolet Bolt key drive unit specifications

Type	Permanent magnet synchronous motor (PMSM)
Peak power	150 kW / 204 HP
Peak torque	360 Nm
Max rpm	8,810
Acceleration	0-60 mph in 6.9 seconds
Top speed (capped)	145 km/h
Cost today	$1,200
… E-motor	$800
… Gearbox, housing, rest	$400
Cost 2025 (UBSe)	$1,080
--> Cost digression	10%
Weight	76 kg
… E-motor	35 kg
… Gearbox, housing, rest	41 kg
Size / volume	~25 x 25 x 40 cm = 25,000 ccm
Gearbox final drive ratio	7.05:1

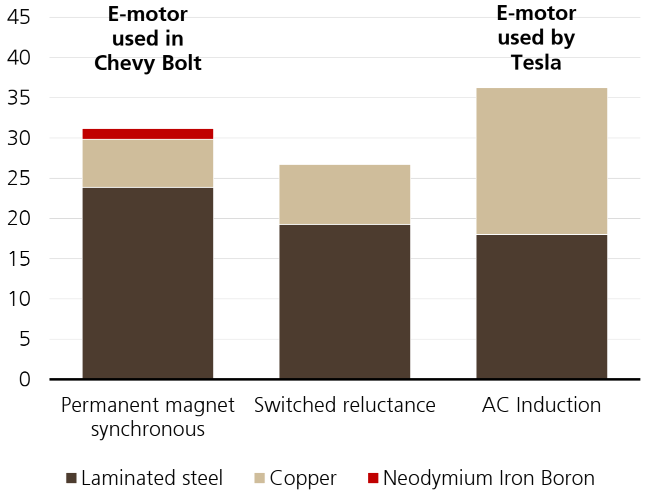
Source: General Motors, UBS

Figure 61: Chevy Bolt electric motor / gearbox unit



Source: GM

Figure 62: Electric motor commodity breakdown (kg)



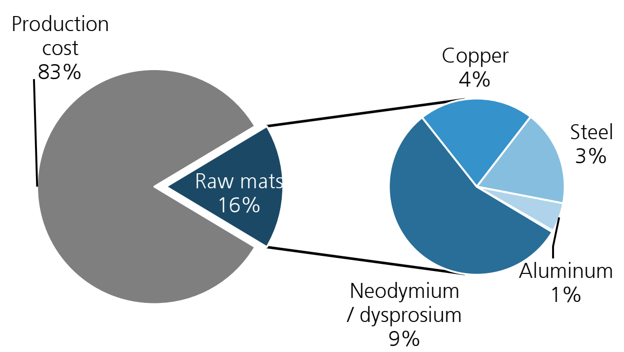
Source: UBS

Technology

There are different e-motor designs in the market, and each one has pros and cons. The electric rotor design in the Bolt optimizes magnet placement between the adjacent poles asymmetrically to lower torque ripple and radial force. It offers 204hp (150kW) of power, 360Nm of torque (almost 2x the ICE) and is maintenance free. This motor type requires the highest amount of neodymium and dysprosium for the magnets – rare earth materials that have experienced a volatile price curve over the past few years. We estimate a neodymium and dysprosium content in the Bolt's motor of ~1kg, which represents ~$100 unit cost or ~8% of the total e-motor cost. In a world of 14m EVs sold every year (our 2025E base case), the incremental demand would represent 54% of global neodymium production in 2016. While the rare earths, the raw material for magnets, are abundant (14.2m annual EV production would deplete reserves only by 0.04% p.a.), there could be risks of temporary bottlenecks in extraction. A well-known fact is that rare earths supply is highly concentrated in China.

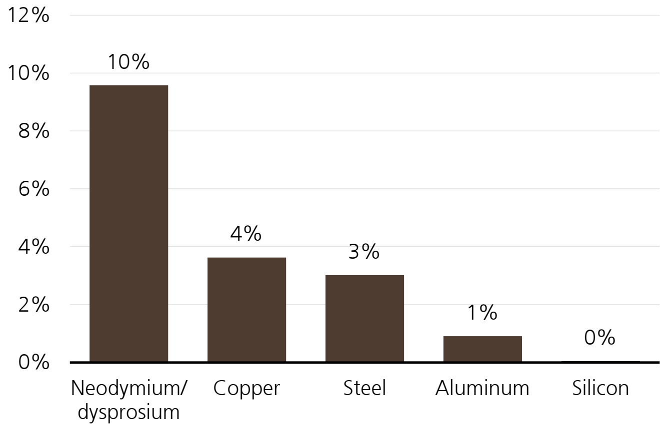
The one-speed transmission is directly attached to the e-motor and sits in the same housing. We counted only four gear wheels. A fixed transmission ratio (to reduce the rpm of the engine while increasing the torque) is sufficient due to the constant torque across the entire usable rpm range of the motor.

Figure 63: Bolt e-motor cost breakdown (total = $1,200-1,550)



Source: UBS estimates

Figure 64: Stress test – impact of doubling commodity prices on total e-motor module costs



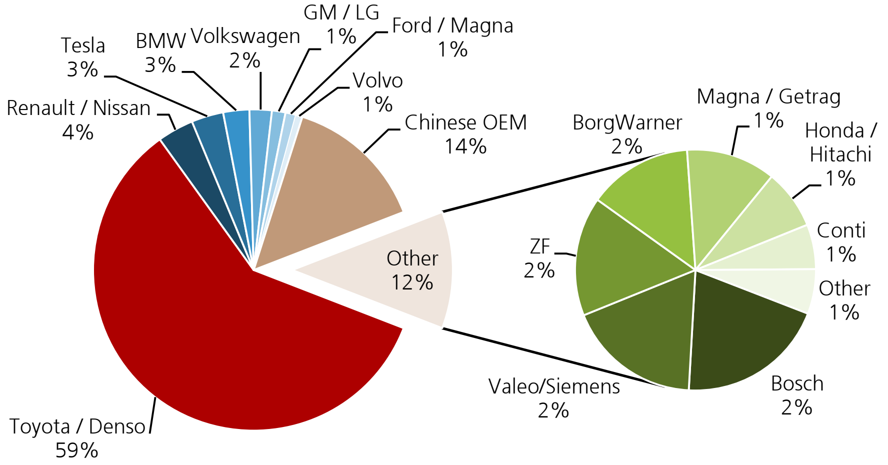
Source: UBS estimates

Competitive landscape

Make or buy decision is not clear-cut for e-motors

E-motors are either manufactured by the automakers or by suppliers, the latter of which can be split into "traditional" tier-1 suppliers and new players from the electronics industry, including LG Electronics. As OEMs need to focus their investments in a rapidly changing industry, there is a case for outsourcing to prevail longer-term. For the next five years, however, some OEMs (including Tesla, Toyota, Nissan and BMW) will likely hold on to in-house manufacturing in order to better understand the technology and also the levers of cost reduction. In-house manufacturing at some OEMs (such as Volkswagen) is also likely driven by job considerations. Finally, as there is still potential for innovation in e-motor technology, some OEMs might be able to create a competitive advantage with in-house produced motors. However, as the mechanical complexity of e-motors is much lower compared to combustion engines, the number of plant workers should be dramatically lower in any case.

Figure 65: E-motor production split by OEMs and traditional suppliers (2016)



Source: Company data, UBS
Note: Includes only high-power e-motors for BEV and hybrid cars; "Other" includes smaller suppliers including Torque Trends (USA), Buehler Motor (Germany), Electric Motorsport (USA), EVDrive (USA) and others

Costs today and future reduction potential

We conservatively forecast a ~10% cost reduction by 2025

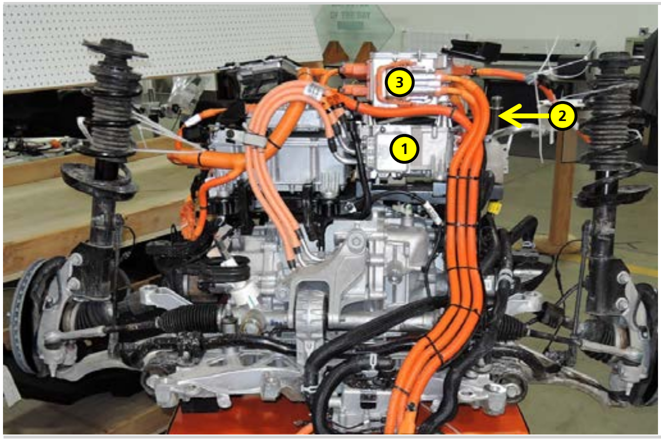
Munro estimates the costs of the Chevy Bolt e-motor and transmission at $800. Motor housing, gear train, resolvers etc. add another $400, resulting in $1,200 total e-drive module cost. Upside risks to e-motor costs are the rare earths, which represent ~8% of the total module cost today. In the future, economies of scale are likely a key cost driver. Furthermore, active cooling of the rotor could reduce rare earth content, as manufactured by Toyota. Daido Steel and Honda have created Hot Deformation Magnets. These are Neodymium magnets that do not contain Dysprosium or Terbium, yet have not lost any of the strength of Neodymium and maintain heat resistance. No cost data is available currently but Daido Steel plans to invest heavily in a US-based production facility in 2019. Generally speaking, reducing rare earth use and improving efficiency of motors (increasing range) will be key areas of product optimisation. Possibly, new e-motor variants including switched reluctance (SR) or variable magnetic motors could become more relevant, but are currently not used in mass production. This would eliminate the need for rare earths. We therefore consider our ~10% cost reduction potential assumption for 2025 as conservative. There could also be potential for in-wheel motors, which would improve drivability drastically, but this requires a much more sophisticated motor and control system.

Power electronics

Need-to-knows

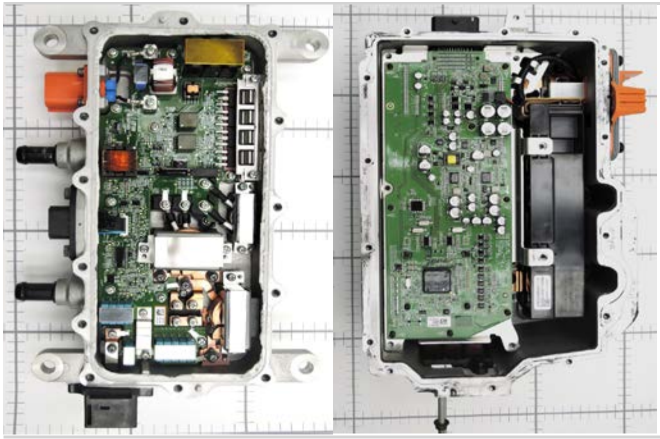
Power electronics include: (1) the e-motor controller / inverter; (2) the DC/DC converter; and (3) the high power distribution module. All modules are assembled by **LG Electronics and LG Innotek**.

Figure 66: Positions of the inverter (1), DC/DC converter (2) and power distribution module (3)



Source: UBS

Figure 67: Cutaway of a DC/DC converter (left) and inverter (right)



Source: UBS

Technology

The DC/DC converter converts high-voltage DC from the battery management system to low voltage for the non-propulsion electricity users. Before "arriving" in the DC/DC converter, the current is routed through the power distribution module (PDM) from the battery management module. An inverter takes DC supplied from the PDM and converts it to 3-phase AC for synchronous motor control. The inverter assembly also houses all e-motor control hardware. The modules share the same cooling loop as the e-motor.

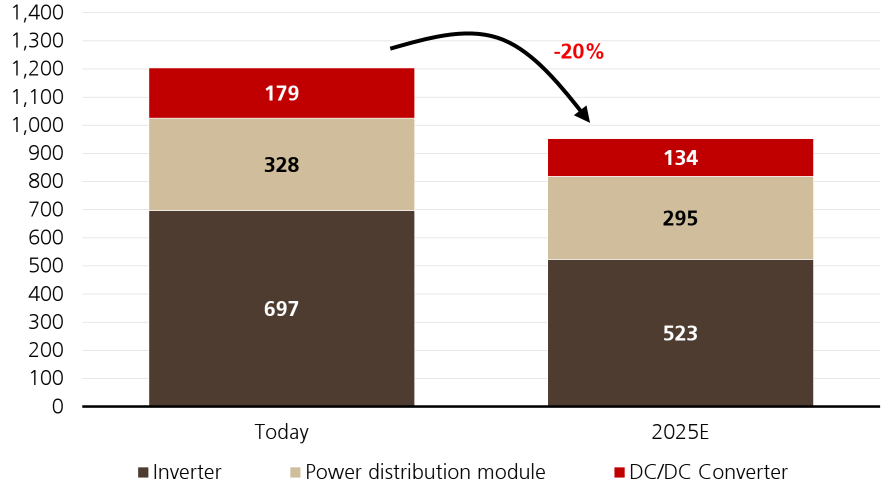
Competitive landscape

Chip content is from TDK (Epcos), Shizuki, Texas Instruments, Freescale, Infineon, among others. Other suppliers for the semi content include Würth Electronics, Schaffner EMC, STMicroelectronics, Atmel, Fairchild Semiconductor and others.

Costs today and future reduction potential

All the aforementioned components in this sub-group cost $1.2k according to Munro, as the following overview shows. The inverter/converter assembly is the most expensive module at an estimated $697 (Munro). The DC-DC converter costs $179 (Munro). The cost reduction potential for both modules is estimated at ~25% on a 2025 view, mainly on new semiconductor materials that reduce cost and size. The high-power distribution module costs $328 (Munro) and cost reduction potential is mainly seen through economies of scale.

Figure 68: Power electronics cost reduction potential of ~20% by 2025E



Source: UBS estimates

Thermal management

Need-to-knows

The Bolt has three separate thermal management circuits:

(1) for the battery (heating and cooling);

(2) for e-motor/power electronics (cooling only);

(3) for the cabin (heating and cooling).

Technology

All heating is performed by liquid heating circuits; AC functionality is similar to ICE cars

As there isn't enough heat produced by the e-motor in an EV for heating up the cabin and the battery, separate electric heaters are required for both the battery module as well as the cabin. Battery heating/cooling as well as cooling of power electronics is performed by liquid circuits, in the battery pack through aluminium plates and in the e-motor and electronics through built-in passages in the module housing. This avoids the need for a dedicated e-motor oil cooling loop, reducing cost, mass and design complexity. AC functionality is similar to an ICE car.

Competitive landscape

Electric heaters and coolant pumps are supplied by "traditional" tier-1 suppliers, as shown in the list below:

Figure 69: Thermal management supplier overview

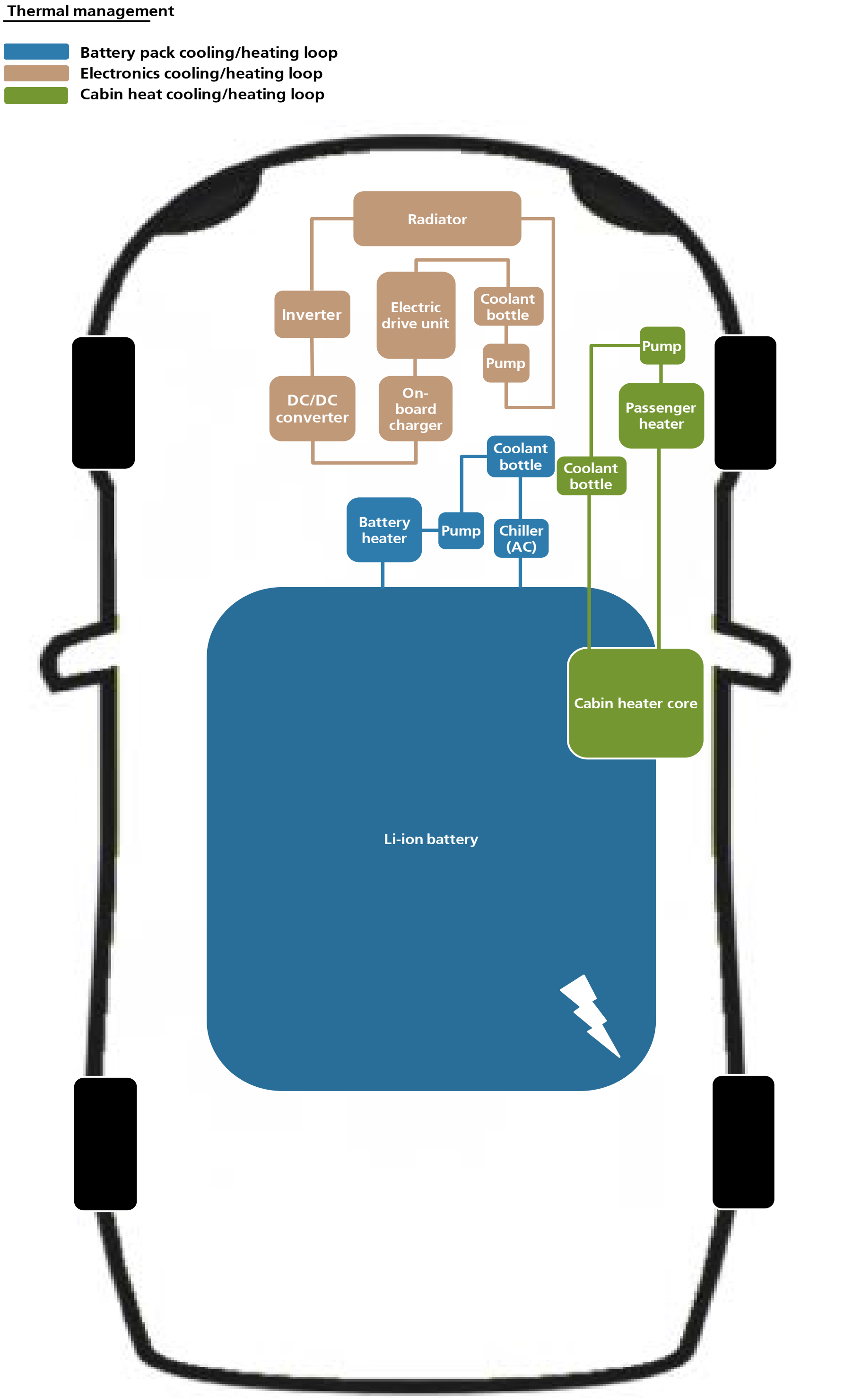
Electric heater	Electric coolant pump
Beru	Bosch
BorgWarner	Buhler
Denso	**Continental**
Eberspächer	Nidec GPM
Valeo	**Valeo**
Infineon	**Pierburg (Rheinmetall)**
Mahle	**Schaeffler**

Source: UBS; UBS-covered companies in **bold**.

Costs today and future reduction potential

The incremental costs of electric heaters and pumps compared to an ICE are seen at $298 by Munro. A potential future technology is to use the AC also as a heat pump for cabin heating. The VW e-Golf has such a technology. Munro believes it is ~40% more expensive than a traditional heater, but consumes less electricity.

Figure 70: The Bolt has three thermal management circuits



Source: UBS

Charger, charging cord and high-voltage cables

Need-to-knows

Charging requires an on-board charger module, a communication controller and a charging cord. The charger module is responsible for charging the battery pack by converting AC to DC with high efficiency. Various high-voltage cables are required to connect the modules with each other and with the battery.

Technology

The charger module is responsible for charging the battery pack by converting AC to DC with high efficiency. The EV communication controller is a core device that supports communication between the vehicle and charger for fast charging.

Competitive landscape

The charging cord is supplied by ClipperCreek. For cables, the suppliers for harness include Delphi, Yazaki, Sumitomo, Lear, Leoni and Nexans. Harness components are supplied by Huber + Suhner, Judd Wire, Leoni, Acome, Rosenberger (HVConnectors) and Coroplast.

Costs today and future reduction potential

The on-board charger cost is estimated at $698 by Munro (high-performance optional charger included in our Bolt – not a standard feature). Our vendor sees ~25% cost-cutting potential for the module on a 2025 view. The EV communication controller costs $51, and the charging cord is estimated at $150 by Munro. All other high-voltage cabling costs $335 according to Munro. The cost-cutting potential is largely limited to economies of scale in manufacturing.

Figure 71: On-board charger

Source: UBS

Figure 72: Charging cord incl. electronics module

Source: UBS

Differences in production processes

Figure 73: BEV production process schematic

	Power Train Assembly	Stamping	Body Shop	Paint Shop	General Assembly	Quality Assurance
Summary	The EV powertrain production contains three main components (inverters, motors, battery). The electric motor is often manufactured in-house, e.g. at Tesla. The process is largely manual with some help of robots.	In the stamping plant, the metal for the frame is unrolled, cut, and stamped into panels by hydraulic presses.	Robots assemble the stamped metal panels, joining them through welding, riveting, or using adhesives. The final output is the "body-in-white", the unpainted metal shell of the car.	The body-in-white is primed and top coats are applied by robots in an environment that is carefully controlled to prevent contamination and defects in the paint. Baking and drying completes the process. Whilst the paint shop is highly automated, human input is required to inspect work and repair defects.	The shell is transformed into a fully functioning vehicle as the battery, pony pack, trim, and seats are attached. General assembly would typically be divided into three lines: trim, chassis, and final. The complexity of the process means that general assembly is labour intensive, with manual stations rather than robots.	The BEV is given alignment, and gets a water test, a drive test and a BSR (bumps, squeaks, rattles test).
Companies affected	SKF GKN Sandvik	Sandvik Andritz GKN	Atlas Copco Kuka	Dürr	Dürr Siemens ABB Kuka	
Number of robots, sample ICE plant (capacity > 350,000 p.a.)			700	150		
Number of robots, sample BEV plant (capacity c.120,000 p.a.)			350	70		

Source: UBS

In the following we will describe the elementary differences in the production process between Internal Combustion Engine (ICE) cars and Battery Electric Vehicles (BEVs). We look at the key process steps: 1) Powertrain assembly, 2) Stamping, 3) Body Shop, 4) General Assembly and 5) Quality Assurance.

Powertrain Assembly

Companies impacted from …

Fewer bearings: *Schaeffler, SKF*

Less machining: *Sandvik, Kennametal*

Need for battery capacity: *Automation players in cap goods*

The motor in a BEV replaces the engine and transmission in an ICE vehicle and will contain a significantly lower number of moving parts. For instance, we expect that electric vehicles will have 6-7 bearings in the drive module (e-motor and mini gearbox) compared to 40-50 bearings in a traditional ICE. This clearly changes the market-place for companies such as Schaeffler and SKF in this end market. Although the process is largely manual, e-motors are significantly easier and less costly to manufacture compared to engines and transmissions, with lower cost and less labour input required. We also expect significantly less machining will be required for the e-powertrain vs. conventional ICEs. Our channel checks indicate up to 80% of the cutting tool work needed to manufacture a car happens in the combustion engine. Significantly less machining is required for the e-motor. In our European and US coverage, we believe Sandvik and Kennametal will be impacted the most here. Depending on the platform, BEVs may also contain a higher ratio of lighter materials (predominantly aluminium), such as the current Tesla models. Lighter materials such as aluminium are also softer in comparison to steel. This means that tooling intensity will come down as well, leading to less usage of tools. That being said, we believe that in the long run it is likely that range benefits come from better battery cell technology rather than from dramatically changing the material mix in the car body. We will elaborate on this in the "stamping section" below. In addition to the motor, key componentry are inverters, converters and power management systems, as well as obviously the battery. Battery manufacturing will lead to new suppliers entering the auto supply chain and is an incremental opportunity for the automation players in our coverage given that these manufacturers build factory capacity.

Stamping

The stamping process depends on the type of metal used. When manufacturing with aluminium, it is not possible to stamp out or extrude large panels, because these panels would be comparatively weak. This is critical for capital goods as more panels mean more robots in the body shop, as we will explain later. However, before we get there, let's think about what the typical mass-market BEV will be made of?

While manufacturing with aluminium would be more complex, the Bolt's frame has roughly as much steel as a conventional ICE mass-market car

The EV frame is typically majority aluminium in most high-end EVs available today (a lower-density material, to compensate for the weight of the battery), whereas the typical ICE vehicle has a steel frame. However, also BEVs can still be majority steel (e.g. the Chevy Bolt, as our teardown has shown). Ultimately this will be a weight (range!) vs. cost trade-off. We expect that most of the advances to range come from better battery technology in the near term and that the material mix in a typical mass-market BEV will not be materially different from today's ICE. This is due to the fact that applicable aluminium alloys are 5-10x more expensive vs. steel. This buys the OEM a weight advantage of 40%. In an EV manufactured from aluminium, you might have four or five different parts, while in a steel ICE vehicle you would stamp a single panel. In the case of the Chevy Bolt, with a 95% steel frame, the stamping process would be more in line with a conventional ICE car.

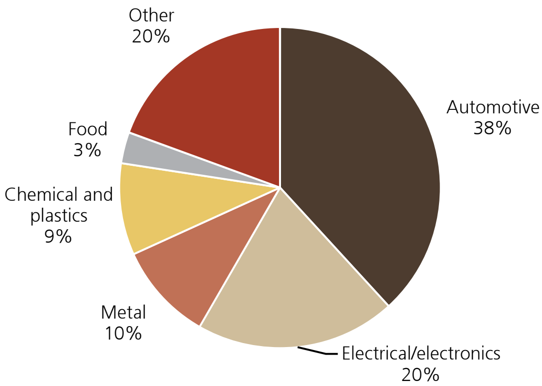
Body Shop

If the BEV is manufactured from aluminium, then more capital equipment may be required compared to a regular steel frame car because of the higher number of panels (as discussed in the stamping section). Equally, different end-effectors may be required on the robots for joining aluminium vs. steel, making it difficult to set up a flexible body shop able to produce both BEVs and ICE vehicles. Hence, incremental body shop capacity may have to be created depending on the material of choice for the vehicle. Whether manufacturing a BEV or an ICE, the process is highly automated; as many as 80% of a final assembly plant's robots would be located in the Body Shop. Considering that ca. 38% of the operational stock of industrial robots is in the automotive industry, the material choice for a car's frame could be an important growth lever for robotics / motion control players in the capital goods universe (Kuka, ABB, Siemens most notably) if, e.g., existing ICE OEMs add platforms where aluminium is the material of choice. However, given our base case assumption that material composition will not move heavily towards aluminium, we do not foresee a step change in demand for robots from this.

Aluminium bodies require different capital equipment – though we do not expect a material move away from steel

Companies potentially affected include Kuka, ABB and Siemens

Figure 74: The Automotive sector accounts for 38% of the worldwide operational stock of industrial robots (year end 2015)



Source: International Federation of Robotics

ICE vehicle manufacturers typically work with a strategic or owned body shop vendor. There are fewer high-volume aluminium body shops, meaning that the cost is significantly (perhaps 2-3x) higher.

Paint Shop

The differences between BEV and ICE vehicle production are minimal in the paint shop. Manufacturers would use the same equipment, although the paint might be chemically different for a BEV manufactured from aluminium.

General Assembly

General assembly is a similar process for BEVs and ICE vehicles. Given the assembly is modular, and stations can be shifted around, it would be possible to set up a general assembly manufacturing line for both BEVs and ICE vehicles. There may be differences in terms of software, given that BEVs tend to rely more heavily on software than mechanical processes. The need to upload new software as updates are made can slow the production process, and require more engineers to fix issues. Also final assembly for BEVs will require new risk management procedures once the battery is installed (and hence the vehicle is 'powered up').

Quality Assurance

The testing process is less lengthy for a BEV than an ICE vehicle, largely because there is no need for emissions testing.

Q: How profitable are EVs like the Bolt and the upcoming Tesla Model 3?

How profitable is the Bolt for GM?

Figure 75: Previous UBS EV powertrain cost estimate versus teardown findings

Powertrain	Previous UBS estimate	Teardown cost analysis
Battery cell	8,700	8,700
Battery pack (including BMS & thermal mgmt)	6,300	3,822
BMS	*500*	*222*
Thermal management	*-*	*100*
Other	*5,800*	*3,500*
Electric drive module	1,200	1,200
Inverter	850	697
DC/DC Converter	500	179
On-board charger (excl. fast-charge option)	700	273
Power distribution module		328
Thermal management		250
Vehicle interface control module (VCIM)		93
Electric Vehicle communication controller (EVCC)		51
High-voltage powertrain cabling		335
Charging cord		150
Other power electronics	2,400	
Total	**20,650**	**16,078**

Source: UBS

The powertrain turned out to be $4.6k cheaper than we thought

The components of the Bolt we tore down (everything that relates to powertrain and battery) have turned out to be $4.6k cheaper than previously anticipated, based on Munro findings. It has to be noted that our Bolt had various options, including the "Premier" trim with various additional ADAS and comfort functions, as well as the fast-charging capability. That's why we have done the maths for both "our" Bolt and a "naked" Bolt without any options. For the parts and components out of the scope of the teardown, we believe we have a fairly solid understanding of costs because the Bolt does not differ from a standard ICE car.

On our analysis, the total **direct production costs** of the "naked" Bolt add up to $28.7k, as the following analysis shows. This implies a positive contribution (selling price less cash manufacturing costs) of $3.2k per vehicle sold. The contribution represents 10% of the vehicle price (excl. dealer mark-up). Hence, GM has an incentive to sell more vehicles. At **EBIT level**, however, including proportionate overhead costs and D&A, GM likely incurs a loss of $7.4k per vehicle sold. We have assumed an initial annual production of 30k Bolts, in line with LG Chem's guidance for the Bolt's battery production. As it stands, GM/Opel currently have difficulties in meeting European demand for the car – therefore, 2018 production could increase (leading to better fixed cost coverage).

On a 2025 view, the "next-gen" Bolt's **total costs** (down to EBIT level) should decrease by $13.2k, in our view, driven by:

- **Innovation and economies of scale at supplier level:** Lower costs for the battery and for other EV powertrain components ($5.5k);
- **Economies of scale at OEM level:** Lower unit costs through mass production and better R&D and overhead coverage ($7.7k).

Figure 76: Detailed Chevrolet Bolt profitability analysis ($)

	Today		2025E		Commentary
Battery cost ($, total)	**12,300**	**12,300**	**7,800**	**7,800**	
Battery cost ($ / kWh)	**205**	**205**	**130**	**130**	
Cell	145	145	90	90	Based on GM disclosure and UBS cost forecast
Pack*	60	60	40	40	Previous UBS estimate for 2016: ~$100/kWh
	w/ options	**Basew/ options**		**Base**	
MSRP	**42,635**	**36,620**	**42,635**	**36,620**	Future Bolt MSRP likely lower; kept stable only for this exercise
Dealer/incentive (15%)	5,561	4,777	5,561	4,777	
Price charged by OEM	**37,074**	**31,843**	**37,074**	**31,843**	
Direct powertrain costs	**16,403**	**16,078**	**11,272**	**10,028**	$4.6k or 26% below our previous estimate
Battery cell	8,700	8,700	5,400	5,400	
Battery pack*	3,600	3,600	2,400	2,400	Pack cost based on teardown analysis
BMS	222	222	200	200	
Thermal management	250	250	225	225	
Inverter	697	697	523	523	
DC/DC Converter	179	179	134	134	
Power distribution module	328	328	295	295	Cost reduction of 10-25% per component on a 2025 view driven by scale, technology improvements and competition
High-voltage cables	335	335	302	302	
Electric drive module	1,200	1,200	1,080	1,080	
VCIM & EVCC**	144	144	130	130	
Onboard charger	598	273	449	205	
Charging cord	150	150	135	135	
Other direct costs	**15,608**	**12,600**	**14,908**	**11,900**	
Warranty provision	700	700	500	500	
Direct assembly staff cost	2,400	2,400	2,400	2,400	Based on average OEM factory assembly staff costs
Direct materials (assembly)	1,500	1,500	1,500	1,500	Primarily body and chassis
Supplier components	8,000	8,000	7,500	7,500	Includes interior, safety, ADAS & other electronics, etc.
Costs of optional features	3,008	0	3,008	0	Assume OEM generates 50% gross margin on options
Contribution margin	**5,063**	**3,165**	**11,895**	**8,916**	
% margin	14%	10%	29%	28%	
D&A	1,929	1,929	952	952	D&A cost degression driven by higher unit sales
R&D	7,143	7,143	714	714	R&D cost degression driven by higher unit sales
SG&A	1,512	1,512	1,512	1,512	Assume company-wide average SG&A / car for GM
D&A % of sales	5%	6%	3%	3%	
R&D % of sales	19%	22%	2%	2%	
SG&A % of sales	4%	5%	4%	5%	
EBIT	**-5,520**	**-7,418**	**7,716**	**5,737**	
EBIT margin	-15%	-23%	21%	18%	Assumed Bolt sticker price stays constant

Source: UBS
* ex BMS (Battery management system) ** VCIM = Vehicle interface control module; EVCC = Electric vehicle communication controller

We note that the estimated loss of $7.4k on the base model is lower than GM's guidance. The company talked about an initial EBIT loss of ~$9k per vehicle. Hence, there is a difference of $1.6k or 4% of the total costs of the Bolt between our analysis and GM guidance. As we don't have a detailed breakdown from GM, we cannot reconcile this number, but we believe the difference stems from differences in allocation of overhead costs.

TCO parity to be reached starting in 2018E in Europe; true parity in 2023E

Naturally, competitive forces and the need to improve consumer economics for EV mass adoption should drive down the selling price. Below, we look at the years of consumer TCO parity under the condition of GM: (1) making an EBIT loss like it does today; (2) breaking even; (3) making a 5% EBIT margin. The TCO parity would be reached one year later using the $9k loss indicated by GM as a starting point.

Figure 77: Projected years of TCO parity, breakeven margin and 5% margin for OEM

Projected year of ...	US	Germany	China	Japan
TCO parity	2025	2018	2023	2023
TCO parity & breakeven OEM margin	2027	2022	2025	2025
TCO parity & 5% OEM margin	2028	2023	2026	2026

Source: UBS estimates

Implications for the Tesla Model 3

Many similarities between Chevy Bolt and Tesla Model 3

We believe the profitability analysis of the Bolt can to a large extent be applied also to the upcoming Tesla Model 3, the company's long-awaited EV with a mass-market base price of $35,000. We summarize below what's similar and what's different between the two EVs.

- **What is similar:** Base version pricing, range / battery capacity, single e-motor with two-wheel drive, about the same interior space.
- **What is different:** Higher premium appeal of the brand (more pricing power and longer list of profitable options), different battery chemistry and more scale in battery manufacturing (Gigafactory), rear-wheel drive instead of front-wheel drive (all-wheel drive version at a later stage), more connectivity functionality (eg, over-the-air-upgrades) and autonomy-relevant hardware as standard (cameras, sensors), and better likely fixed cost absorption thanks to more ambitious production targets (>10x vs. the Bolt).

Further to that, there are differences in the distribution model and marketing. While Tesla receives the entire MSRP thanks to its fully-owned distribution operations and lack of discounting, GM's MSRP includes a ~15% mark-up for the independent dealerships and incentives. This also implies Tesla has higher distribution costs in SG&A.

The biggest uncertainty in the read-across from the Bolt to the Tesla is the battery costs. However, there are some data points that help us to narrow the range. For the Model S, the Tesla gives total battery pack costs of $190/kWh. Cell costs are $140-150/kWh today, similar to the price of the cells in the Bolt. Assuming that the next generation of cells produced in the Gigafactory have 20% higher energy density, ie, less use of active battery commodities and lower packaging volume, we think the pack costs for the Model 3 will initially be in a range of $160-180/kWh. The table below summarizes the expected profitability of the Model 3. We assume that the 55kWh battery pack is $9,075, or 26% cheaper than the Bolt's, mainly due to economies of scale in the Gigafactory.

Below, we use the estimated cost for the Chevy Bolt and BMW 3-Series to estimate the profitability of the Tesla Model 3. We looked at stripped-down and optioned-up versions of each model. We assume the Model 3 will be $7k higher with options (~20% of base). We estimate the Model 3 battery pack will be 26% cheaper than the Bolt and that EV powertrain components will be about $400 higher as the Model 3 will likely have stronger luxury performance. We also assume the assembly body will be $700 more costly due to the use of more aluminium. Our estimated warranty is about half the initial Model S accrual (given relative price). Lastly, we assume the non-powertrain components would be about $400 lower than the BMW 3-Series as the interior content will likely be more limited.

Figure 78: Detailed Model 3 profitability analysis ($) and comparison to Bolt (today)

	Chevy Bolt		BMW 330i		Tesla Model 3		
	Base	w/ options	Base	w/ options	Base	w/ options	Comments
MSRP	**36,620**	**42,635**	**38,750**	**45,000**	**35,000**	**42,000**	*Model 3 assumed +20% of base*
Dealer/incentives (15%)	4,777	5,561	5,054	5,870	-	-	
Price charged by OEM	**31,843**	**37,074**	**33,696**	**39,130**	**35,000**	**42,000**	
Battery cost ($ / kWh)	**205**	**205**			**165**	**165**	*Assumes ~20% lower cost due to Gigafactory*
kWh	60	60			55	55	*TSLA guided to <60*
Battery cost ($, total)	**12,300**	**12,300**			**9,075**	**9,075**	
Powertrain cost	**3,778**	**4,103**	**8,500**	**8,500**	**4,503**	**4,503**	*$400 higher vs. Bolt (performance related)*
Warranty provision	700	700	674	783	1,700	1,700	*Half of Model S initial accrual*
Direct assembly staff cost	2,400	2,400	2,800	2,800	2,400	2,400	
Direct materials	1,500	1,500	1,800	1,800	2,200	2,200	*$700 higher vs. Bolt due to aluminium*
Supplier components	8,000	8,000	10,400	10,400	10,000	10,000	*Less luxury content but more ADAS tech than BMW 3-Series*
Optional features	0	3,008	0	3,125	0	3,500	*est. 50% contribution on options*
Contribution margin	**3,165**	**5,063**	**9,522**	**11,723**	**5,122**	**8,622**	
% margin	10%	14%	28%	30%	15%	21%	
D&A	1,929	1,929	1,685	1,685	3,000	3,000	*Higher due to Gigafactory*
D&A % of sales	6%	5%	5%	4%	9%	7%	
R&D	7,143	7,143	1,685	1,685	952	952	*Lower vs. Bolt given higher units*
R&D % of sales	22%	19%	5%	4%	3%	2%	
SG&A	1,512	1,512	2,965	2,965	4,000	4,000	*BMW's base; +$2k for dealer SG&A; -$1k for advertising*
SG&A % of sales	5%	4%	9%	8%	11%	10%	
EBIT	**-7,418**	**-5,520**	**3,187**	**5,388**	**-2,830**	**670**	
EBIT margin	-23%	-15%	9%	14%	-8%	2%	

Source: UBS

In terms of vertical integration, the Model 3 has much more OEM content than the Bolt. While we consider the cell manufacturing as external purchasing from

Panasonic, the packaging is done by Tesla. Also, Tesla produces the e-motor unit in-house. Consequently, Tesla will have more capital employed.

$2.8k loss on base model; break-even at $41k likely exceeded on take rate of profitable options

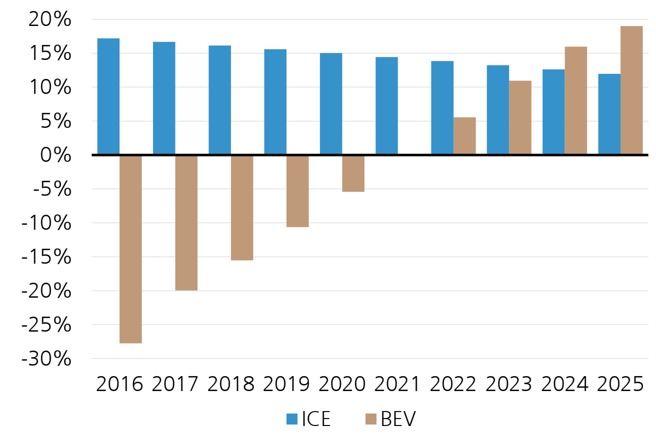
Our analysis shows that Tesla is likely to incur a loss of $2.8k on the base model. However, we expect Tesla to break even at a selling price of $41k, which requires $6k of options. On average, the break-even $41k selling price is likely to be exceeded on a high take rate of options. As the Model 3 is expected to feature all sensor hardware for autonomy functionality already in its base version, the optional software activation should deliver (almost) 100% gross margin for Tesla.

Q: What is the impact on the auto industry?

Shift to EVs could deliver faster returns and major CO_2 benefits, particularly for European OEMs

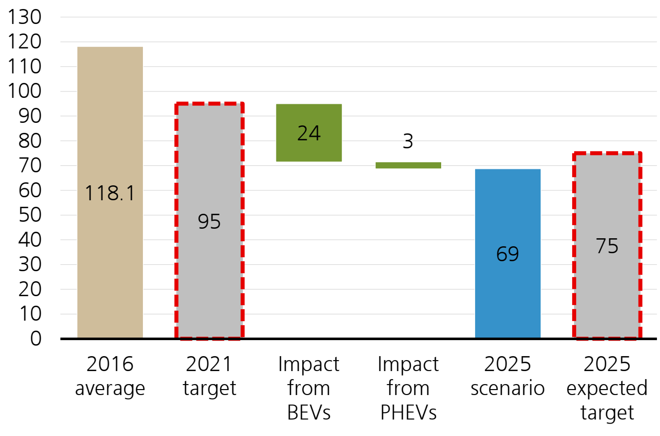
EVs should be cheaper to build, and there is likely more demand than we thought previously. Hence, the profitability of EVs is likely to improve faster (first in the premium segment), and current R&D should have a better and quicker return than anticipated by consensus. Higher EV penetration means a higher contribution of zero-emission vehicles to fleet-wide CO_2 targets, easing the structural cost headwinds for the OEMs, in particular in Europe. On our new EV sales forecasts, the CO_2 relief would be a big deal for European OEMs.

Figure 79: OEM ROIC trend



Source: UBS estimates

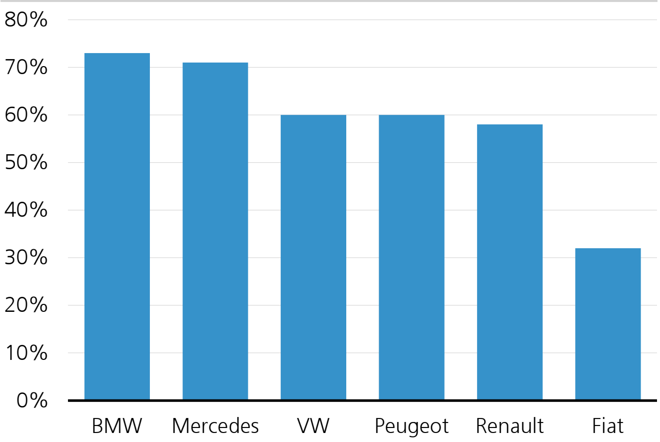
Figure 80: Impact on European fleet CO_2 emissions



Source: ICCT, UBS estimates

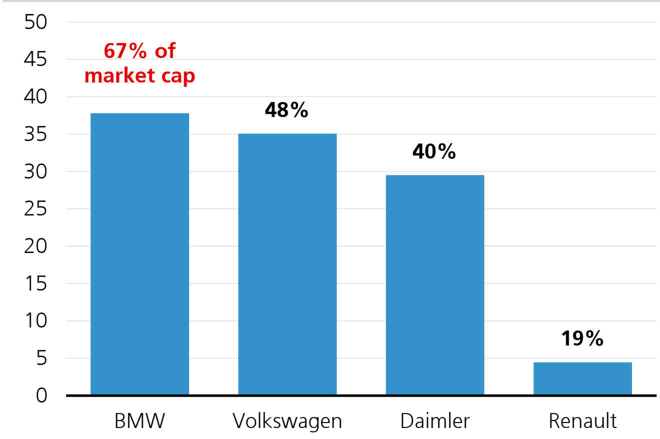
The flipside of an accelerated shift to EVs would be that ICE cars lose value more quickly, with less time for the OEMs to (1) adjust production capacity and workforce and (2) manage residual value risk through their fincos. European OEMs would be most exposed to this risk, in particular as EVs are likely to fuel the demise of the diesel.

Figure 81: EU diesel shares today – EVs could replace the diesel to a large degree



Source: UBS estimates

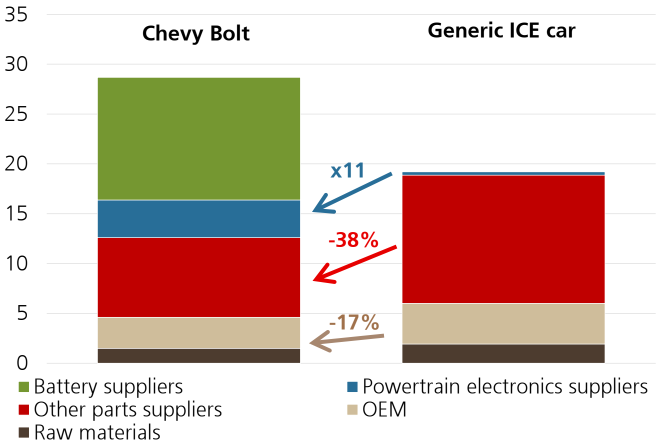
Figure 82: Lease book size by OEM – an accelerated shift to EVs implies residual value risk (€bn)



Source: UBS estimates

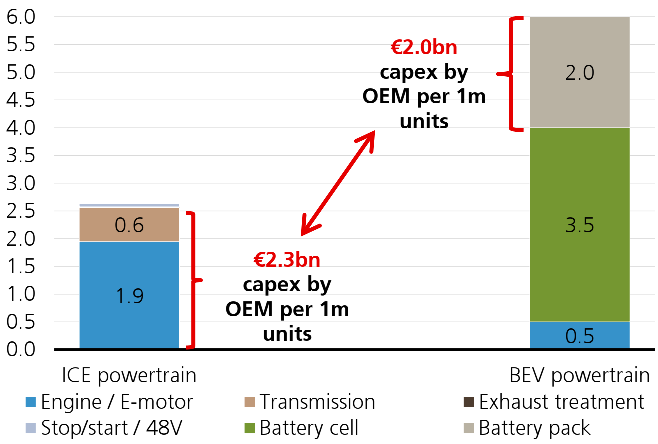
Also, the Bolt teardown has delivered evidence about a shrinking OEM content in an EV, which should lead to lower value-add. GM has outsourced almost the entire electric powertrain including the battery. Out of the total estimated **direct production costs**, we estimate $3.9k or 14% is GM's own content. OEMs will need to find other areas of differentiation to preserve brand value and pricing power. However, as capital intensity is also going to drop sharply, industry ROIC is unlikely to be materially different after the shift to EVs, all else being equal (new mobility models are a bigger threat). Once all major carmakers have EVs in their portfolio, we expect entry barriers to remain high from a financial standpoint (building/maintaining a brand and (after) sales network) – less so from a technological perspective.

Figure 83: Vehicle content level by sub-sector ($k)



Source: UBS

Figure 84: Powertrain capex EV vs. ICE



Source: UBS

A separate point not to be ignored: Because EVs have much fewer moving and wearing parts, the attractive spare parts business, which represents ~10-15% of an OEM's EBIT, is likely to shrink considerably long-term. However, this should take another 15-20 years longer, due to the replacement cycle of the existing car parc.

OEMs positively and negatively impacted by the theme

Daimler, Volkswagen, Renault best positioned

- **Europe:** Based on our findings in this report, we are confident that premium OEMs will have a sooner-than-expected return on current EV investments. More so, the OEMs without competitive EV product are at risk of forgoing revenue that is more profitable than feared. EV winners in the premium segment are also likely to enjoy the biggest CO_2 relief from EVs. But also in the mass segment, it will be essential after 2020 to offer a comprehensive line-up of EVs. Against this backdrop, we prefer **Daimler, Volkswagen and Renault. BMW** should invest more in EVs based on our market forecasts in order to protect its market share medium-term. The company faces the biggest revenue risk from Tesla's Model 3 (the 3-series is the closest peer). In a European context, **FCA** and **PSA** appear to be laggards on the theme.

GM leading mass maker, Tesla too expensive

- **US:** For US-centric OEMs Ford, GM and FCA that are underweight in premium, EVs are of lower relevance near-term. **GM** has clearly been ahead of the curve on electrification with seven years of development experience from the Chevy Volt PHEV that launched in 2010, and with the Bolt, GM is the first to market with a mass-market pure electric with a +200-mile range. However, the Chevy Bolt won't move the needle for GM's overall result given its low volume. Long term, with the sale of Opel in Europe, GM is leaving the potentially fastest-growing EV market. **Ford** has more modest EV experience with the C-Max and Focus EVs launching in 2012 and Fusion HEV in 2013; however, they will be quickly catching up as they spend $4.5bn over the next five years on 13 'electrified' vehicles (hybrid/PHEV/EV). **FCA** tends to lag GM and Ford on EV development. **Tesla** remains too expensive for the projected profitability and volumes level of the upcoming Model 3. Moreover, we see rising competition from the luxury automakers over the next few years as they roll out EVs.

Toyota leads thanks to hybrids

- **Asia: Toyota** is well positioned thanks to its brand image (UBS Evidence Lab survey confirmed the high credibility of the brand for EVs) and technological expertise in hybrid cars. It self-produces core components used in HEVs and BEVs, including batteries, motors, PCUs, etc., and already has a cost advantage from producing over 1.4 million HEVs/year. The additional R&D burden for BEV-related technologies is therefore relatively small. For a long-term response to environmental regulations, Toyota takes a portfolio approach of pursuing all products. Proactive in developing technology for BEVs, Toyota categorizes them as short/medium-range commuter cars and plans to progressively move from HEVs to PHEVs to BEVs. **Honda**, like Toyota, takes a portfolio approach to next-generation zero-emission cars. The company aims for PHEV/BEV/FCVs to comprise two-thirds of total sales by 2030. **Nissan** places BEVs at the core of its next-generation zero-emission cars and leads global BEV sales with the "Leaf", for which a model update is planned for 2017. We expect an expansion in the number of models Nissan launches to maintain a leading position in the space.

Figure 85: OEM EV heat map – who are the best and worst positioned players?

OEM	EV sales potential	Investment focus on EV	Potential CO_2 benefit	Residual value risk
Tesla	Very high	Very high	n.m.	Low
Daimler	Very high	High	High	High
JLR	Very high	Medium	High	Low
Volvo	Very high	Medium	High	Low
BMW	Very high	Medium	High	High
VW	High	High	High	High
Renault	High	Medium	High	Medium
Nissan	High	High	Low	Low
Toyota	High	Medium	Medium	Medium
PSA	High	Low	High	Low
Hyundai	Medium	Medium	Medium	Low
Ford	Medium	Medium	Medium	Medium
GM	Medium	Medium	Medium	Medium
Kia	Medium	Low	Low	Low
Mazda	Medium	Low	Medium	Low
Honda	Low	Medium	Low	Medium
FCA	Low	Low	Low	Low
Subaru	Low	Low	Low	Low
Suzuki	Low	Low	Low	Low

Source: UBS

Figure 86: EV targets and strategies by OEM (where available)

	Volumes	Models	Other
Volkswagen Group	20-30% of sales	>30 BEV	Investing in dedicated EV platform, €9bn investment for program over next five years
VW brand	1m unit sales		€1bn p.a. investment for 'ID' family in next few years, including R&D and plant re-tooling
Audi	25-30% of sales	3 BEV by 2020	
BMW	15-25% of sales		Investing in flexible EV architecture
Honda	67% of sales by 2030		
Mercedes	15-25% of sales	10 BEV by 2022	Dedicated EV platform, €10bn investment for total program
GM	~30k Bolts in 2017		Bolt architecture to underpin future BEVs
Ford	40% of line-up incl. hybrids	13 BEV + PHEV	$4.5bn by 2020E, including $700m to expand a Michigan plant to produce EVs
Volvo	1m cumulative by 2025		Using flexible EV architecture
Hyundai		4 PHEV, 4 BEV	Investing in dedicated EV platform
Kia		4 PHEV, 4 BEV	Investing in dedicated EV platform
Tesla	0.5m by '18, 1m by '20		35GWh cell capacity @ Gigafactory by 2018E, 50GWh by 2020E
PSA		7 PHEV, 4 BEV	Investing in dedicated EV platform
Toyota	1.5m HEV + 30k FCV		90% reduction in average CO_2 emissions of new vehicle sales by 2050E (vs. 2010 levels)
Nissan	20% of European sales		Dedicated EV platform with Renault
BYD	240k units	16 BEV, 5 PHEV	34 GWh battery capacity by 2020E; Rmb10bn capex each year
Changan	400k units cumulative	27 BEV, 7 PHEV	Rmb 2-3.3bn in next 3 years
SAIC	600k units (200k domestic brand)	13 BEV, 17 PHEV	Rmb 20bn through 2020E (including JVs)

Key

2017/18
2020/21
2025

Source: Company information, UBS

Financial implications for auto suppliers

OE business: >50% of the Bolt from outside the traditional supply chain

The supply chain looks very different for electric cars in general and for the Bolt specifically:

- **The content of "traditional" tier-1 suppliers is materially lower in the Bolt.** Based on Munro estimates for the powertrain, ADAS, connectivity / HMI modules, the content from "traditional" tier-1 suppliers in the Bolt is nearly zero. The other parts and components outside the scope of this teardown (interior, lighting, etc) are similar to an ICE car and therefore represent content from established suppliers.

- **The Bolt has a very high share of content supplied by the LG group of companies.** LG companies supply not only the battery, but almost the entire powertrain, including all electronic modules. On top, they supply connectivity / infotainment modules. Our teardown analysis based on Munro estimates suggests a total LG content of **$16.0k or 56%** of the total vehicle direct production costs (14% excluding the battery). Of course, an LG-assembled electronics module has substantial third-party semiconductor content, which is not subtracted from the aforementioned number. LG is a **new entrant** in the automotive space, but we expect more electronics or chemicals conglomerates to enter the space. For example, Samsung acquired infotainment specialist Harman in 2016. We believe that the LG-GM deal for the Bolt is very specific: We think it is possible GM committed to buy the non-battery components from LG in exchange for a very competitive battery cell price of $145/kWh. Therefore, the average content of "new entrant" suppliers in future EVs might be lower than in the Bolt.

Figure 87: Who supplies what into electric cars?

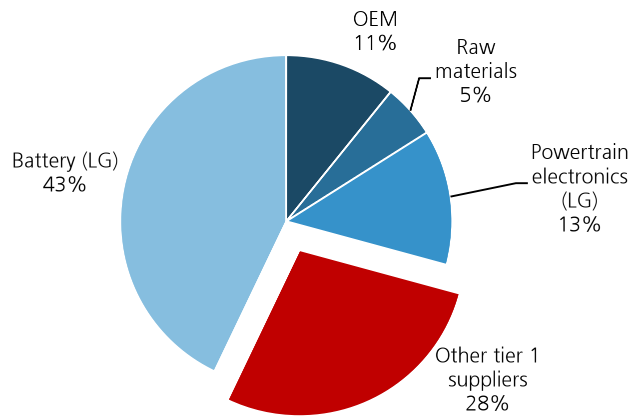
	Battery cell	BMS	Battery pack	Battery charger	Charge cord	Electric motor	Gear-box	Power distr. module	Inverter	DC/DC conv.	Thermal mgmt	Connec tions / wiring
Cell suppliers	●		●									
Aisin Seiki						○	●		○			
BWA						●	●				●	
Bosch						●		●	●	●	●	
Conti		●		○		●		●	●	●	●	
Delphi		●		●				●	●	●	●	●
Dana											●	
Denso		●		●		●		●	●	●	●	
Faurecia											○	
GKN							●					
Hella		●								●	●	
Hitachi	●		●			●			●			
Lear				●								●
Leoni												●
LG Electronics		●	●	●		●		●	●	●	●	
Magna							●				●	
Mahle						●					●	
Nidec						●						
Schaeffler							●					
SKF							Bearings					
Valeo/Siemens				●		●	●		●	●	●	
ZF						●	●		●	●		

Source: UBS

Note: Light blue cells indicate product is currently being developed

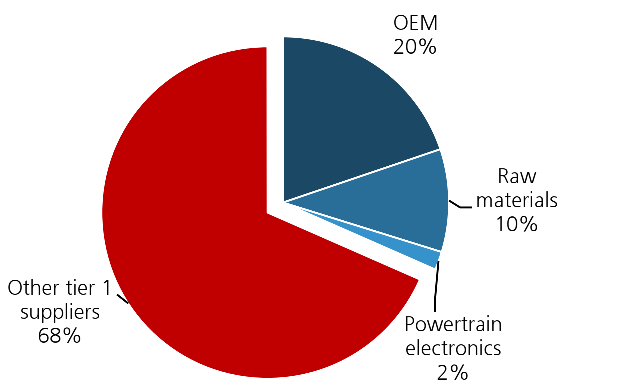
Aggregating the Chevy Bolt's content by sub-group gives the following picture. It can be seen that while the OEM content in the Bolt is slightly lower than in a generic comparable ICE car, the content from "traditional" tier-1 suppliers in the Bolt is meaningfully lower. LG has the biggest content share in the Bolt.

Figure 88: Chevy Bolt content breakdown



Source: UBS estimates

Figure 89: Generic comparable ICE car content breakdown



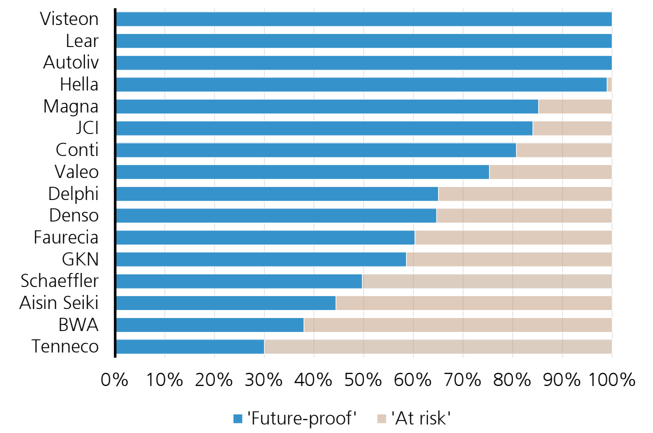
Source: UBS estimates

'Traditional' tier-1 suppliers could have less EV content growth than many investors think

The level of preparedness of our global auto supplier coverage varies greatly, and high R&D is required to develop EV products. Also, the level of vertical integration (ie, the value-add) of tier-1 players is also likely to shrink due to higher content of electronics from semiconductor suppliers. In light of the valuation premium of suppliers vs. OEMs, we see potential for disappointment in some names.

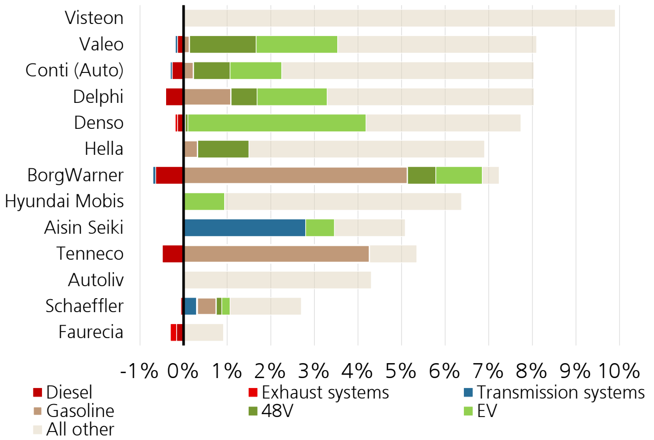
The Bolt example underscores the threat of new entrants. LG has >50% content share in the Bolt, higher than the "traditional" tier-1 suppliers altogether. This adds to competitive pressure in the industry and might imply lower market shares of the "traditional" tier-1 players than many people think. The headline content numbers that suppliers refer to in their investor presentations might overstate the opportunity, not least because today's costs are used. Even if a specific firm has, for example, potentially 3x the content in an EV compared to an ICE car, its actual value-add and its market share might be much lower than in ICE cars today.

Figure 90: UBS global supplier revenue mix – 'future proof' vs. at-risk business in EV world



Source: UBS estimates

Figure 91: Secular revenue CAGR impact of powertrain mix shift, 2016-25E



Source: UBS estimates

Threat in aftermarket business becomes relevant only in the very long-term

Aftermarket revenue pool to drop by ~60% in a 100% EV world

The difference in the number of moving and wearing parts has widespread implications for various players:

- The Bolt requires much **less maintenance** (negative for dealerships and repair shops).
- Over the life of the car, the Bolt will require much **fewer spare parts** than the Golf. This should undermine the spare parts business, which has been very lucrative for suppliers, OEMs and dealerships/repair shops alike.
- The amount of **liquids that require regular replacement is dramatically lower** in the Bolt. For example, there is no regular engine oil change.

Figure 92: Annual maintenance costs of the Bolt and Golf compared ($)

Chevrolet Bolt		VW Golf
790	**Retail value of wearing parts**	**3,950**
	Annual costs ($)	
	Common maintenance only (annualised)	
185	Parts replacement (incl. service)	450
55	Inspection (preventive)	75
15	Liquids (incl. service)	85
255	**Total maintenance**	**610**
	'Worst-case' maintenance (annualised)	
520	Battery/engine/transmission replacement	485

Source: JD Power, Edmunds, General Motors, Volkswagen, UBS

First Bolt inspection after five years

The dramatic differences can be seen at a glance in the respective owner manuals. Except for rotating the tyres and replacing the cabin air filter, the Bolt does not require any maintenance for the first **150k miles / 240k kilometres or five years**, whatever comes first. The Golf, however, requires servicing every **10k miles**.

Figure 93: Comparing the Bolt's vs. the Golf's service and maintenance schedule

VW Golf

Miles	**10k**	**20k**	**30k**	**40k**	**50k**	**60k**	**70k**	**80k**	**90k**	**100k**	**110k**	**120k**
Tyre rotation	X	X	X	X	X	X	X	X	X	X	X	X
Oil change	X	X	X	X	X	X	X	X	X	X	X	X
Oil filter change	X	X	X	X	X	X	X	X	X	X	X	X
Cabin filter change		X		X		X		X		X		X
Transmission fluid change				X				X				X
Spark plug change						X						X
Engine air filter change						X						X
Brake fluid change	**Every two years**											

Chevy Bolt

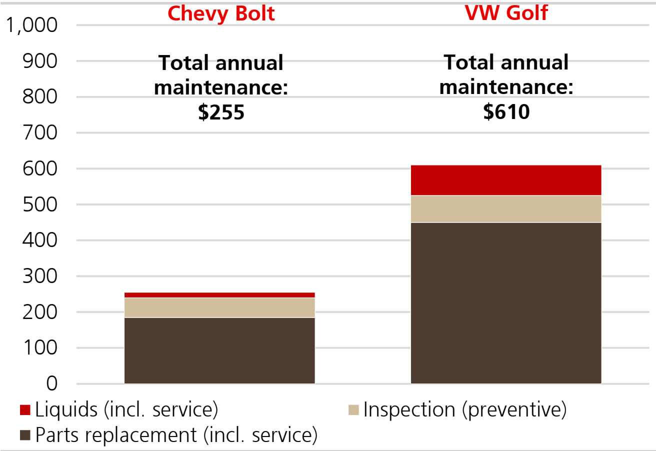
Miles	**7.5k**	**15k**	**22.5k**	**30k**	**37.5k**	**45k**	**52.5k**	**60k**	**67.5k**	**75k**	**82.5k**	**90k**
Tyre rotation	X	X	X	X	X	X	X	X	X	X	X	X
Cabin filter change			X			X			X			X
Vehicle coolant change	**Every five years**											
Brake fluid change												

Source: General Motors, Volkswagen

In the following, we model the after-sales revenue pool for the first 150k miles for both the Bolt and the Golf. On an annual basis, the maintenance costs for the Bolt are about $355 lower than for the Golf. The differences result from (1) no liquids replacement for the first five years; (2) fewer pre-emptive inspections; (3) less wearing on mechanical parts that require replacement.

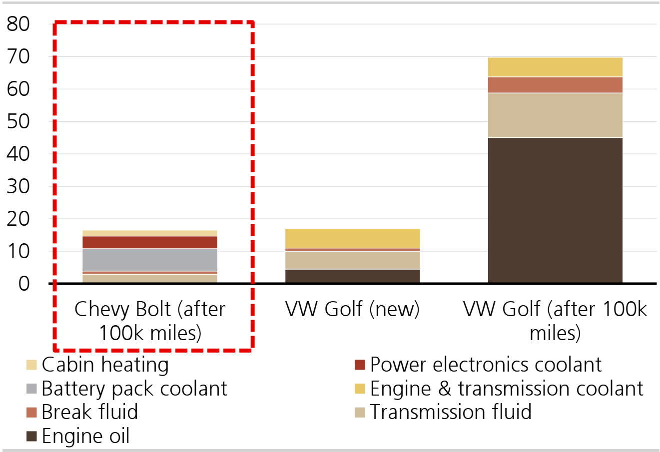
The only thing wearing faster in an EV are the tyres, due to the higher curb weight and higher torque of the vehicle. In our example, we assume that tyres wear 22% faster due to the 22% difference in the curb weight between the Bolt and the Golf. This represents an opportunity for tyre makers. However, as energy density in batteries keeps going up (and battery weight per kWh keeps coming down), the difference in curb weight might gradually disappear in the long run.

Figure 94: After-sales revenue pool shrinks up to 60% ($)



Source: UBS estimates

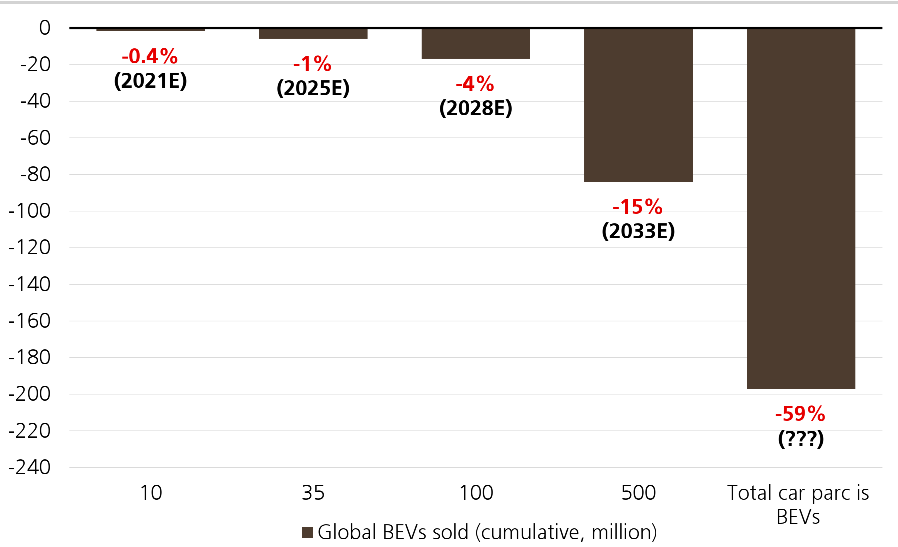
Figure 95: Fluids and coolants required ($)



Source: UBS estimates

Over the coming decades, the aftermarket revenue pool should shrink as ICE cars get scrapped and replaced by EVs. However, as the average life of a car is 15 years or even higher, the speed of change in the car park should be much lower than the shift that will be observed in the OE business. Therefore, we think the decline in the aftermarket revenue pool should be limited to ~1% on a 2025 view. We expect the impact to become much more meaningful only after 2030.

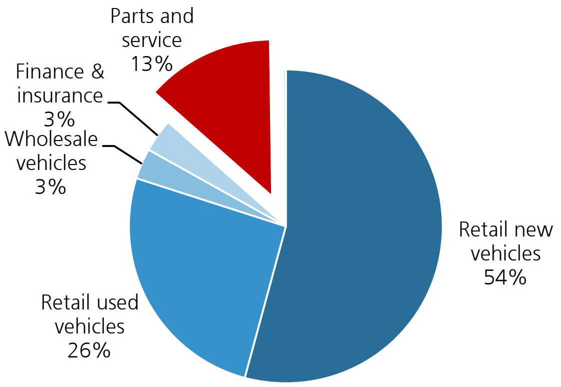
Figure 96: The global automotive aftermarket should ultimately shrink by 60%, although a material impact should not be felt before ~2030



Source: UBS estimates

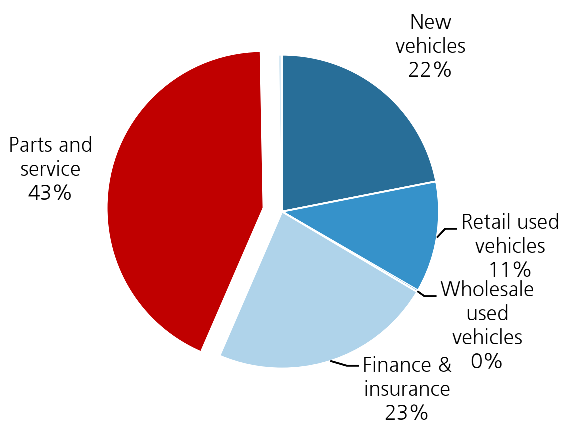
The almost maintenance-free electric car is also a big deal for dealerships. Their business model heavily relies on selling high-margin spare parts and providing regular service and maintenance to vehicles. Almost half of the gross profit of dealerships stems from parts and service.

Figure 97: Dealership revenue mix



Source: UBS (based on average numbers for AutoNation, Penske, SonicAutomotive, Group1, Asbury and Lithia)

Figure 98: Dealership gross profit mix



Source: UBS (based on average numbers for AutoNation, Penske, SonicAutomotive, Group1, Asbury and Lithia)

More supplier M&A ahead

Tier-1 suppliers need to adapt their portfolios to the car of the future, and at the same time, electronics giants as new entrants in automotive need to expand their portfolios, potentially including M&A. There have been several deals recently we would see in the context of a rapidly changing industry:

- **Samsung** buying infotainment specialist **Harman** (2016);
- **Delphi** announced it would spin its conventional powertrain business, but retain the EV powertrain activities;
- **Bosch** announced the disposal of its starter-generator business to a Chinese mining company.

We expect elevated M&A activity in the supplier space in the coming years, driven by the need to (1) adjust product portfolios to the automotive megatrends, (2) create balance sheet headroom for necessary investments and (3) crystallize hidden SOTP value. Spinning off or selling cash-generative (potentially under-valued) legacy businesses in the combustion engine space could prove an attractive way to create value for shareholders, in our view.

Suppliers positively and negatively impacted by the theme

Valeo and Conti to benefit most; Faurecia and Schaeffler at risk

- **Europe: Valeo** and **Conti** appear set to benefit most from the switch to EVs. On top, both companies have very small exposure to the "legacy" combustion engine business. Based on our expectation of a rapidly shrinking diesel share, mild hybrid gasoline engines should represent an important bridge technology that Valeo in particular should benefit from. The tyres business should also benefit from EVs (higher weight, better acceleration) as replacement demand should be positively impacted. **Michelin** is amongst our Buy-rated stocks. At the other end of the spectrum, **Faurecia** and **Schaeffler** have the largest exposure to combustion engines.

- **US:** We see **DLPH** as being best positioned for the shift to EVs given its exposure to wiring content in E/EA and power electronics in its Powertrain division. We see incremental opportunities for **LEA**'s E-System segment and **DAN**'s thermal business (within Power Technologies). We believe both **BWA** and **MGA** are relative hedged for the EV segment shift risk. On the other hand, we think **TEN** is the most at risk given its emissions exposure.

Delphi leads

Figure 99: Summary of US Supplier EV vs. ICE Exposure

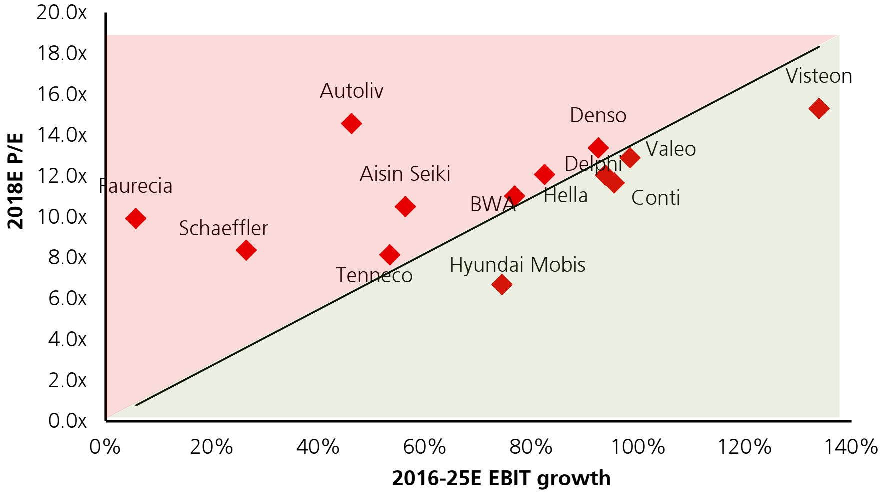
Company	% of EBIT from ICEs	At Risk ICE Content	Added EV Content	Commentary
DLPH	16%	Direct Injection ($300-500) Variable Value Train	High voltage cables ($335) On-board charger ($598) Inverter ($697) DC/DC Converter ($179) Battery Mang Sys ($222)	DLPH appears the best positioned of the US suppliers for EVs. Its core E/EA business should benefit from high-voltage cables and the on-board charger. On the Powertrain side, about 60% of this segment is at risk from the end of the ICE with content associated with direct injection and variable value train. However, this is more than offset by high content components like the inverter, DC/DC converter, the battery management system, and the supervisory controller/software.
LEA	N/A	N/A	High voltage cables ($335) On-board charger ($598)	35% of LEA's EBIT is from its E-System division, which benefits from high-voltage cables and the on-board charger.
DAN	N/A	N/A	Thermal Mang. ($250)	DAN is a leading supplier for light- and heavy-vehicle drivelines. The company sees incremental content opportunities in EVs from thermal management, e-axles, and electronic transmissions.
BWA	72%	Turbochargers ($250) Variable Value Timing Exhaust Gas Recirculation	E-Motor ($1,200) EV Transmission Thermal Mang. ($250)	BWA is a global leader in engine technology with Engine sales representing 72% of its profits; however, the recent Remy acquisition significantly hedges its exposure to EVs. Key BWA engine products include turbochargers, variable cam timing, and exhaust gas recirculation; today BWA's average content per ICE is ~$185/car. With the recent Remy acquisition, BWA now has exposure to e-motors ($1,200/car) and electric drivetrains, and it estimates it will have a content per EV of $285/car by 2023. With a similar number of competitors relative to its ICE business, BWA expects to maintain similar margins on its EV content as its ICE content.
MGA	21%*	ICE Transmissions 4WD/AWD Pumps	EV Transmission Thermal Mang. ($250)	21% of MGA's production sales are in Powertrain; however, most of the key products are largely driveline. MGA is the #1 supplier of transmissions, 4WD/AWD systems, and mechanical pumps. The company has hedged this exposure with its EV transmission and thermal management products, and sees an overall increase in addressable content of $500/vehicle.
TEN	65%	Exhaust ($300-500)	None	We believe TEN is the worst positioned of the US suppliers given ~65% of EBIT comes from Clean Air (emission), which has no content on an EV; fortunately only 14% of EBIT is Clean Air Europe, the region with the fastest EV growth.

* Reflects % of Production Sales as MGA does not disclose EBIT by division
Source: Company reports, UBS

Denso best positioned

- **Japan**: We see **Denso** as best positioned given its experience in manufacturing a wide range of core EV components, including electric motors, semiconductors and ECU. As a main supplier for Toyota HEVs, which makes more than 1.4m units annually, Denso has a competitive edge as it is able to benefit from economies of scale for many of these components. HEVs are complex from a technological perspective, requiring control of both electric and ICE components. Applying its HEV technology to BEVs should be relatively easy for Denso, as BEVs do not have ICE components. The additional R&D burden for BEV-related technologies is therefore relatively small.

Figure 100: Valuation vs. secular EBIT growth – identifying under- and overvalued auto suppliers



Source: UBS estimates (PE based on Bloomberg consensus EPS)

Figure 101: UBS cross-sector coverage impacted by the theme

Stock	Positively/ negatively impacted?	Price (lc)	P/E (2018E)	UBS Analyst
Analog Devices	Positively	81	20.3x	Stephen Chin
Albemarle	Positively	112	22.0x	John Roberts
Asahi Kasei	Positively	1,082	12.4x	Go Miyamoto
Atlas Copco	Positively	328	21.7x	Guillermo Peigneux Lojo
Continental	Positively	206	11.4x	David Lesne
Daimler	Positively	69	7.6x	Patrick Hummel
Delphi	Positively	87	11.4x	Colin Langan
GKN	Positively	352	9.5x	Cristian Nedelcu
GM	Positively	33	4.9x	Colin Langan
Hella	Positively	46	12.5x	Chervine Golbaz
Hexagon	Positively	392	18.6x	Guillermo Peigneux Lojo
Hyundai Mobis	Positively	249,500	7.4x	Young Chang
Infineon	Positively	20	18.1x	Gareth Jenkins
Lear	Positively	146	8.8x	Colin Langan
LG Chem	Positively	285,500	10.7x	Tim Bush
LG Display	Positively	28,800	6.0x	Nicolas Gaudois
Maxim	Positively	47	19.2x	Stephen Chin
Melexis	Positively	81	26.5x	Francois-Xavier Bouvignies
Nissan	Positively	1,103	6.8x	Kohei Takahashi
Renault	Positively	88	5.4x	David Lesne
Renesas	Positively	1,023	20.2x	Kenji Yasui
Samsung SDI	Positively	153,000	11.0x	Bonil Koo
Siemens	Positively	131	15.4x	Markus Mittermaier
Sika	Positively	6,300	22.2x	Patrick Rafaisz
STMicro	Positively	15	16.3x	Gareth Jenkins
Sumitomo Chem	Positively	604	8.7x	Go Miyamoto
Tesla	Positively	317	-86.8x	Colin Langan
Texas Instruments	Positively	82	19.3x	Stephen Chin
Toyota	Positively	6,093	9.6x	Kohei Takahashi
Umicore	Positively	59	23.3x	Geoff Haire
Valeo	Positively	64	13.0x	David Lesne
Volkswagen	Positively	143	5.4x	Patrick Hummel
ABB	Neutrally	25	17.6x	Guillermo Peigneux Lojo
Aisin Seiki	Neutrally	5,620	11.9x	Kohei Takahashi
Autoliv	Neutrally	103	15.8x	David Lesne
BMW	Neutrally	86	8.7x	Patrick Hummel
Dana	Neutrally	20	9.0x	Colin Langan
Denso	Neutrally	4,915	15.6x	Kohei Takahashi
Ford	Neutrally	11	5.6x	Colin Langan
Honda	Neutrally	3,167	8.3x	Kohei Takahashi
Hyundai	Neutrally	157,500	5.7x	Young Chang
Kia	Neutrally	36,900	5.5x	Young Chang
Kuka	Neutrally	109	31.8x	Sven Weier
Magna	Neutrally	46	7.2x	Colin Langan
Mazda	Neutrally	1,555	6.0x	Kohei Takahashi
Subaru	Neutrally	3,922	7.0x	Kohei Takahashi
Suzuki	Neutrally	5,235	17.5x	Kohei Takahashi
Visteon	Neutrally	103	14.9x	Colin Langan
BASF	Negatively	87	14.2x	Andrew Stott
Clariant	Negatively	21	13.2x	Patrick Rafaisz
EMS-Chemie	Negatively	668	33.6x	Patrick Rafaisz
Faurecia	Negatively	46	15.8x	David Lesne
FCA	Negatively	10	3.9x	Patrick Hummel
Johnson Matthey	Negatively	3,143	14.5x	Andrew Stott
LG Electronics	Negatively	79,000	12.2x	Nicolas Gaudois
Panasonic	Negatively	1,373	14.4x	Kenji Yasui
PSA	Negatively	19	9.1x	David Lesne
Rheinmetall	Negatively	87	13.2x	Sven Weier
Sandvik	Negatively	140	20.5x	Guillermo Peigneux Lojo
Schaeffler	Negatively	15	8.7x	Julian Radlinger
SKF	Negatively	183	15.7x	Markus Mittermaier
Tenneco	Negatively	58	7.4x	Colin Langan
W.R. Grace	Negatively	70	17.9x	John Roberts

Source: UBS estimates

Impact on various industries at a glance

Auto OEMs

EV impact on sector … **Growth:** → **Margins:** ↘ **ROIC:** → **Valuation:** →

KEY FINDINGS

Q: What did we learn from the teardown?

EVs are cheaper to build than we thought. Cost parity to consumers should be reached starting 2018, which is why we raise our 2025 EV sales forecast by ~50% to 14.2m. We expect 30% EV penetration in Europe by then.

Q: What was the most non-consensual finding?

The detailed P&L for the Chevy Bolt and the upcoming Tesla Model 3. We demonstrate that at a transaction price of $41k ($6k above the base price), Tesla should break even on the Model 3. This is likely to be exceeded.

FINANCIAL IMPACT

Q: What will be the impact on the industry?

Earlier cost parity implies sooner and higher returns on EVs, in particular in the premium segment and, regionally speaking, in Europe. European OEMs can also benefit from a strong tailwind to CO_2 fleet targets post 2020. The flipside of the accelerated shift is the residual value risk to fincos and lower contribution from highly profitable aftermarket long-term.

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from EVs?

Mixed picture. Tesla aside, Daimler and Volkswagen are showing the biggest effort. Overall, investments in EVs (R&D and capex) have risen sharply over the past 12 months.

SECTOR VALUATION

Q: Could the trend to EVs lead to a change in sector valuation multiples?

There is a negative impact, which is likely to stay through the transition period. After 2020, however, returns should become visible and there could be major CO_2 tailwinds, in particular in Europe and China. OEM shares also trade at a discount today due to expected earnings headwinds from CO_2 targets.

STOCK IMPACT

Q: What stocks should be impacted most positively and negatively?

We believe stocks with skew to (1) premium and (2) Europe and China are set to enjoy fastest EV sales growth.

MOST FAVOURED on the theme

Stock	2018E PE	EPS impact 2025	Comment
Daimler	7.6x	10-25%	Highest R&D in EV, likely premium leader
Volkswagen	5.5x	10-25%	Can become global #1 EV producer
Renault	5.5x	10-25%	EV investments already done
GM	4.5x	10-25%	EV investments already done, launched the Bolt

LEAST FAVOURED on the theme

Stock	2018E PE	EPS impact 2025	Comment
FCA	3.8x	<10%	No EV platform; exposure to US non-luxury
PSA	10.4x	<10%	Low investment focus on EV so far
SUBARU	7.1x	<10%	Low investment focus on EV; exposure to US mass

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Auto suppliers

EV impact on sector … **Growth:** → **Margins:** ↘ **ROIC:** ↘ **Valuation:** →

KEY FINDINGS

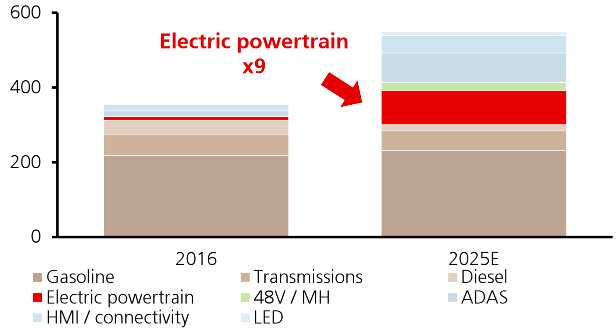
Q: What did we learn from the teardown?
Mixed. More supplier content in an EV, but the Chevy Bolt has >50% content from LG, a new entrant in automotive. The aftermarket revenue pool for the Bolt is ~60% smaller than for a comparable ICE car.

Q: What was the most non-consensual finding?
No "traditional" tier-1 supplier content in the Bolt's powertrain. About $4k electr(on)ics content in the Bolt, all of which assembled by LG. Only 35 moving + wearing parts in the Bolt, vs. 167 in the VW Golf.

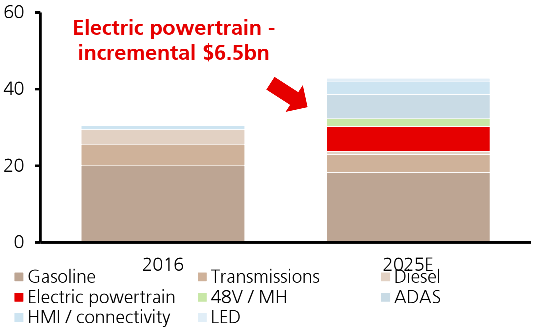
FINANCIAL IMPACT

Q: What will be the impact on the industry …
Mixed. Supplier with strong exposure to EV/hybrid and other megatrends (autonomous driving, connectivity, LED, etc) likely to sharply outperform industry growth; those with big combustion engine legacy business likely to underperform. Electronics giants likely to put margins and market shares of traditional suppliers under pressure.

Revenue pool (€bn) – source UBS



EBIT pool (€bn) – source UBS



SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from EVs?
Some players like Valeo, Conti, Delphi and others yes; companies like Faurecia and Schaeffler need much more transformation, we believe.

SECTOR VALUATION

Q: Could the trend to EVs lead to a change in sector valuation multiples?
We should continue to see a wide range of multiples depending on the exposure to secular trends. But overall there is a risk the relative valuation premium of suppliers shrinks as the threat of new entrants in EVs is likely under-estimated.

STOCK IMPACT

Q: What stocks should be impacted most positively and negatively?
Our preferences reflect our view on who's going to be a winner / loser on secular trends in automotive.

MOST FAVOURED on the theme

Stock	2018E PE	EPS impact 2025	Comment
Valeo	13.3x	15-20%	JV with Siemens to supply EV powertrain parts
Conti	11.5x	10-15%	Developing EV powertrain solutions in-house
Delphi	11.3x	10-15%	Spinning off ICE powertrain to focus on EV
Hyundai Mobis	7.5x	5-10%	Sole supplier of EV powertrain parts to Hyundai

LEAST FAVOURED on the theme

Stock	2018E PE	EPS impact 2025	Comment
Schaeffler	8.6x	<5%	Highly skewed to ICE powertrain
Faurecia	15.8x	0%	Leading PV ICE exhaust systems player
Tenneco	7.5x	0%	Exposure to PV exhaust systems but strong in CV

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EV battery tech (battery cell suppliers)

EV impact on sector … **Growth:** ↗ **Margins:** ↗ **ROIC:** → **Valuation:** →

KEY FINDINGS

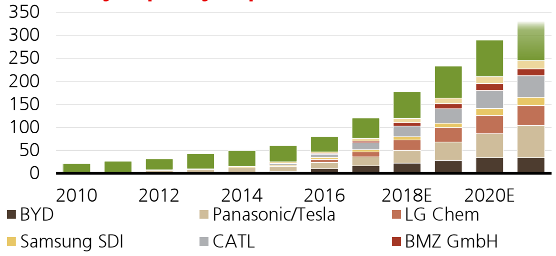
Q: What did we learn from the teardown?
Our teardown analysis validated our view that a mass-market EV passenger vehicle is viable from a costs perspective. This is leading our Autos Team to raise its EV penetration forecasts longer term. In turn, this will likely support further capacity build-up by the key battery cell suppliers, which will eventually lead to lower costs and improved profitability. In addition, the teardown gave us more details on the technology used by known suppliers LGE (battery packs) and LG Chem (battery cells).

Q: What was the most non-consensual finding?
We forecast that EV makers can reach the break-even point sooner than market expectations, which would help the overall profitability of its supply chain. We expect the largest EV battery makers to turn profitable by 2018-19.

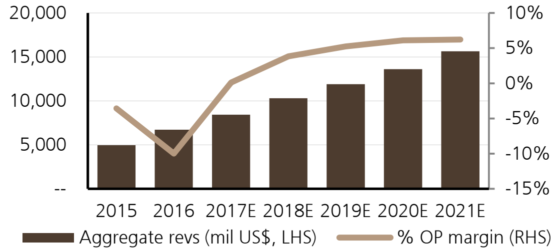
FINANCIAL IMPACT

Q: What will be the impact on the industry?
We forecast that both revenues and operating profits should grow significantly. EV battery cell makers have been loss-making so far, but we expect a turnaround in profits thanks to growing industry demand, increasing production capacity and improving battery technologies.

EV battery capacity expansion (GWh) – source UBS



EV battery maker revenues and OP – source UBS



SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from EVs?
Yes, the battery packs/cells are core components and the most expensive part of EVs. All major EV battery makers are expanding their production capacity and developing battery technologies at the same time. The battery makers are closely working with auto OEMs from an R&D phase to mass production.

SECTOR VALUATION

Q: Could the trend to EVs lead to a change in sector valuation multiples?
Yes, we think so. Currently, most of the battery makers are losing money in their EV battery business. However, we expect that multiples could be re-rated when investors see the evidence of EV makers making profits.

STOCK IMPACT

Q: What stocks should be impacted most positively and negatively?
This should overall be very positive for EV battery makers.

MOST FAVOURED on the theme

Stock	2018E PE	EPS impact 2025	Comment
LG Chem	10x	>30%	UBS APAC Key call Buy
Samsung SDI	7.5x	>30%	

LEAST FAVOURED on the theme

Stock	2018E PE	EPS impact 2025	Comment
Panasonic	13x	<30%	

Q: What else should investors know? / the sector impact in more detail
The battery has been segmented by type (NMC, NCA, LFP, etc) and auto brands. We think this will continue for a while due to the natural stickiness between auto OEMs and battery makers. We expect China to remain closed to foreign battery makers; Chinese battery makers would be the only beneficiaries from domestic EV growth.

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Capital Goods

EV impact on sector: Varies considerably by company (details in the following pages for each company)

KEY FINDINGS

Q: What did we learn from the teardown?

Given the breadth of our coverage, the impact analysis has to be done at company by company level. We see an impact from changing material usage (more lightweight materials leading to impacts on machining as well as joining technologies: Atlas Copco, Sandvik), incremental auto-related capex from battery manufacturing to upgrades on manufacturing lines (all being else equal, a benefit to Siemens, ABB, Kuka), and finally direct component supplies into electric vehicles where we see different demand patterns (e.g. 50-75% fewer bearings a negative for SKF and Rheinmetall, needing to shift away from their core strengths which are in ICE components).

Q: What was the most non-consensual finding?

Timing. We believe this topic is seen as important, but still rather far away in terms of having a material impact on our companies. We have heard comments, e.g. at SKF, that there is still quite some time to get ready for this transition. However, it appears from the teardown that the value proposition to the end user could be interesting earlier than people thought, and as a result EV adoption (at least in Europe) might be faster and higher than previously thought. This means the 'time to get ready' and win in the space shrinks.

FINANCIAL IMPACT

Q: What will be the impact on the industry …

Not material in the near and medium term (up to a three-year view) in aggregate, given the diluted impact for most companies in the coverage. However, given we see a steeper-than-anticipated adoption rate in Europe in the first half of the 2020s, we believe this will become selectively material (e.g. Siemens/Valeo JV).

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from EVs?

We see automation players prepared to serve incremental demand from any platform switches or incremental capex in the space (the product is there). For instance, German car OEMs are planning to upgrade existing lines and we estimate BMW and VW will spend an incremental €10bn and €9bn, respectively, over the next c. five years on their BEV platform rollouts. It has not been disclosed how much of this will go towards tooling, but we expect upgrades to existing lines. We believe the industry is ready for this transition and will give companies such as Siemens, ABB, Hexagon and Kuka the opportunity for holistic discussions around production set-up. We see Siemens as particularly well positioned given its front-to-back offering from design software to motion control and factory automation. Component suppliers (Rheinmetall, SKF, etc) will need to adapt their products, but we believe this is a core topic for management teams at the moment.

SECTOR VALUATION

Q: Could the trend to EVs lead to a change in sector valuation multiples?

Not material in the near term at a sector level, but certainly for individual companies, as we see adoption rates pick up. We provide a detailed company by company view below.

STOCK IMPACT

Q: What stocks should be impacted most positively and negatively?

This list is grouped specifically on EV impact, not our aggregate view on the companies.

MOST FAVOURED on the theme

Stock	2018E PE	Comment
Siemens	15.3x	Incremental auto capex good for Digital Factory business (PLM, factory automation, motion control, etc, estimate ca. 30% of sales driven by autos). Charging infrastructure positive for Energy Management ePowertrain pick-up positive for 50/50 JV with Valeo
Atlas Copco	22.1x	Incremental Auto/Electronics capex a positive for Industrial Technique (critical joint assembly platforms) and, to a lesser extent, Vacuum Technique (Vacuum pumps used for electronics manufacturing)
Hexagon	18.8x	Incremental Auto capex a positive for the Industrial Ent. Solutions (3D modelling CAD/CAM, sensors and simulation)
GKN	9.6x	Higher content to offset lower market share and lower margins

LEAST FAVOURED on the theme

Stock	2018E PE	Comment
SKF	16.3x	~ 20% of SKF's automotive sales relates to drive-train components for cars and light trucks (largely cars). At 100% EV adoption, about 5% of SKF's top line today would disappear.
Rheinmetall	13.1x	Theoretical content per car could be equal, but we note that Rheinmetall has a leading position in the traditional product range today. It will remain to be seen how this plays out for future product.
Kennametal	21.4x	Legacy ICE component business at risk
Sandvik	20.4x	Decreased steel and parts content combined with the transition to the electric motor from the combustion engine should impact Sandvik Machining Solutions

Company level analysis

ABB
ABB's principal exposure to the Automotive industry is found in the Robotics and Motion Business unit, which has an 18% revenue exposure, or 4.1% of group, and has seen growth coming particularly from Asia over the past years as China has ramped up its light vehicle production capacity. Within the exposure, the key product is industrial robots and systems, which, across all end-markets, made up 7% of group revenue in 2016, and likely a considerable part of the revenue exposure to the Automotive sector as well. We believe the gradual adoption of BEVs will alter the type of robot heads used in the production process, notably in the robots associated with the power train and the joining of vehicle body parts, but that the total number of robots and the automation levels in the plant will remain stable or increase slightly, meaning the overall impact could be considered as limited.

Atlas Copco
We estimate that >50% of Atlas Copco's Industrial Technique revenues and profits today (or c.>7% of group sales) could benefit from the increased penetration of hybrid/electric vehicles. In this segment, Atlas Copco provides the motor vehicle industry with accurate fastening tools that minimize errors in production and allow full traceability of operations, as well as adhesives and sealants, and self-pierce riveting and rivets equipment. An increased number of new models and platforms emerging from the rising penetration of EVs in the market should inevitably lead to increased spending in these areas, in our view. We also estimate a very limited but positive impact for the automotive exposures in Atlas Copco's Vacuum Technique (vacuum products, exhaust management systems, valves and related products) and Compressor Technique division, which we estimate at <5% of group sales.

GKN
We estimate that 15%-20% of GKN's group profits today could be at risk in an all-hybrid/electric world. Yet, we take comfort in: a) GKN's leadership incumbent position in eAxles and eTransmissions with more than 300k units on the road; b) our expectations for higher content for hybrid/electric vehicles to offset potential lower market share in a more competitive market. The main findings of our teardown exercise support our view: i) we concluded that the e-drive module is a simple product – and we expect relatively low entry barriers will lead to an intensification of competition in this space; ii) the teardown offered us explicit cost estimates of the electric drive module – which are aligned with UBS estimates – supporting the view that for GKN the higher content per vehicle has the potential to offset the lower market share/lower margins on EVs. Concerns that Driveline profits could decline long-term, as hybrid/EVs gain market share, are overdone – and we expect GKN's Driveline profits to structurally grow long term.

Hexagon
Around 25% of Hexagon's Industrial Enterprise Solutions revenues and profits today (or c.10% of group sales) could be benefiting from the increased penetration of hybrid/electric vehicles in the car market. In this segment, Hexagon offers mainly metrology sensors and software products for statistical process control, CAD/CAM, industrial engineering and schematics design, 3D modelling and visualization, stress analysis, procurement, fabrication, construction and information management for various industries. An increased number of new models and platforms emerging from the increased penetration of EVs in the market should inevitably lead to rising spending in these areas, in our view. With the introduction of EVs into the market, the industry faces ever-reducing design-to-production times, which will need extra spending in industrial metrology and 3D measurement as enablers of productivity (including a move from off-line quality inspection to near-line or in-line measurement techniques, enabling higher sampling rates and faster inspection times, even into automating inspection and integrating metrology data with product lifecycle management systems, statistical process control and supply-chain management software, optimizing ramp-up times and minimizing rework and scrap.

Kennametal
Around 20% of Kennametal's revenues come from the automotive/transportation sector. Kennametal provides a variety of products and solutions that address metal cutting/machining, surface finishing and protection, and advanced materials. Kennametal provides cutting tools for a variety of engine-related products, including shafts and turbines, exhaust manifolds, transmission housings, cylinder blocks and heads, and crankshafts. In turbochargers, Kennametal provides metal shaping, surface finishing and technology, and advanced materials. The Bolt analysis shows that several legacy components are at risk (traditional transmissions, exhausts, turbos, blocks, etc.), and that e-motors do not require the same degree of metal cutting that ICE require. Heat impact and corrosion would also be less relevant. Accordingly, we think Kennametal would face headwinds in these products over time.

Rheinmetall
Rheinmetall's product portfolio is heavily geared into combustion engines (pistons, air supply, emission control and pump products, such as EGR (exhaust gas recirculation) systems, solenoid valves and electric coolant pumps). Rheinmetall has several products for hybrid and electric vehicles, too. It does expect that its theoretical content by car in the next few years will be on a par with today's value for combustion engines. However, we take a slightly different focus on that end, as we believe this number needs to be seen in the context of market share. Rheinmetall has leading positions in its traditional product range, whereas we assume a less favourable position in products for hybrid and electric vehicles. Therefore, we think that, from today's point of view, rapid adoption of electric vehicles would be negative for Rheinmetall, while a more steady evolution would allow it to position itself more meaningfully in electric, too.

SANDVIK
We believe the penetration of EVs in the light vehicle market will have a negative impact on Sandvik's revenues and profits, as it will have clear implications for Sandvik Machining Solutions' (SMS) revenues and profits (accounting to 40% of group revenues and >50% of profits). With c.30% of SMS revenues going to the Automotive segment (or over 10% of total group sales), the penetration of EVs in the market should negatively impact the demand for cutting tools in three different ways, in our view: 1) As our UBS Evidence Lab research indicates, EVs could have up to 75% fewer moving parts, which should result in significantly lower need for tooling work. 2) Even though related to the previous point, it is worth to mention that, as our expert channel checks indicate (click here), up to 80% of the cutting tool work needed in a car happens in the manufacturing of the combustion engine. 3) Finally, although it will depend on models and platforms (e.g. Tesla >80% aluminum content, Chevrolet Bolt >60% steel content and the average combustion engine car 80% steel content), the steel content in an EV should decrease materially in favour of lighter materials such as aluminum, which will require lower tooling intensity.

SIEMENS
We see several divisions benefit from the EV adoption (link to our recent note on Siemens).

1) **Digital Factory**: We expect incremental auto capex from factory upgrades related to BEVs and estimate that ca. 30% of Digital Factory is driven by automotive demand. For instance, German car OEMs are planning to upgrade existing lines and we estimate BMW and VW will spend an incremental €10bn and €9bn, respectively, over the next c. five years on their BEV platform rollouts. It has not been disclosed how much of this will go towards tooling, but we think Siemens stands to benefit with its front-to-back offering in the space from design software to factory automation, motion control, etc. Potentially, major upgrades may trigger changes in PLM software providers, as we saw at Daimler a few years ago, when it switched from Dassault Systems to Siemens. We believe these decisions are nowadays being made at the C-level and occur at times of strategic changes in global production / design requirements in an effort to optimize global product development.
2) **Energy Management:** Siemens produces both high-power charging stations (power ratings up to 350kW), as well as charging units for the home or semi-public areas (WB140A). We estimate that the total investment required to put this infrastructure in place between now and 2025 in Europe alone is $14bn, thereof $12bn for slow chargers and $2bn for high-power charging / fast chargers. Globally we estimate an investment requirement of $39bn, thereof $10bn for public fast charging (e.g. on highways) to fulfill our EV production forecast.
3) **Siemens/Valeo JV (reported as part of CMPA, below the line):** This JV was established in 2016 (50/50) and it was reported that they have already obtained an order backlog of €1.6bn. Siemens largely provides full drivetrain integration, electric motors, inverters and converters to this effort, whereas Valeo contributes generators and on-board chargers.

SKF
We expect that an electric vehicle will have 50-75% fewer bearings compared to today's combustion engine cars (link to our publication on this). We expect bearing content in the drive-train content to drop by at least 80%. We estimate that currently ca. 7-8% of SKF's sales are drive-train related, which would suggest that at 100% EV adoption, more than 6% of the top line would be at risk.

Capital Goods

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Chemicals

EV impact on sector … **Growth:** → **Margins:** → **ROIC:** ↘ **Valuation:** →

KEY FINDINGS

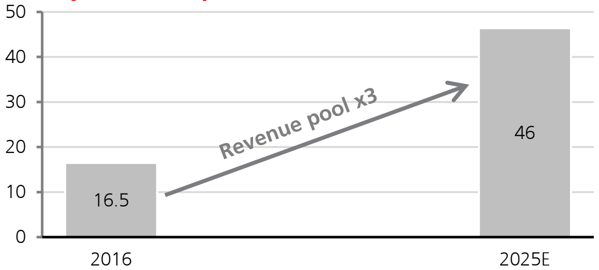
Q: What did we learn from the teardown?
We learnt that the falling cost of battery materials should facilitate a major shift in EV penetration, especially in Europe (where diesel has a high share, CO_2 emission targets are stringent and fuel costs are significantly higher than, say, the US). A faster-than-expected migration to EVs would pose a number of challenges for chemicals companies exposed to the combustion engine, as well presenting clear opportunities for chemical EV 'pioneers'.

Q: What was the most non-consensual finding?
A material risk to demand for polymers in EVs. At least in the example of the Chevy Bolt 'Teardown' for the engine, wheels and exhaust system, the content value of polymers is significantly lower (9kg vs 24kg for a VW Golf) than a combustion engine. Unless this is compensated by much heavier polymer usage in interior trims and seating, then this is currently a risk to several companies' current upbeat guidance and commentary around EVs.

FINANCIAL IMPACT

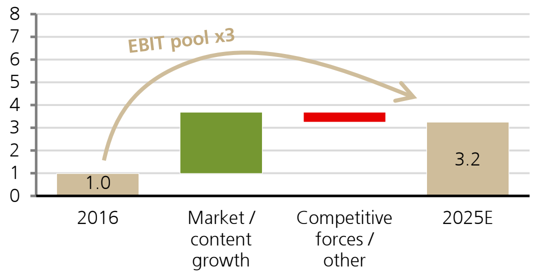
Q: What will be the impact on the industry?
A wide range of impacts, but hard to argue it's positive for the sector overall. The most negative impact from this technology disruption should be among the autocatalysts producers (BASF, Johnson Matthey and Umicore). The UBS view, if correct, would lead to such material revenue loss that it would materially outweigh the positive impact of ongoing legislation tightening for gasoline and diesel engine emission standards. It is still plausible, however, especially in the premium end of the auto market, that content growth for polymer and adhesives companies is positive (aiding companies such as Sika). Finally, we have to consider the long-term risk to future hydrogen growth in the industrial gas industry, as well as the process catalyst companies (Clariant, W.R. Grace, Johnson Matthey), given a likely negative impact on refining demand.

Revenue pool for EV (€bn): beneficial for chemicals battery materials producers



Source: UBS

EBIT pool (€bn): Opportunity at the cost of diesel & gasoline exposure



Source: UBS

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from EVs?
Yes, but not likely at the pace we suggest. Management teams have been looking to deepen exposure to the fast-growing EV segment in recent years. Similarly management, no doubt, will be planning strategies around various powertrain scenarios. Perhaps, though, none of them see a '1 in 3 world' for European EV penetration by 2025.

SECTOR VALUATION

Q: Could the trend to EVs lead to a change in sector valuation multiples?
Unlikely to be highly influential beyond a few names. Whilst certainly a game changer for the autocatalysts' companies, we think the sector as a whole is too diversified to be able to claim a major imprint on multiples that investors are willing to pay. Supply dynamics (especially in China), energy costs curves and construction and consumer end-markets should remain highly influential in the debates.

STOCK IMPACT

Q: What stocks should be impacted most positively and negatively?
The significant migration to EV powertrains could significantly impact a number of key stocks in our sector, both positively (Albermarle, Sika, Umicore) as well as negatively (BASF, Clariant, Johnson Matthey).

MOST FAVOURED on the theme

Stock	2018E PE	EPS impact 2025	Comment
Umicore	23x	+30%	Net beneficiary from leading position in cathode materials, outweighing diesel exposure in catalysts and risk to PGM pricing in recycling operations
LG Chemicals	10x	+15%	LG Chemicals has between 10% and 14% of global battery capacity. We expect the business to break even by 2018 and to grow by almost 3x 2017e-2021e
Asahi Kasei	12x	10-20%	We assume an EBIT increase of ¥15-30bn for LIB separators by 2025 (2017 base)
Sumitomo Chem	9x	5-15%	We assume an EBIT increase of ¥8-25bn for LIB separators by 2025 (2017 base)
Albemarle	22x	0-10%	We estimate c30% of 2018e EBITDA is battery-grade lithium, and we model that growing to c.60% by 2025, with batteries for EVs being the largest market by then
Sika	18x	3-5%	c.8% of group exposed to high growth adhesives and sealants in EV market

LEAST FAVOURED on the theme

Stock	2018E PE	EPS impact 2025	Comment
Johnson Matthey	15x	(15-20%)	The biggest net negative impact due to size of light-duty diesel (16% of EBIT) and currently modest position in battery materials
BASF	15x	(3-4%)	We assume a loss of c€150m of EBIT in autocatalysts and PGMs by 2025 as compared with 2017e
Clariant	14x	(1-2%)	Refinery is c15-20% of Catalysis and c10% of Natural Resources, i.e., c.5% of group
EMS Chemie	33x	-	Over 60% of sales exposed to transport end-markets, largely specialty polymers

Q: What else should investors know?

The Autos sector is one of the key end-markets for the Chemicals industry (we estimate around 13% of the sector's revenues directly, but up to 20% of revenues indirectly, i.e. to products that ultimately end up in a vehicle). As a consequence, this should be a major theme for the industry, but we will most likely see positives and negatives counterbalancing each other. Higher content growth for polymers may well continue in both OEM production and EV infrastructure. Conversely, lower demand for components for the combustion engine, such as auto-catalysts and certain engineering plastics, should ensue. The less straightforward analysis is on the energy supply chain overall, considering that there may well be bottlenecks in the pace of EV infrastructure build-out. We capture these risks in our downside scenarios.

Figure 102: End-market splits by stock: we estimate around 20% directly and indirectly are auto-related

	Transport (incl Aerospace)	Agriculture	Chemicals Plastics	Housing /Glass/ Construction	Consumer Goods	Electronics Solar	Oil&Energy	Food Feed	Health Care	Paper & Packaging	Steel & Metal	Textiles	Other
Air Liquide	9%		11%		9%	3%	20%	5%	5%		10%		28%
Akzo Nobel	17%			43%	18%								22%
Arkema	10%		34%	8%	11%	4%	14%	3%					16%
BASF	13%	8%	15%			5%							60%
Covestro	20%		8%	17%	27%	12%							16%
Clariant	5%	5%	27%	14%	10%	5%	12%			10%	3%		9%
Croda	7%	5%	12%	13%	35%		7%		15%			6%	0%
DSM	7%			6%		5%		59%	7%	7%		1%	8%
Elementis	18%			37%	8%		12%				9%	3%	13%
EMS Chemie	64%			7%		5%							24%
Evonik	17%	1%	12%	15%	17%	6%	3%	15%	4%	2%			8%
Frutarom								90%	10%				0%
Givaudan					48%			52%					0%
Johnson Matthey	61%		13%				12%		11%		3%		0%
K+S		45%	14%		8%			6%					27%
Lanxess	35%	15%	15%	10%	10%	5%							10%
Linde			17%		5%	5%		5%	20%		11%		37%
Novozymes		15%			33%		18%	27%	7%				0%
Sika	15%			79%									5%
Solvay	26%	5%		11%	21%	6%	8%	5%					18%
Symrise					40%					60%			0%
Syngenta		85%			10%			5%					0%
Synthomer			27%	17%					2%	34%		19%	1%
Umicore	35%					23%			11%				31%
Victrex	22%					25%	12%		6%				35%
Wacker Chemie	4%		14%	22%		41%						4%	15%
Yara	5%	85%	5%					5%					0%
AVERAGE	**13%**	**9%**	**8%**	**10%**	**11%**	**5%**	**4%**	**10%**	**3%**	**4%**	**1%**	**1%**	**13%**

Source: Company data, UBS estimates

Polymers – teardown reveals lower polymer content in EV powertrain

Probably one of the most surprising outcomes of the teardown was the lack of polymer content in the Chevy Bolt. The below shows the kg weight of polymers on the Bolt versus a TSI VW Golf and we can clearly see that for the Engine, gearbox, battery cell, fuel tank, exhaust system, wiring, wheels and chassis, there was actually less weight than for the combustion engine. *That said, the caveat that we would provide is that the analysis did not include the interior trim or seating or roofing.* Many of our companies have already stated that here they expect increased content, eg, for polyamides, polycarbonates and, in some cases, higher-spec grades of MDI.

Figure 103: Polymer content Bolt versus Golf (kg) – on major % of vehicle (engine, gears, battery, etc)

	Materials	
Chevy Bolt	**Total (kg)**	**VW Golf**
652	Steel	707
169	Aluminum	97
91	Copper	50
40	Iron	102
24	Rubber	24
640	Other	342
9	**Polymer**	**24**

Source: UBS estimates

Figure 104: Battery cell materials (kg)

Weight distribution by material	
Aluminum	68
Graphite	63
Steel	57
Iron	40
Copper	33
Cobalt	24
Nickel	24
Manganese	22
Polyester	15
Lithium	10
Other	80
Total	**436**

Source: UBS estimates

Autocatalysts: expect a significant loss of revenue from diesel and gasoline

Whilst electrification seems to offer some significant opportunities, the risk remains that the current technology JMAT has in battery materials (LFP) is less impactful for medium- and long-range battery EVs (albeit it has a role to play in plug-ins, busses, delivery vans). Consequently as we explore in our separate company reports, we see JMAT as a net loser of this UBS base case for powertrains and Umicore a net winner. We assume around $1,200/vehicle for JMAT's battery materials and a 3% global share. We have a similar value per vehicle for Umicore, but an initial 30% market share, fading to a 20% share by 2025E.

Figure 105: Value potential in each powertrain

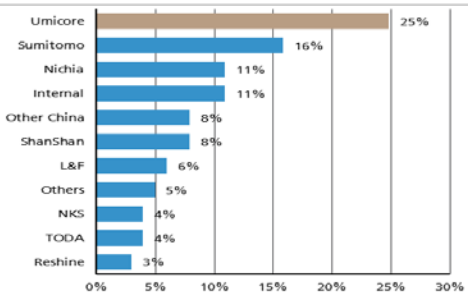
	12v Starter	Micro HEV	HEV	PHEV	BEV medium	BEV long	Delivery van	E-bus
LFP	Major	Major	Major	Major	Minor		Major	Major
NMC		Minor	Major	Major	Major	Major	Minor	
NCA			Minor	Minor	Minor	Major	Minor	
LMO			Minor	Major	Major			

Major / Minor

Source: Johnson Matthey

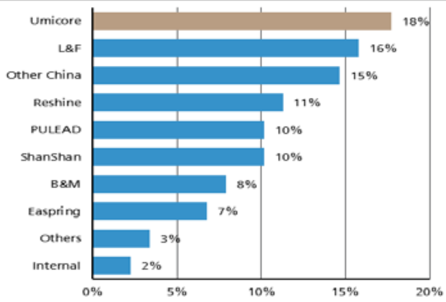
Market shares for the key battery materials producers can be seen below, for each key category. We see Umicore as better able to compensate for its future loss of combustion engine technologies.

Figure 106: 2016E NMC (Nickel manganese cobalt) battery market share



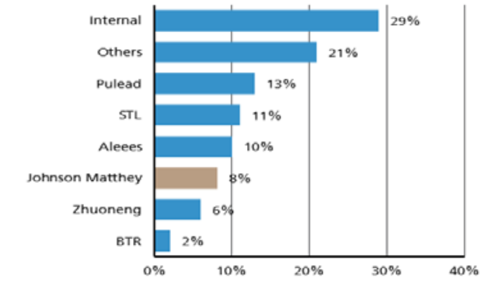
Source: UBS estimates, IHS

Figure 107: 2016E LCO (Lithium cobaltite) battery market share



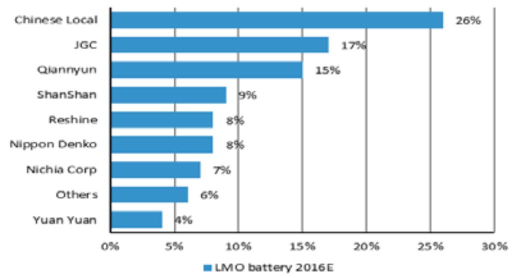
Source: UBS estimates, IHS

Figure 108: 2016E LFP (Lithium iron phosphate) battery market share



Source: UBS estimates, IHS

Figure 109: 2016E LMO (Lithium manganese oxide) battery market share



Source: UBS estimates, IHS

Process Catalysts – smaller risk to the sector, but Clariant exposed

The outlook for process catalysts companies is less negative as the majority of the technologies are related to chemicals production, but nevertheless there is some exposure to refinery catalysts amongst both European (BASF, Clariant, and Johnson Matthey) and US companies (Albemarle and Grace). However, these are much smaller within a group context than the autocatalysts' exposure, with the exception of Clariant, where the Catalysis division is c.20% of EBITDA.

Figure 110: Catalysts exposure to refineries

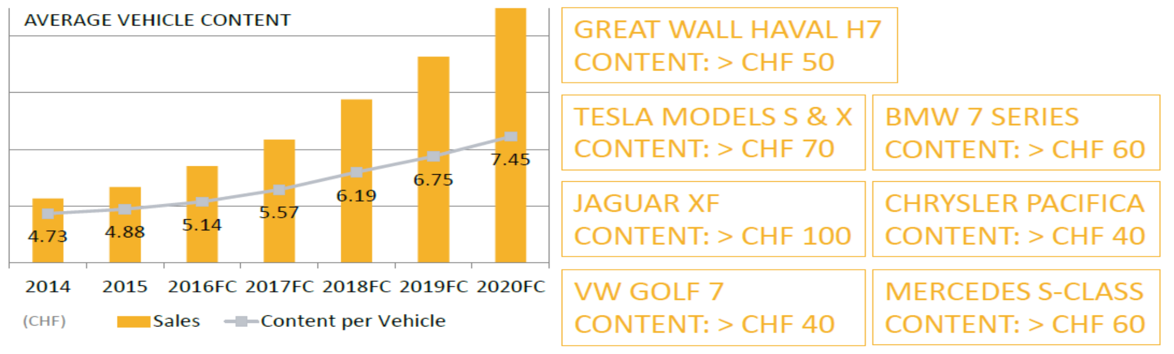
Competitor	Chemicals	Petrochemicals	Refinery	Olefin Polymerisation	Key products	Comments
Sud-Chemie	X	X	X	X	Styrene, Houdry, Syngas, etc	
BASF	X	X	X	X	FCC, Oxidation, HCS, Custom, Houdry, Styrene, Hydro, Polymerisation	Large player with strong product base but conservative growth profile
Johnson Matthey	X		X		Syngas, HCS, Traps, Engineering	Strong commitment to catalyst business with strong marketing and service
Haldor Topsoe	X	X	X		Syngas, HT, HC, Oxidation (FA), (Fluid Bed Dehydro)	Strong catalyst and technology provider with upside through R&D and engineering
CRI		X	X		Styrene Catalyst, Selective Hydro, EO, HT, HC, Isom, Dewax	Main player in petrochemicals with resources for organic growth
Axens		X	X		HT, Traps, Isom, Selective Hydro	Good process know-how and R&D with willingness to grow
Uop		X	X		SPA, HC, Isom, Zeolite	Strong market position and branding in refinery. Weaker in petrochemicals
Albermarle	X		X	X	FCC + HT	Focus on refinery catalysts
Grace			X		FCC + HT	Focus on refinery catalysts
Degussa	X				HCS, Custom	Strong base in fine chemicals
ExxonMobil		X			Zeolite Catalysts	large resources but business not core to group

Source: Clariant 2014. Note: Süd Chemie is owned by Clariant and Degussa is Evonik

Adhesives, sealing and bonding: Sika a likely beneficiary

EVs require more acoustic dampening when compared to an ICE car due to the absence of engine noise, which results in a plethora of other disturbing noises in the cabin (e.g. from wind or tyres). Also, heat-absorbing structures around the batteries require adhesive fixing, while special body structures need reinforcement solutions. We believe Sika, with its product portfolio ranging from structural adhesives, acoustic systems to lamination adhesives to reinforce systems, is best positioned to benefit from higher content per unit. Sika Automotive has been growing by double digits in LCY since 2012 and we expect this trend to continue at a similar pace (UBSe +9% p.a. 2017-21E). While content per vehicle currently stands at just above CHF5 per unit, an EV like Tesla (models S & X) already requires >CHF70 per unit, a similar amount as required by high-end and premium cars. On a side note, content per unit in China is still only around half of the global average (2016 cCHF2.6 per unit), with the stated ambition of doubling by 2020. Sika's current exposure to auto is CHF485m (2016), c8% of the group, and it directly caters to OEMs, with all the players worth mentioning on its customer list. In addition, Sika generates another cCHF250m of sales in transport (i.e. rail and track) and cCHF200m in auto aftermarket (wind-shield replacement).

Figure 111: Vehicle content for Sika products



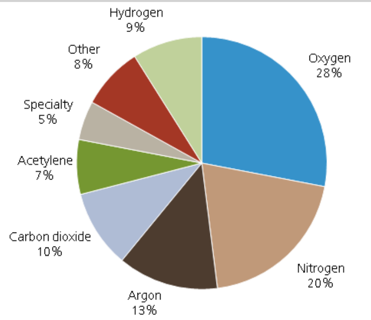
Source: Sika

We note that EMS-Chemie has a similar exposure through its EMS-EFTEC segment, where EMS commands a leading cost position and generates strong margins (UBSe 20% on EBIT). Products include plastisols for sealing (e.g. underbody), waxes for cavities and corrosion protection, adhesives for windows and sound-dampening. While we would expect EMS-EFTEC to benefit to a similar extent as Sika from an increasing EV penetration, the impact for the group is less clear. EFTEC accounts for c. one-third of the Higher Performance Polymers division, with the EMS-GRIVORY (engineering plastics such as PA6, PA12, PA66, PPA) accounting for the balance. Here, EVs also pose a threat in the sense that an electric engine needs much fewer parts, there is less corrosion from oil or chemicals, and no heat. EMS-Chemie will therefore need to increasingly focus on finding solutions for interior and exterior parts as well as the powertrain.

Industrial Gases: negative impact on hydrogen demand – too small to matter

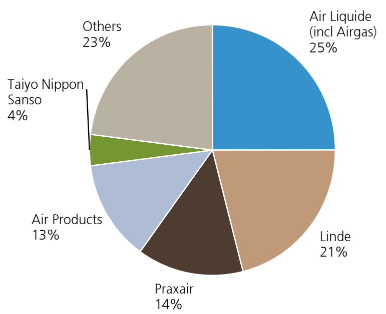
Finally, we should focus on the potentially negative impact of electric vehicles on the industrial gases industry. Gases have a role to play in oil refining, with the injection of hydrogen designed to aid with the de-sulphurisation process. Not all of the global hydrogen market is purely for oil refining, but it does represent a lion's share of the 9% of the market globally for industrial gases. That said, our oils team estimates the total hit to oil demand as likely to be only 1-2% by 2025, given the fact that diesel for passenger vehicles is only 3% of total oil demand. Thus, while this is a real risk, it looks to be a manageable one for all the key global players.

Figure 112: Industrial gas demand (US$m)



Source: UBS estimates

Figure 113: Global market share for total gases



Source: UBS estimates

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Korea Auto Tech: LG companies

EV impact on sector … **Growth:** **Margins:** **ROIC:** **Valuation:**

KEY FINDINGS

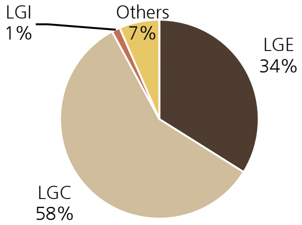
Q: What did we learn from the teardown?
Our teardown analysis suggests that a large portion of the powertrain of the GM Bolt (c93%), as well some of the infotainment, is done by LG tech companies (LG Electronics, LG Display and LG Innotek), with no less than 15 different components.

Q: What was the most non-consensual finding?
The total value created by the LG group was higher than our estimates, and also a higher portion of the total car BOM than we expected. If the sales of GM Bolt are better than our expectation, the magnitude of the positive impact to the LG group would be higher than the market currently expects.

FINANCIAL IMPACT

Q: What will be the impact on the industry?
We expect that revenue contributions from EV would continue to grow to all the LG tech affiliates. It is, however, more material for LG Chem (battery cells) and LG Electronics (part of 'Vehicle Components'). From a profits contribution though, EV should remain more meaningful for LG Chem (15% of UBSe OP in '20) vs. LGE (24%).

Powertrain component value breakdown by supplier for GM Bolt – source UBS



The list of components that LG affiliates supply to GM Bolt – source UBS

LG Electronics	LG Chem
Battery pack	Battery cells
Traction motor	**LG Display**
Inverter	LCD display panels
Onboard charging module	**LG Innotek**
Power distribution units	Battery management system
Infotainment modules	DC-DC converter
Climate control system	Power line communication module

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from EVs?
We understand that the LG group has worked closely with global auto OEMs and maintained solid relationships with them. For some of the projects at GM (like Bolt), the LG affiliates are currently sole vendors. We believe that EV will remain a core priority for the LG Group.

SECTOR VALUATION

Q: Could the trend to EVs lead to a change in sector valuation multiples?
We believe that EV is a key valuation driver for LG Chem. For LG Electronics, EV and Infotainment matters, but it remains less important than TVs and Appliances, while Mobile may continue to drag profits down. The Autos segment overall is less material for LG Display and LG Innotek.

STOCK IMPACT

Q: What stocks should be impacted most positively and negatively?
The growth of EVs is overall positive for all stocks, but much more meaningful for LG Chem, in our view.

MOST FAVOURED on the theme

Stock	2018E PE	EPS impact 2025	Comment
LG Chem	10x	>30%	UBS APAC Key call
LG Display	6x	>10%	UBS APAC tech team Most Preferred

LEAST FAVOURED on the theme

Stock	2018E PE	EPS impact 2025	Comment
LG Electronics	12x	>25%	-

Q: What else should investors know? / the sector impact in more detail
The auto tech business is a new revenue source for LG affiliates, so most of them haven't generated profits. However, the companies guided for strong revenue growth on the back of strong order flows, and therefore they expect the operating margin to improve gradually. LG group has a solid relationship with GM, and they are supplying most of the value of the powertrain of GM Bolt, but the global market share is still not significant. LG affiliates are trying to broaden the customer base.

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Metals & Mining Commodities

EV impact on sector … Growth: ↗ **Margins:** ↗ **ROIC:** → **Valuation:** ↗

KEY FINDINGS

Q: What did we learn from the teardown?

The Bolt has more aluminium, copper & manganese than comparable ICE vehicles. Battery composition (60KWh, NMC 1-1-1 cathode, ~0.9-1.0 kg LCE/KWh, ~1.1kg Graphite/KWh) was within expectations, but total battery costs were less than expected, pointing toward faster EV growth & demand for battery and related commodities.

Q: What was the most non-consensual finding?

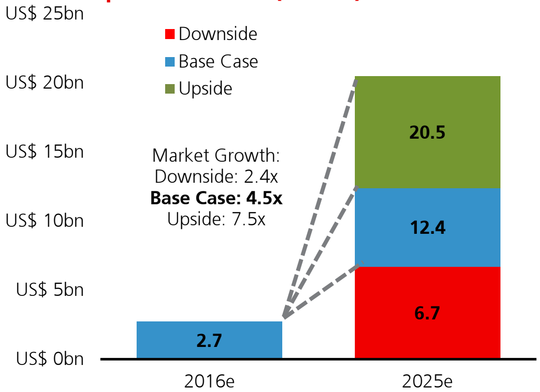
The lower-than-expected battery pack & management system costs. This is now anticipated to drive faster EV penetration rates thanks to total cost of ownership ICE vehicle break-even tipping points being reached sooner.

FINANCIAL IMPACT

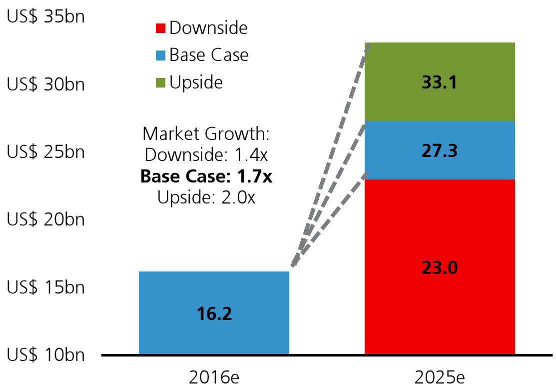
Q: What will be the impact on the industry?

Strong demand for battery and non-battery EV materials will tighten demand-supply balances, resulting in higher prices than otherwise. The combination of strong demand growth and higher prices will incentivize new supply to be developed which, in the case of battery raw materials especially, should drive transformative industry growth.

Revenue pool – Lithium (US$bn) – source UBS



Revenue pool – Graphite (US$bn) – source UBS



SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from EVs?

Yes and no. While prospective EV growth potential presents a major opportunity for revolutionary growth, challenges abound, including long and challenging lithium project development and ramp-up timelines, and qualification of new graphite supply for battery component makers with a near-zero tolerance for impurities.

SECTOR VALUATION

Q: Could the trend to EVs lead to a change in sector valuation multiples?

The listed Lithium & Graphite mining sector includes many companies looking to fund & build greenfield projects. These don't trade on earnings multiples because they are not yet in production, instead trading on net present value or EV/t of resource multiples. Only some of these will fully make the transition into production & cash flow.

STOCK IMPACT

Q: What stocks should be impacted most positively and negatively?

US: Albemarle (ALB, Neutral): We believe the diversified specialty chemicals producer is well placed to expand production and capture substantial lithium market growth via its tier 1 Chilean brine and West Australian hard-rock assets.

MOST FAVOURED on the theme

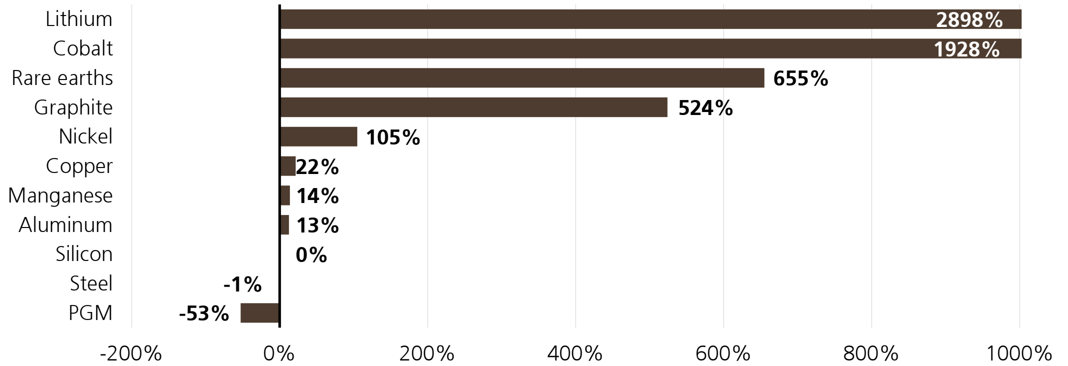
Commodity	Comment
Lithium	Sufficient new supply near term if funded, but delay risks are real as project execution takes time; new projects are needed longer term to support EV penetration rates
Cobalt	Supply is tight; produced as a by-product, also dependent on risky Central African supply. Demand to be moderated as NMC chemistry moves from 1-1-1 to 8-1-1 early next decade
Graphite	Sufficient graphite exists to supply battery growth, currently ~7% of total demand; but project qualification for battery use is a real hurdle, as are alternate anode materials longer term
Nickel	Elemental supply is plentiful, but less in the preferred Ni hydroxide form; EV growth & shift to more Ni intensive cathodes should lift Ni hydroxide demand from sulphide and laterite projects
Rare Earths	Supply highly dependent on China, which dominates the global trade; new experimental magnets with less/no REs may help the global RE supply chain meet EV demand growth

KEY BATTERY COMMODITY THEMES

Q: Can battery raw materials supply a total EV revolution?

Below is projected EV-related commodity demand assuming 100% of passenger vehicles (approx. 100mn units) are EV, as per Bolt specifications. Relative to today's market size, Lithium and Cobalt demand increase by factors of 29x and 19x, respectively. Rare Earths & Graphite demand lifts by factors of 5x-6x, while Nickel demand doubles. In a world of full EV penetration, the battery raw material supply chain needs to expand dramatically.

Commodity demand change – 100% EV – source UBS



CHEMISTRY SUBSTITUTION

Q: Are substitutes available to displace current Li-ion chemistries?

There are many competing battery chemistries with variable raw materials in the cathode, anode and electrolyte, offering variable performance. Higher raw material prices may see changes in chemistry, hence substitution. For example, high Cobalt prices should reinforce changing NMC chemistry ratios of 1-1-1 (nickel-manganese-cobalt) to 8-1-1 by early next decade, resulting in cobalt demand likely growing less quickly than overall EVs.

GRID RENAISSANCE

Q: How will electricity grids change to support the EV revolution?

EVs need to be fuelled with electricity, preferably from low carbon sources such as renewable (hydro/solar/wind) or nuclear, for there to be a carbon dividend from migration from combustion engines. This should lead to a step-change investment requirement in the grid and also for charging stations. While not analysed in this report, this is likely to be materially positive for copper and aluminium demand, above and beyond the estimates above.

NICKEL HYDROXIDE

Q: Is the world's Nickel chain ready to feed EV battery growth?

Most mine supply growth and investment in the past five years has been in low-grade nickel laterite ores, which are processed into a nickel-pig-iron product of 3-10% Ni and 85-90% Fe as stainless steel feed. This source is not suitable for battery use, which uses Nickel Hydroxide. Producers of Nickel Hydroxide may stand to benefit and receive premium prices.

LITHIUM PROJECT RISKS

Q: Is Lithium supply as easy to ramp up as it is abundant?

Lithium is relatively abundant. Yet successfully designing, building, commissioning and maintaining output from brine and hard-rock deposits is more technically challenging than many other mineral commodities. A shortage of experienced knowhow, lengthy development timelines, process plant issues and quality differentials present challenges likely to result in more gradual supply growth than developers may wish for.

GRAPHITE QUALITY

Q: How important is graphite quality?

Graphite too is relatively abundant. Battery anode manufacturers currently have a preference for high-quality synthetic graphite that features near-zero impurities, as impure graphite in anodes leads to safety and performance issues. Graphite producers need to convince battery customers of the merits of their product, often through a qualification process lasting many month/years.

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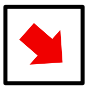
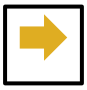
Platinum and Palladium

EV impact on sector … Demand:  **Supply:**  **Market balance:** 

PIVOTAL QUESTIONS

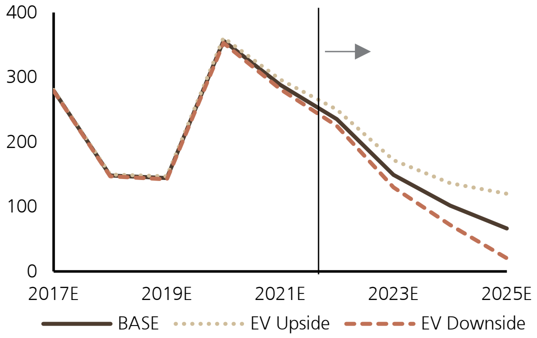
Q: What is the impact of higher EV penetration on platinum and palladium demand?

Higher EV penetration translates to lower platinum and palladium demand, driven by a decline in automotive demand. However, our calculations do not suggest a significant deviation from our previous estimates over our forecast period out to 2021. We estimate only low-single-digit percentage declines vs our previous auto demand forecasts. In turn, this implies that, all else being equal, our current estimates for platinum and palladium market balances are still broadly in line with our previous expectation that the platinum market is likely to remain relatively balanced, while the palladium market should continue to be in deficit. For now, we don't see much influence on our price targets as a result of the recent changes in our colleagues' expectations for EVs. We continue to see considerable downside risks for our platinum price forecasts and upside risks for palladium. If anything, palladium upside risks have probably moderated slightly.

Q: Is the market likely to ease or tighten depending on the level of EV penetration?

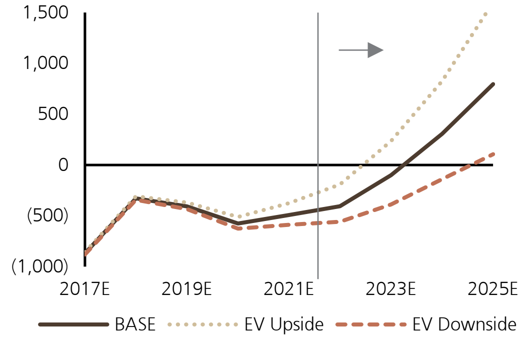
Higher EV penetration corresponds with lower automotive demand and would therefore tend to ease PGM markets, while lower penetration rates vs the base case would result in higher automotive demand and, in turn, tighter PGM balances. We expect the palladium market to be more sensitive to fluctuations in EV market share, given that gasoline vehicles would be most affected, and for this impact to be more pronounced in the long term, particularly as BEVs gain more traction. Beyond our forecast period, much would depend on the supply response. But given limited visibility on the long-term supply side response, we refrain from making strong conclusions.

XPT balance under different EV scenarios



Source: UBS

XPD balance under different EV scenarios



Source: UBS

UBS VIEW

We continue to estimate a relatively balanced market for platinum and sizeable deficits in palladium, over our forecast period out to 2021, even under different EV penetration scenarios. We think the divergence in price action between the two metals and the clear preference for palladium among investors is likely to continue, underpinned by prevailing themes in the auto sector.

EVIDENCE

The platinum:palladium ratio has come under considerable pressure this year as investors increasingly favour the latter. There have been signs of fundamental strength in palladium, but this has likely been amplified by investor flows, reflected in elevated Nymex positioning and the positive turn in ETFs. Similarly, while platinum fundamental signals have indeed been weak, pressure on prices has likely been compounded by investor selling.

SIGNPOSTS

Trends in the auto sector will be important, particularly diesel shares in Europe and global EV penetration. The platinum:palladium price ratio will also be key and we will be monitoring whether certain levels eventually trigger a response from the industry in terms of autocatalyst loadings. We will also be closely watching indicators such as forwards and sponge premium to assess demand as well as investor flows via Nymex positioning and global ETFs.

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Precious Metals Strategist

Semiconductors

EV impact on sector … **Growth:** ↗ **Margins:** ↗ **ROIC:** ↗ **Valuation:** →

KEY FINDINGS

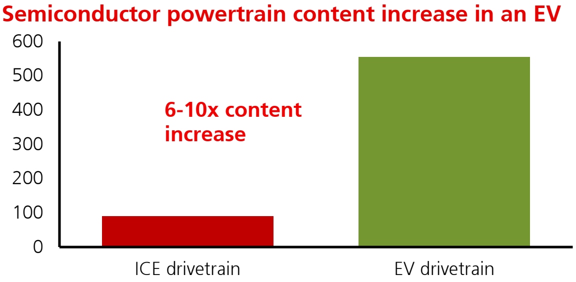
Q: What did we learn from the teardown?
Semi content in the EV drive train is c6x higher. Watch out for further research on the semi content in the Bolt, but focusing on the EV drivetrain we found the semi content in the powertrain increased c6-10x (c$580 compared to the $60-90 content we believe is present in an ICE powertrain today). Major suppliers into the Bolt include Infineon (supplies the IGBT module) and NXP/Freescale (supplying multiple MCUs).

Q: What was the most non-consensual finding?
Content increase higher than many expect. The shift to EV content is widely expected to be a significant driver of semi content growth, but we believe that a $490-520 increase in the powertrain alone is much higher than many people expect. We believe the total within the powertrain could even be higher than this as not every single chip could be seen, especially in the battery cells with the energy storage subsystem.

FINANCIAL IMPACT

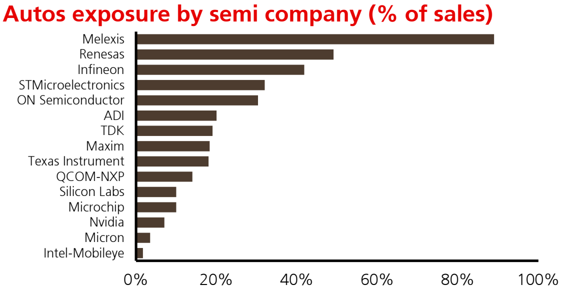
Q: What will be the impact on the industry …
Sustained high revenue growth in auto semis. We expect that the powertrain will be one of the fastest-growing areas of semis content as we shift to EV drivetrain with 6-10x higher content, particularly given our overall positive conclusions on the profitability of an EV, and hence the potential cost points that could be met to stimulate adoption. Globally, autos is expected to be one of the fastest-growth areas for semis, as has already been seen in recent years, having grown at a CAGR of 8% between 2012 and 2016 compared to the wider industry of 3.4%.

Semiconductor powertrain content increase in an EV



Source: UBS estimates

Autos exposure by semi company (% of sales)



Source: Company data (2016 reported)

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from EVs?
Yes. Autos is already seen as the key driver of growth for many of the analog semi names and as such there has already been significant capex investment into capacity to support this growth (e.g. Infineon has significant capacity in 300mm that can continue to support growth). The US Semis industry appears prepared for higher semis sales to EV given sustained double-digit growth from the auto segment from recent electrification and efficiency trends, and we would expect this to continue from greater adoption of HEVs and EVs.

SECTOR VALUATION

Q: Could the trend to EVs lead to a change in sector valuation multiples?
It already has. The growth expected for semis from the shift to EV and autonomous has already led to an increase in multiples for analog semis (including Infineon, STMicro, TI, ADI, Maxim) to 12x 12m fwd EV/EBITDA vs. 5y average 8x.

STOCK IMPACT

Q: What stocks should be impacted most positively and negatively?
Within the teardown, we mostly found content from Infineon, NXP/Freescale and STMicro, although we are conscious this is just one EV. More generally, the semis names most exposed to automotive are Melexis, Renesas, NXP and Infineon. We expect that Infineon will be one of the most positively impacted by EV powertrain given its IGBT exposure, although over time we could see more competition as the industry moves to SiC solutions (STMicro is more competitive here). Of the other US Semis, TI, Maxim and ADI all have c15% exposure to autos semis.

MOST FAVOURED on the theme

Stock	2018E PE	Comment
Infineon	18x	One of most exposed to autos and particularly to the power content increase in an EV drivetrain. Valuation is our concern.
Texas Instruments	20x	Autos has growth from 11% to 18% of sales in 5 years, driven by infotainment, power management, and signal conditioning.

LEAST FAVOURED on the theme

Stock	2018E PE	Comment
Melexis	26x	We have concerns on market share and valuation – Sell.
STMicro	16x	Solid exposure to autos but SiC opportunity should take time.

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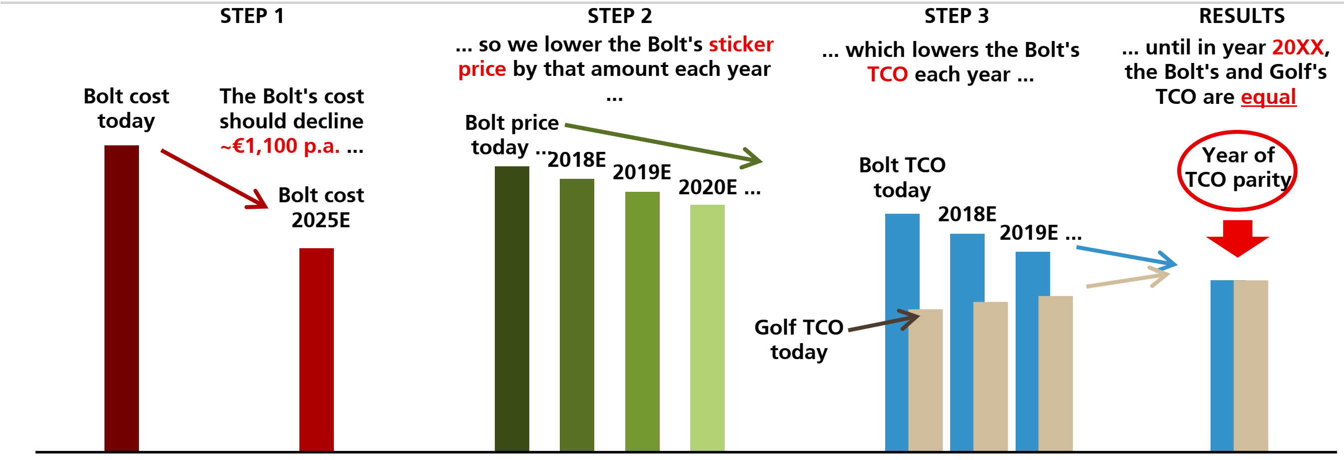
Appendix

How do we estimate total cost of ownership (TCO) parity?

STEP 1: ESTIMATING THE YEAR OF TCO PARITY

To estimate the year of total cost of ownership (TCO) parity, we tie the Bolt's sticker price to the annual expected decline in GM's cost to produce it. The annual cost decline is based on our and Munro's forecast prices for the battery and other components in the Bolt in 2025. We model the cost decline linearly. Based on our price forecasts, it comes to ~$1,100 p.a. For the Golf, we model 0.5% cost inflation p.a., but also a 2% increase in fuel efficiency p.a. As the Bolt's sticker price declines in line with its costs, so does its TCO. The parity year is the one at which annual TCO of the Bolt matches that of the Golf.

Figure 114: How we estimate the year of TCO parity between the Chevy Bolt and VW Golf

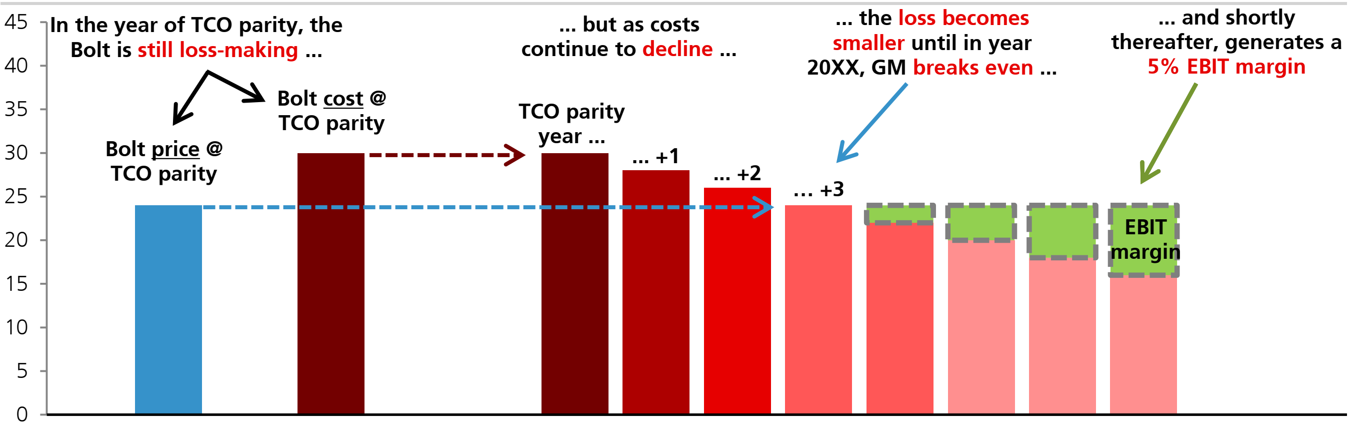


Source: UBS estimates

STEP 2: ESTIMATING THE YEAR OF EBIT BREAKEVEN

To estimate the year that GM breaks even on the Bolt, we first lock in the sticker price at which TCO parity is achieved (from step 1). As the Bolt's costs continue to decline each year on the back of battery and parts cost declines and higher volumes, the profit margin rises. Once the Bolt's total costs equal its sticker price, GM breaks even. The margin then increases until it reaches 5%. Based on our modelling, we are able to identify in which years this is likely to happen, by region.

Figure 115: How we estimate the year in which GM breaks even on the Bolt



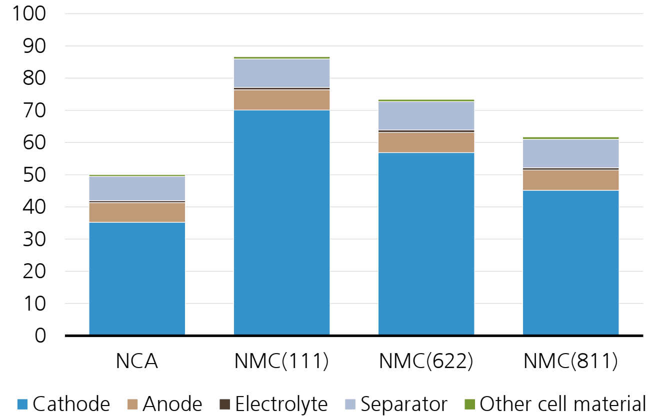
Source: UBS estimates

Figure 116: TCO analysis – core assumptions

Region		US	Germany	China	Japan
Currency		$	€	RMB	¥
Distance		miles	km	km	km
Gasoline fuel metric		Gallons	Litres	Litres	Litres
Universal inputs					
USD exchange rate		-	0.9	7.0	112
Annual driving distance	miles/km	9,000	15,000	15,000	15,000
Maintenance cost BEV	Cent / mile/km	2.6	2.3	18	286
Maintenance cost ICE	Cent / mile/km	6.1	5.5	43	683
Gasoline cost today	per gallon / litre	2.70	1.40	6.8	130
Gasoline cost 2020+	per gallon / litre	3.00	1.50	7.0	140
Cost of electricity	per kWh	0.15	0.30	0.55	15.0
Lease scenario					
Purchase method		3 year lease, 10% down-payment			
Time of ownership	years	3			
Residual value	%	50%			
Interest rate	%	3.5%			
Lifetime scenario					
Purchase method		Cash purchase			
Time of ownership	years	15			
Residual value	%	0%			
Battery replacement cost	In 2025	11,700	10,636	81,900	1,310.4k

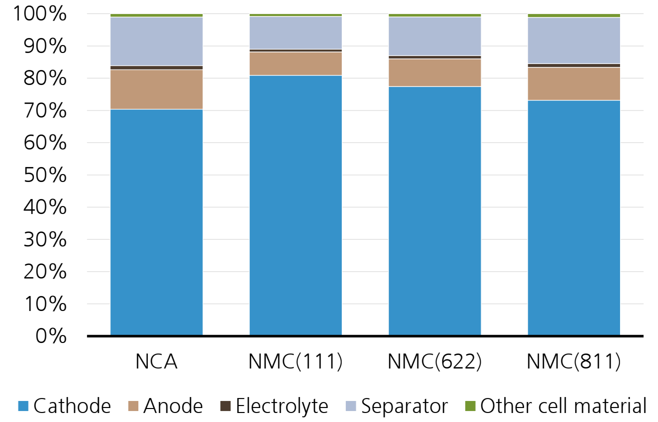
Source: UBS estimates

Figure 117: Battery active materials cost ($/kWh)



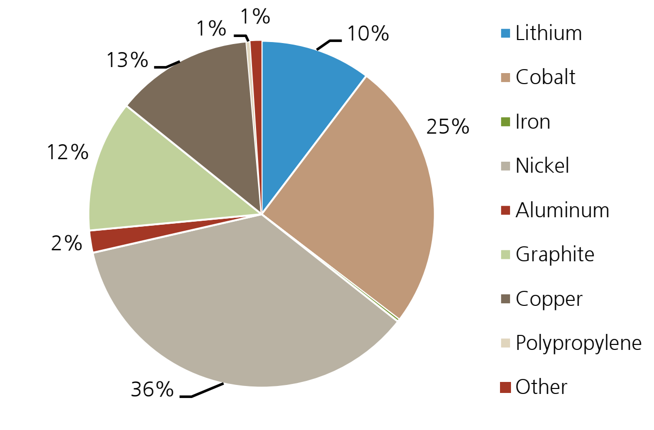
Source: UBS estimates

Figure 118: Active material cost (% of total bill of mat's)



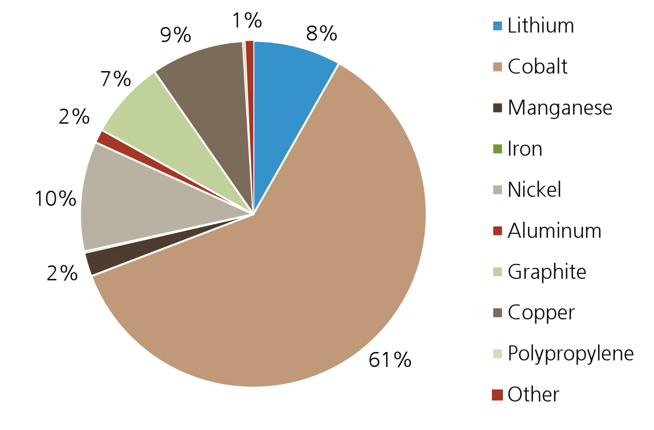
Source: UBS estimates

Figure 119: Total active material bill of materials (NCA)



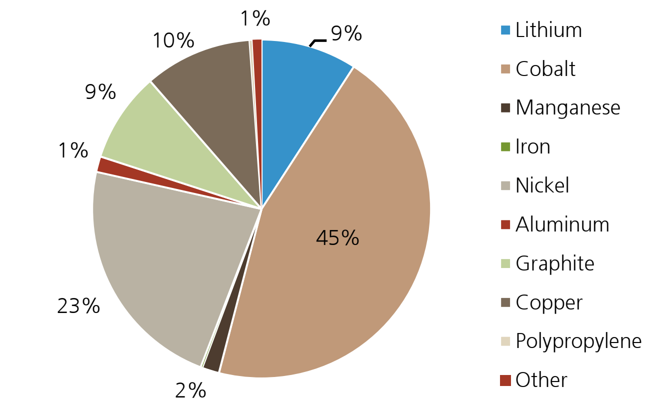
Source: UBS estimates

Figure 120: Total active material bill of materials (NMC111)



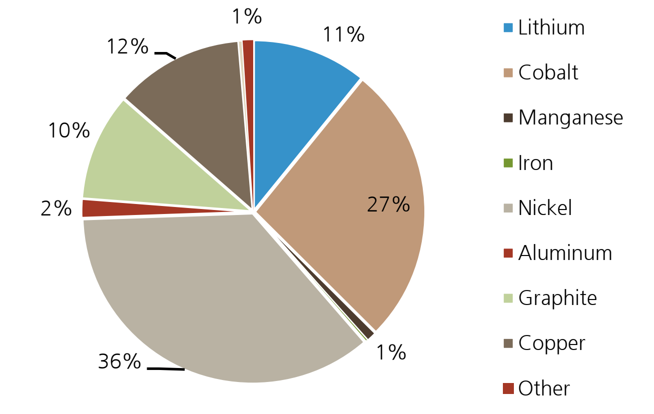
Source: UBS estimates

Figure 121: Total active material bill of materials (NMC622)



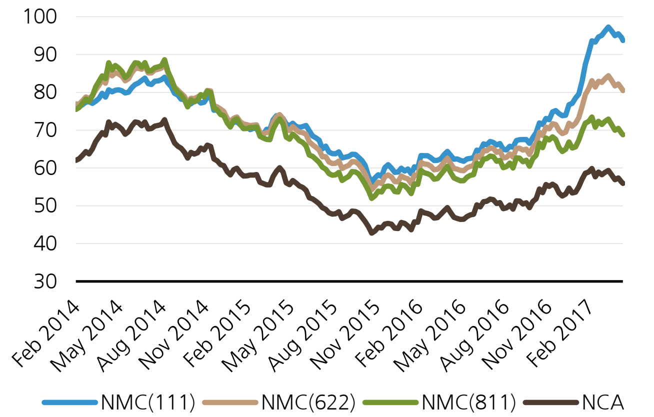
Source: UBS estimates

Figure 122: Total active material bill of mat's (NMC811)



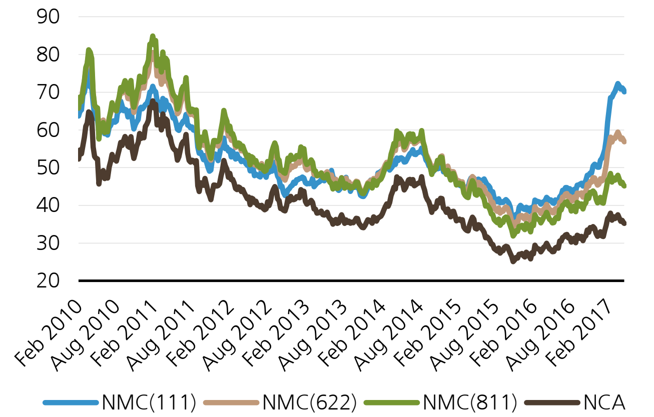
Source: UBS estimates Note: NMC based on NMC(111) cell chemistry

Figure 123: Li-ion total active cell material cost by technology ($/kWh)



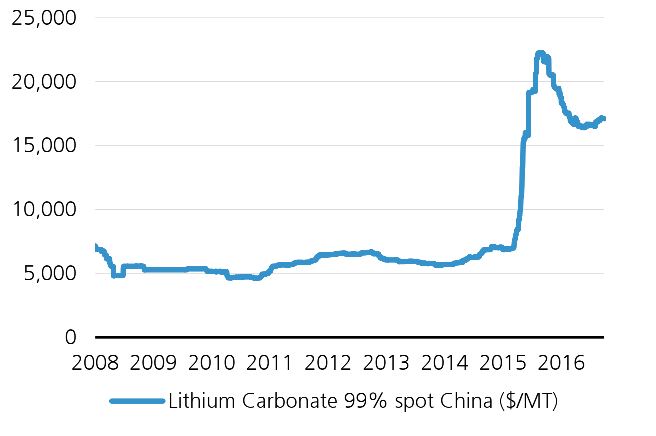
Source: Datastream, Bloomberg, UBS estimates

Figure 124: Li-ion cathode cost by technology ($/kWh)



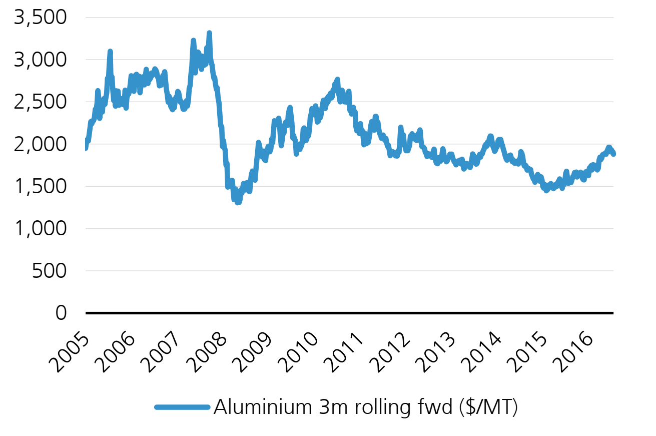
Source: Datastream, Bloomberg, UBS estimates

Figure 125: Lithium Carbonate 99% spot China ($/MT)



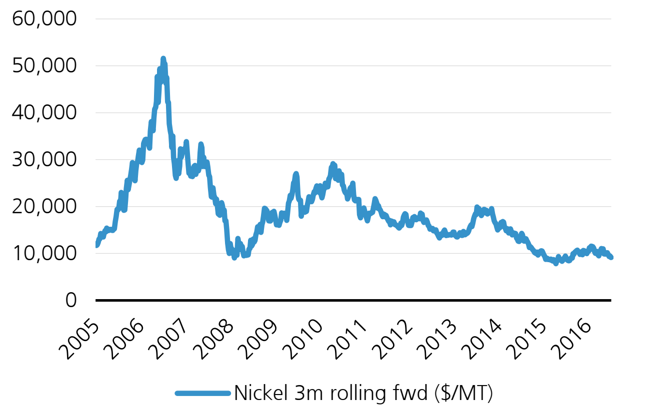
Source: Asian Metals

Figure 126: Aluminium 3m rolling fwd ($/MT)



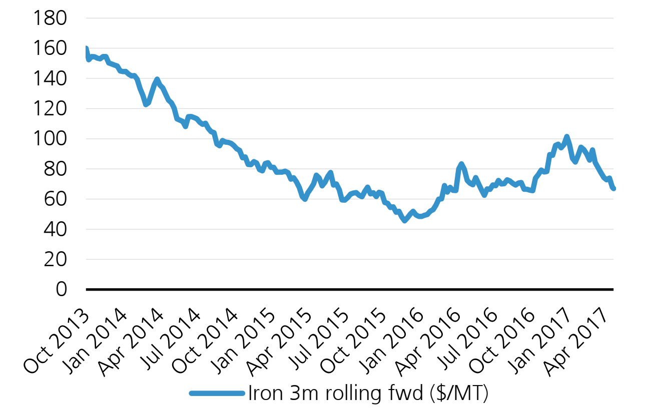
Source: Bloomberg

Figure 127: Nickel 3m rolling fwd ($/MT)



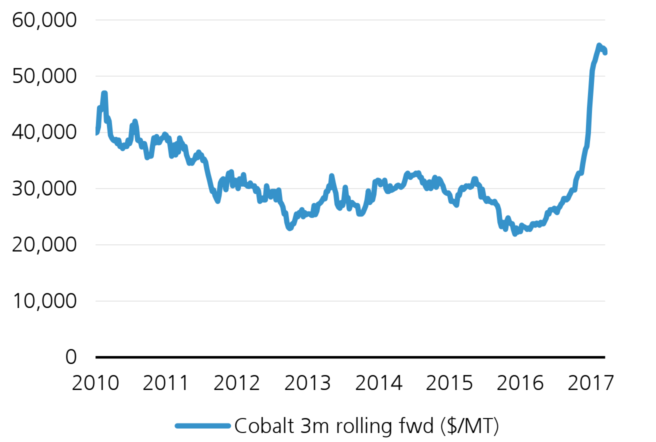
Source: Bloomberg

Figure 128: Iron 3m rolling fwd ($/MT)



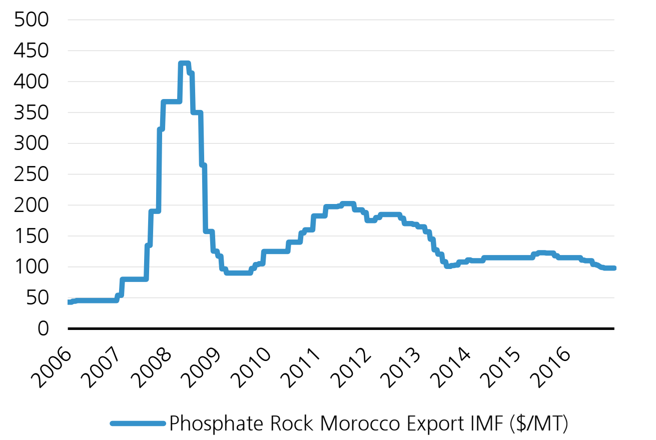
Source: Bloomberg

Figure 129: Cobalt 3m rolling fwd ($/MT)



Source: Bloomberg

Figure 130: Phosphate Rock Morocco Export IMF ($/MT)

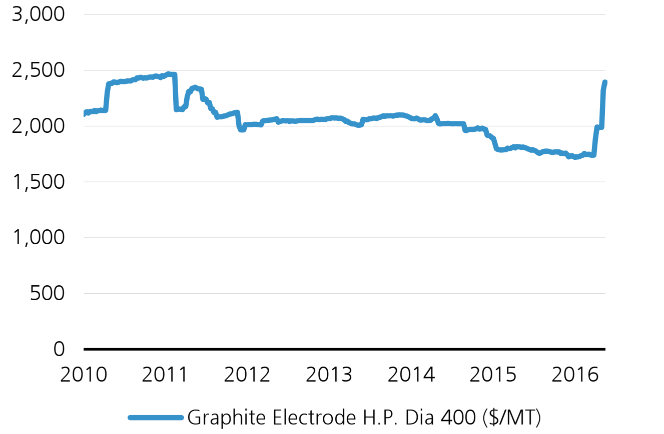


Source: Bloomberg

Figure 131: Manganese Spot ($/MT)

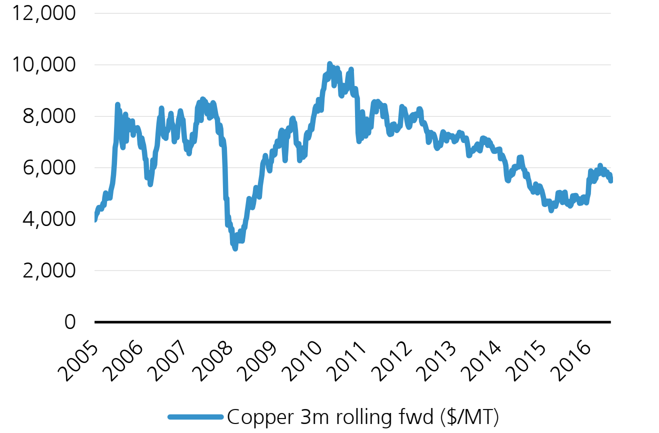
Source: Bloomberg

Figure 132: Graphite Electrode H.P. Dia 400 ($/MT)



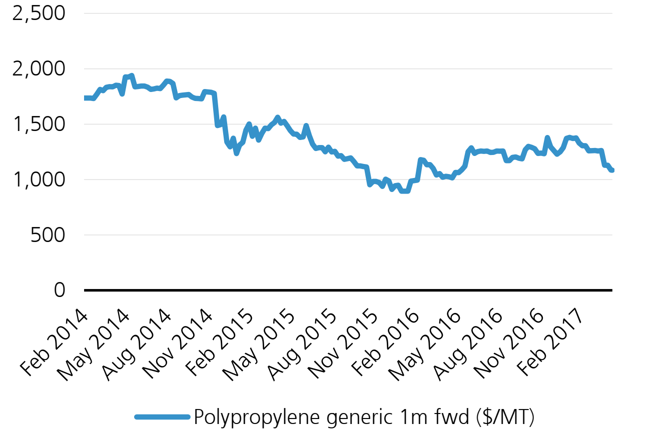
Source: Asian Metals

Figure 133: Copper 3m rolling fwd ($/MT)



Source: Bloomberg

Figure 134: Polypropylene generic 1m fwd ($/MT)



Source: Bloomberg

Figure 135: External battery cost estimates

Total pack cost $/kWh	Time of est.	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
LG Chem	2017									200-250								
Daimler	2016							200-300					150					100
Carnegie Mellon University	2016								190-400									
Cairn Energy Research Advisors	2016								200-240				168					149
Nat. Renewable Energy Lab. (NREL)	2016						217-278											
Panasonic	2016										190-222							
Tesla	2016									190			150					
MIT (Sadoway)	2016							300										
Ford	2016												120 (cell)					95 (cell)
Tesla	2015												100					
GM	2015									145-245			120-220		100-150			
MIT (Industry expert interviews)	2015							200-300			170							
Stockholm Environment Institute	2015	600-1250	410-1100	400-880	280-820	280-700	250-500											
Johnson Matthey	2015							300										
Argonne National Lab	2015											109						
Tesla	2014					200-300							150-200					100
US Dept. of Energy	2014					325	300								125			
MIT (Sakti et al.)	2014						190-330											
Umicore	2014	1100					360						200					
Australian Renewable Energy Agency	2014						550			300			200					
Advanced Automotive Batteries	2014					310	280	260	250	240	230	215	190		170			150
VTT Technical Research Centre of Finland	2014							185-215										
USABC (Industry)	2013												250					
Argonne National Lab	2013					220-360												
Johnson Matthey	2012				500-900													
LG Chemical	2010		625															

Source: Sources as names in table

Figure 136: Key technical features Chevrolet Bolt vs. VW Golf

Chevrolet Bolt LT		VW Golf Wolfsburg 1.8 TSI
36,620	**Base price ($)**	23,515
	Dimensions – exterior	
1,616	Base curb weight (kg)	1,371
417	Length (cm)	425
160	Height (cm)	145
176	Width (cm)	180
260	Wheelbase (cm)	264
	Dimensions – interior	
2,673	Passenger volume (l)	2,648
1,178	Front legroom (l)	1,167
1,124	Front headroom (l)	1,087
1,034	Rear legroom (l)	1,008
1,073	Rear headroom (l)	1,079
	Performance specs	
Electric	Propulsion	Internal combustion
200	Horsepower	170
360	Torque (Nm)	270
145	Top speed (km/h)	200
6.5	0-100 km/h (sec)	7.3
	Fuel efficiency (EPA)	
128	MPG city	25
110	MPG highway	35
119	MPG combined	29
383	Range (km)	617
0	g CO_2 / km	192
	Powertrain description	
60kWh lithium ion battery	Fuel storage	50l fuel tank
Permanent magnetic drive motor	Engine	1.8l 4 cylinder turbocharged DI ICE
Single-speed integrated gearbox	Transmission	6-speed automatic transmission

Source: General Motors, Volkswagen, UBS

Figure 137: BEV line-up (ex China)

OEM	Model name	Range (EPA) km	Price $	Battery capacity kWh	Fast charging time mins	Power HP	Battery supplier
2009							
Daimler	Smart Electric Drive	110	26,070	18	n/a	75	Tesla (Panasonic)
2010							
Mitsubishi	i MiEV	100	23,760	16	~30	67	GS Yuasa
Peugeot	Peugeot iOn	110	19,635	15	~30	67	GS Yuasa
Peugeot	Citroen C-Zero	110	19,635	15	~30	67	GS Yuasa
2011							
Renault	Twizy	100	7,700	6	n/a	17	LG Chem
Renault	Kangoo Z.E.	110	22,330	22	n/a	60	AESC / LG Chem
Renault	Fluence Z.E.	100	28,600	22	n/a	94	AESC / LG Chem
Nissan	Leaf (24kWh)	120	29,040	24	~30	107	AESC
2012							
Tesla	Model S 70D	385	92,400	70 / 85	~30-45	315	Panasonic
Tesla	Model S 90D	460	108,350	90	30-45	373	Panasonic
Ford	Focus Electric	76	29,194	23	n/a	130	LG Chem
Bolloré	Bluecar	200	20,900	30	n/a	68	-
Honda	Fit EV	135	35,970	20	n/a	75	GS Yuasa
2013							
Renault	Zoe	170	23,650	22	~30	88	LG Chem
BMW	i3	135	38,500	19	~30	170	Samsung SDI
Volkswagen	VW e-Up!	120	29,700	19	~30	82	Toshiba
FCA	Fiat 500e	140	32,010	24	n/a	111	Samsung SDI / Bosch
GM	Chevy Spark EV	135	25,960	19	~30	140	LG Chem
2014							
Volkswagen	VW e-Golf	135	38,500	24.20	~30	115	Panasonic
Daimler	Mercedes B-Class ED	140	43,120	28	n/a	179	Tesla (Panasonic)
Kia	Soul EV	160	30,800	27	~30	111	SK Innovation
Nissan	e-NV200	170	26,400	24	30	109	AESC
2015							
Tesla	Model X	350	88,000	70 / 85	~30-45	328	Panasonic
Nissan	Leaf (24kWh – upgr.)	135	29,040	24	~30	107	AESC
Nissan	Leaf (30kWh)	170	33,990	30	~30	107	AESC
2016							
BMW	i3 (upgrade)	185	38,500	30	~30	170	Samsung SDI
Peugeot	Citroen e-Mehari	100	30,580	30	~30	48	Bolloré
GM	Chevy Bolt	385	37,400	60	~60	200	LG Chem
Daimler	Smart Fortwo	110	24,200	18	~30-45	81	LG Chem
Renault	Zoe (upgrade)	300	35,200	41	~60	91	LG Chem
2017							
Hyundai	Ioniq EV	200	36,300	28	~60	120	LG Chem
GM	Opel Ampera-E	380	36,620	60	~60	200	LG Chem
Volkswagen	VW e-Golf (upgrade)	200	39,490	36	~30	135	Samsung SDI
Daimler	Smart Forfour	110	24,860	18	~30-45	81	LG Chem
Daimler	Smart Cabrio	110	27,720	18	~30-45	81	LG Chem
Honda	Clarity EV	130	-	-	-	-	-
Ford	Focus Electric (upgr.)	120	-	34	~30	145	LG Chem

Source: Manufacturer data, EPA, Media reports, UBS

Figure 138: BEV line-up (ex China) – continued

OEM	Model name	Range (EPA) km	Price $	Battery capacity kWh	Fast charging time mins	Power HP	Battery supplier
2017							
Hyundai	Ioniq EV	200	36,300	28	~60	120	LG Chem
GM	Opel Ampera-E	380	36,620	60	~60	200	LG Chem
Volkswagen	VW e-Golf (upgrade)	200	39,490	36	~30	135	Samsung SDI
Daimler	Smart Forfour	110	24,860	18	~30-45	81	LG Chem
Daimler	Smart Cabrio	110	27,720	18	~30-45	81	LG Chem
Honda	Clarity EV	130	-	-	-	-	-
Ford	Focus Electric (upgr.)	120	-	34	~30	145	LG Chem
2018							
Tesla	Model 3	300+	35,000	28	~30	-	Panasonic
Volkswagen	Audi Q6 e-tron	500	80-100k	95	-	-	LG Chem / Samsung SDI
Nissan	Leaf (upgrade; tbc)	300+	-	-	-	-	AESC
Nissan	Micra EV	-	-	-	-	-	AESC
JLR	Jaguar I-Pace	335	55,000	90	-	400	-
2019							
Volkswagen	Porsche Mission E	500	-	-	~15	582	-
Volkswagen	2nd Audi BEV	500	-	-	-	-	-
Volkswagen	VW I.D.	400-600	30,000	-	~30	170	-
Volkswagen	Seat BEV	-	-	-	-	-	-
Volkswagen	Skoda Kodiaq BEV	-	-	-	-	-	-
Daimler	Generation EQ	500	50-60,000	70	-	400	SK Innovation (tbc)
Volvo	BEV	-	35-40,000	100	-	-	-
Aston Martin	RapidE (tbc)	300+	200,000+	-	-	800	-
Ford	BEV (tbc)	-	-	-	-	-	-
Hyundai	3 more BEVs by 2020	-	-	-	-	-	-
Kia	2 more BEVs by 2020	-	-	-	-	-	-
Mitsubishi	RVR BEV (by 2020)	-	-	-	-	-	-
BMW	Mini BEV	-	-	-	-	-	-
Mazda	BEV	-	-	-	-	-	-
Lucid Motors	Air	390	55,000	-	-	-	-
Subaru	BEV	-	-	-	-	-	-
2020+							
Tesla	Roadster (upgrade)	-	-	-	-	-	Panasonic
Tesla	Model Y (small SUV)	-	-	-	-	-	Panasonic
Volkswagen	3rd Audi BEV	500	-	-	-	-	-
Volkswagen	2nd Porsche BEV (tbc)	-	-	-	-	-	-
Volkswagen	Up to 20+ BEVs	-	-	-	-	-	-
BMW	X3 BEV	-	-	-	-	-	-
BMW	i-Next	500	-	-	-	-	-
FCA	Maserati Alfieri BEV	-	-	-	-	-	-
Daimler	9 more EQ BEVs	-	-	-	-	-	-
Renault	Low-cost BEV (China)	-	-	-	-	-	-
Faraday	BEV (tbc)	-	-	-	-	-	-
Subaru	BEV	-	-	-	-	-	-

Source: Manufacturer data, EPA, Media reports, UBS

**UBS Evidence Lab provides our research analysts with rigorous primary research. The team conducts representative surveys of key sector decision-makers, mines the Internet, systematically collects observable data, and pulls information from other innovative sources. It applies a variety of advanced analytic techniques to derive insights from the data collected. This valuable resource supplies UBS analysts with differentiated information to support their forecasts and recommendations—in turn enhancing our ability to serve the needs of our clients.*

The **UBS Evidence Lab Electric Vehicle survey** was run in six countries (Germany, the UK, the US, Korea, China and Japan) in July 2016. A representative sample of consumers was invited to take the survey, and in total 9,400 qualified. Representation was based on gender, income and regional distribution. Qualification criteria were based on owning a private vehicle and/or intending to purchase a vehicle in the future – in other words, the sample did not include car objectors. Country samples were as follows: Germany (N=1,625), UK (N=1,549), USA (N=1,503), Korea (N=1,516), China (N=1,613) and Japan (N=1,594). The survey was sent out via an online methodology. The margin of error for whole sample responses is +/-1.01 at a 90% confidence level.

Valuation Method and Risk Statement

The automobile sector has in the past exhibited high levels of volatility in terms of profitability and valuation. Sector earnings and performance are highly sensitive to variations in volume, pricing, raw material costs and currency, all of which have been volatile recently. Interest rates are also a key driver of sector earnings as they affect demand and mix as well as earnings of the OEMs' financial services arms.

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Buy	FSR is > 6% above the MRA.	46%	30%
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Sell	Stock price expected to fall within three months from the time the rating was assigned because of a specific catalyst or event.	<1%	<1%

Source: UBS. Rating allocations are as of 31 March 2017.
1:Percentage of companies under coverage globally within the 12-month rating category.
2:Percentage of companies within the 12-month rating category for which investment banking (IB) services were provided within the past 12 months.
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4:Percentage of companies within the Short-Term rating category for which investment banking (IB) services were provided within the past 12 months.

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Company Disclosures

Company Name	Reuters	12-month rating	Short-term rating	Price	Price date
ABB Ltd[5, 6b, 6c, 7, 13, 16]	ABBN.S	Sell	N/A	CHF24.11	18 May 2017
Aisin Seiki	7259.T	Buy	N/A	¥5,540	19 May 2017
Albemarle Corp[16]	ALB.N	Neutral	N/A	US$110.00	18 May 2017
Analog Devices Inc.[16]	ADI.O	Neutral	N/A	US$80.48	18 May 2017
Asahi Kasei	3407.T	Buy	N/A	¥1,072.0	19 May 2017
Atlas Copco A	ATCOa.ST	Buy	N/A	SKr314.90	18 May 2017
Autoliv[16]	ALV.N	Sell	N/A	US$103.57	18 May 2017
BASF SE[2, 4, 5, 7, 14]	BASFn.F	Buy	N/A	€85.65	18 May 2017
BMW[7, 22]	BMWG.F	Neutral	N/A	€85.00	18 May 2017
BorgWarner Inc.[16]	BWA.N	Buy	N/A	US$40.13	18 May 2017
Clariant[4, 5, 6b, 6c, 7, 13, 18a, 59]	CLN.S	Buy	N/A	CHF20.57	18 May 2017
Continental	CONG.DE	Buy	N/A	€202.10	18 May 2017
Daimler[22]	DAIGn.DE	Buy	N/A	€67.72	18 May 2017
Dana Incorporated[2, 4, 5, 6a, 6c, 7, 16]	DAN.N	Neutral	N/A	US$19.26	18 May 2017
Delphi Automotive Plc[16]	DLPH.N	Buy	N/A	US$85.13	18 May 2017
Denso[7]	6902.T	Neutral	N/A	¥4,769	19 May 2017
Ems-Chemie[5]	EMSN.S	Sell	N/A	CHF653.00	18 May 2017
Faurecia	EPED.PA	Sell	N/A	€44.47	18 May 2017
FCA[5, 7, 16]	FCHA.MI	Neutral	N/A	€9.36	18 May 2017
Ford Motor Co.[16, 26a]	F.N	Buy	N/A	US$10.79	18 May 2017
General Motors Company[6c, 7, 16]	GM.N	Buy	N/A	US$32.47	18 May 2017
GKN[5]	GKN.L	Buy	N/A	350p	18 May 2017
Hella	HLE.DE	Buy	N/A	€45.11	18 May 2017
Hexagon AB	HEXAb.ST	Buy	N/A	SKr382.30	18 May 2017
Honda Motor[16]	7267.T	Neutral	N/A	¥3,050	19 May 2017
Hyundai Mobis	012330.KS	Buy	N/A	Won260,000	18 May 2017
Hyundai Motor[7, 18b]	005380.KS	Buy	N/A	Won165,000	18 May 2017
Infineon Technologies AG[7]	IFXGn.DE	Neutral	N/A	€19.10	18 May 2017
Johnson Matthey[5, 7]	JMAT.L	Sell	N/A	3,080p	18 May 2017
Kennametal Inc.[16]	KMT.N	Sell	N/A	US$37.15	18 May 2017
Kia Motors	000270.KS	Neutral	N/A	Won38,200	18 May 2017
Kuka	KU2G.DE	Buy	N/A	€104.80	18 May 2017
Lear Corporation[6c, 7, 16]	LEA.N	Buy	N/A	US$141.92	18 May 2017
LG Chemical	051910.KS	Buy	N/A	Won280,500	18 May 2017
LG Display[7, 16]	034220.KS	Buy	N/A	Won29,500	18 May 2017
LG Electronics[7]	066570.KS	Neutral	N/A	Won79,100	18 May 2017
Magna International[16]	MGA.N	Neutral	N/A	US$44.37	18 May 2017
Maxim Integrated Products Inc.[16]	MXIM.O	Neutral	N/A	US$46.45	18 May 2017
Mazda Motor[13]	7261.T	Buy	N/A	¥1,532.0	19 May 2017
Melexis NV	MLXS.BR	Sell	N/A	€76.74	18 May 2017
Michelin	MICP.PA	Buy	N/A	€117.40	18 May 2017

Company Name	Reuters	12-month rating	Short-term rating	Price	Price date
Nissan Motor	7201.T	Sell	N/A	¥1,093.5	19 May 2017
Panasonic	6752.T	Neutral	N/A	¥1,366.0	19 May 2017
PSA Group	PEUP.PA	Neutral	N/A	€18.52	18 May 2017
Renault[7]	RENA.PA	Buy	N/A	€86.19	18 May 2017
Renesas Electronics	6723.T	Neutral	N/A	¥944	19 May 2017
Rheinmetall	RHMG.DE	Buy	N/A	€85.07	18 May 2017
Samsung SDI[7, 22]	006400.KS	Buy	N/A	Won151,500	18 May 2017
Sandvik	SAND.ST	Sell	N/A	SKr133.50	18 May 2017
Saras[2, 4, 5]	SRS.MI	Neutral	N/A	€2.25	18 May 2017
Schaeffler	SHA_p.DE	Neutral	N/A	€15.14	18 May 2017
Siemens[2, 4, 5, 7]	SIEGn.DE	Buy	N/A	€128.35	18 May 2017
Sika[5, 6b, 6c, 7]	SIK.S	Buy	N/A	CHF6,190.00	18 May 2017
SKF B	SKFb.ST	Sell	N/A	SKr176.20	18 May 2017
STMicroelectronics[5, 7, 16]	STM.PA	Neutral	N/A	€14.49	18 May 2017
Subaru	7270.T	Sell	N/A	¥3,812	19 May 2017
Sumitomo Chemical	4005.T	Buy	N/A	¥613	19 May 2017
Suzuki Motor	7269.T	Buy	N/A	¥5,167	19 May 2017
Tenneco Inc.[16]	TEN.N	Buy	N/A	US$55.16	18 May 2017
Tesla, Inc.[13, 16, 26b]	TSLA.O	Sell	N/A	US$313.06	18 May 2017
Texas Instruments Inc.[16]	TXN.O	Buy	N/A	US$79.23	18 May 2017
Toyota Motor[7, 16]	7203.T	Sell	N/A	¥5,965	19 May 2017
Tupras	TUPRS.IS	Buy	N/A	TRY94.95	18 May 2017
Umicore	UMI.BR	Buy	N/A	€58.50	18 May 2017
Valeo	VLOF.PA	Buy	N/A	€62.78	18 May 2017
Visteon Corp.[4, 5, 6a, 6b, 7, 16]	VC.N	Buy	N/A	US$99.90	18 May 2017
Volkswagen[7, 13, 22]	VOWG_p.DE	Buy	N/A	€138.50	18 May 2017
W. R. Grace & Co[16]	GRA.N	Buy	N/A	US$70.20	18 May 2017

Source: UBS. All prices as of local market close.
Ratings in this table are the most current published ratings prior to this report. They may be more recent than the stock pricing date

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