EQUITY RESEARCH

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RBC Electric Vehicle Forecast Through 2050 & Primer

We've picked up a noticeable increase in the amount of electrification conversations among industry participants and an acceleration in investor expectations for the pace of electric vehicle penetration. With that in mind, we took a fresh look at our electric vehicle forecast, out through 2050, and present a primer on electric vehicles and how different industry participants are preparing for the future.

Forecast global BEV sales penetration of ~7.5% by 2025

We estimate that globally, battery electric vehicles (BEVs) represented ~0.8% of 2017 global demand, while hybrid-electric vehicles (HEVs) and plug-in hybrid-electric vehicles (PHEVs) represented ~2.9%. But we see robust growth off these low figures. The growth will be driven in two phases. The first phase, through 2025, is primarily regulatory driven. By then, we see ~7.5% BEV global penetration of new demand representing a ~34% CAGR from 2017's levels and ~12% HEV/PHEV penetration representing a ~21% CAGR. By 2025, we see BEV penetration in China at ~15%, Western Europe at ~8% and the US at 5%. Our ~7.5% global BEV penetration rate compares to IHS at ~5%.

Forecast global BEV sales penetration of ~66% by 2050

In the second phase, we see change factors aligning to impart more significant revolution. Battery costs decline, infrastructure is built out, and the regulatory-driven push gives way to a consumer-led one. BEVs become more cost efficient than ICE vehicles and take share from HEV/PHEV. By 2050, we see ~66% BEV global new vehicle penetration, representing a ~9% CAGR over a 25-year period from 2025. We see regions like China and Western Europe reaching 85% penetration. We forecast the US at 60% penetration.

BEVs will represent ~35% of global VIO by 2050

Our modeling shows that for global vehicles in operation (VIO) by 2025, ~91% will be ICE, ~3% 48V, ~4% HEV/PHEV (so ~98% still have some sort of ICE), and ~2% BEV. By 2050, we model the global VIO to be ~49% ICE, ~8% 48V, ~8% HEV/PHEV (so vehicles having some sort of ICE down to ~65%), and ~35% BEV. *Please see regional analyses inside and ask your RBC salesperson for our EV model.*

What it means for automakers?

Automakers are accelerating electrification efforts. R&D increases, limiting profits today. But electrification is also an opportunity to rethink production/supply chains/capability, which may represent an opportunity for OEMs to re-capture value. German OEMs doing the most. GM ahead of Ford to-date but Ford spending to catch up. Tesla increasingly competes on attributes besides electrification.

What it means for suppliers?

For ICE/exhaust products, expect margin pressure driven by lower volumes. Ultimately, we see the need for powertrain consolidation. There are opportunities for evolution and new parts such as batteries, electric motors, and power electronics come into vehicles. But evolution means investment now. Suppliers may look to JVs to fill competency gaps. Interim solutions such as 48-volt technology can be a strong growth opportunity (41% CAGR through 2025) for companies like BWA, DLPH and LEA. However, the majority of future electrified platforms likely PHEV/BEVs creating opportunities to add value from motors (BWA) and power electronics (DLPH, BWA). Meanwhile, axle makers (AXL, DAN, MTOR) may have an underappreciated opportunity to grab more value.

Will EVs make China an automotive powerhouse?

EVs present a significant opportunity for China to assert itself within the automotive industry. Our view is informed by: 1) a government that is very supportive of EVs; 2) Chinese companies pushing EV product; 3) China appears to control a large portion of battery supply...; 4) ...and the battery supply chain.

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All values in USD unless otherwise noted.
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For Required Conflicts Disclosures, see Page 89.

Table of contents

Executive Summary **3**

Electric vehicle basics **6**

Powertrain electrification has a range of technologies 6

RBC Global EV forecast **9**

RBC's take: BEV sales penetration ~7.5% by 2025, ~66% by 2050 9

Global regulations supporting EV adoption **16**

Regulatory pressures raise ICE compliance cost 16

Some governments have gone further including potential ban of ICE vehicles 17

BEV adoption will shift from regulation led to consumer led **18**

Let's look at it from the consumer side – today 18

BEVs vs. ICEs – eventually 20

Ultimately, the drivers to EV adoption vary by region **23**

Regulatory vs. economic driven markets 23

Battery costs will dictate EV adoption curve **26**

Battery component costs 27

Battery cell material components 28

Current and future battery technology 29

Battery capacity being added which should drive cost lower 31

Automaker strategies shifting toward electrification **35**

How are automakers impacted by electrification? 35

Current automaker targets 36

OEM strategies: the here, the plan, the future 37

Are suppliers prepared for the electric revolution? **47**

How are suppliers impacted by electrification? 47

What are supplier timelines? 48

Supplier content in an electrified world 49

How are suppliers approaching electrification? 51

EVs as the medium for China auto takeover? **62**

The electrification of commercial and off-highway vehicles **65**

Current electrification trends in CVs 65

Off-highway an early adopter of electric vehicles 67

EV infrastructure **69**

Appendix: **74**

Regional assumptions and detailed forecasts 74

Regulations by region 84

Executive Summary

BEV sales penetration ~8% by 2025, ~66% by 2050

We forecast BEVs will represent ~7.5% of global new vehicle sales by 2025, and ~66% by 2050 driven by a regulatory push giving way to a consumer led one.

The global electric vehicle market is still in its infancy. We estimate that in 2017 there were ~750,000 BEVs sold globally, representing ~0.8% of global demand. However, off this low base, the growth was strong at ~78% y/y. Meanwhile, we estimate 2017 HEV/PHEV units at around 2.7 million, representing ~2.9% of global demand and ~21% y/y growth.

We expect rapid growth of BEVs driven by two phases. The first phase we would put through 2025 and is primarily regulation-driven. We forecast ~7.5% BEV global penetration of new demand by 2025 or ~8mm units, representing a ~34% CAGR from 2017's levels. The growth is driven by China and Western Europe, which we expect to reach 15% and 8% market penetration, respectively. We model the US at ~5% BEV penetration. Our 7.5% global BEV penetration rate compares to IHS at ~5%.

We often find investors want to know our BEV outlook through 2025 and recognize this timeframe is likely more relevant for most investment decisions. Further, we can have a higher degree of certainty through 2025 as we look at factors such as automaker announcements and battery capacity. However, we also thought it useful to put on our "futurist" hats and think out through 2050. In this longer-term horizon, we see change that is much more significant. It is likely that as battery costs decline and the infrastructure build out continues the regulatory driven push gives way to a consumer led one. Economics and cost drive consumer decisions and BEVs can become more cost effective than ICE vehicles. By 2050, we see ~66% BEV global new vehicle penetration, representing a ~9% CAGR over a 25-year period from 2025. We see regions like China and Western Europe reaching 85% penetration. We forecast the US will be at 60% penetration.

History has proven that humans are poor at judging exponential change. However, analyzing the change factors, we see a high probability of a BEV tipping point. We acknowledge the path and transition to that state has a high degree of variability and uncertainty but we have high confidence in the end-state. The actions taken through the 2025 timeframe by different industry participants is likely to determine their success over the following quarter century.

In 2025, 98% of global VIO still have an ICE of some sort…but ~35% BEV VIO penetration by 2050

To judge the impact electric vehicles will have on the world, we believe it is useful to look at how the electric vehicles in operation (VIO) evolves. Our modeling shows that for global VIO by 2025, ~91% will be ICE, ~3% 48V, ~4% HEV/PHEV (so ~98% still have some sort of ICE), and ~2% BEV. By 2050, we model the global VIO to be ~49% ICE, ~8% 48V, ~8% HEV/PHEV (so vehicles having some sort of ICE down to ~65%), and ~35% BEV. *Please see all our assumptions and data for our analysis, including regional analyses in the appendix.*

What it means for automakers?

Traditional (incumbent) automakers are clearly impacted by the shift to electrification. Historically they faced an innovator's dilemma with EVs, as their legacy infrastructure, which generates profits today, is at risk. But OEMs seem to have finally embraced their electric future and are accelerating their electrification efforts.

We think about the impact of electrification on traditional automakers in three broad strokes: R&D, production and supply chain. 1) R&D: It's going higher which limits profitability now. 2) Production: Redesigning a vehicle architecture for BEVs means a company can re-imagine their manufacturing footprint and the product simplification that comes with BEVs could lead to capital efficiencies. 3) Supply Chain: Perhaps the most critical decision the OEMs have to make is deciding who ends up doing what on an EV. Today's supply and value chains are well established. But these are upended with EVs. New suppliers may enter the fray while others leave. OEMs need to decide how they will design EVs but also how much they do internally versus leveraging a supply base. This represents an opportunity for automakers to re-insource and potentially re-capture value.

Among legacy OEMs, the Germans have most ambitious electrification plans. GM has a solid BEV entrant in the Bolt, and expects 20 BEV models by 2023. Ford is behind GM today, but investing $11 billion to catch up with 16 BEVs planned by 2022. Tesla is all BEV, but with more competition coming, will have to rely more on brand and other attributes to differentiate.

What it means for suppliers?

Suppliers face dual headwinds of lower ICE product volumes and investment. We see the need for powertrain asset consolidation.

Electrification will be disruptive for the existing supply chain, particularly those who participate in the powertrain and exhaust arenas. We would expect margin pressure driven by increased competition and lower volumes on ICE products, combined with higher investment dollars for innovation. Suppliers must manage legacy business to fund growth. Ultimately, we see the need for powertrain consolidation.

Looking at electrification's impact by what is on an ICE versus an EV - **Out:** Fuel systems, transmissions, exhaust systems and other powertrain products. **Unchanged:** Seats, safety, interiors and body-in-white. **Evolved:** Braking systems (move to regenerative braking) and axles (to e-Axles). **Winners:** Thermal management, simple gear reduction. **New:** Electric motors, batteries, and power electronics (inverters, converters, on-board chargers, CPUs).

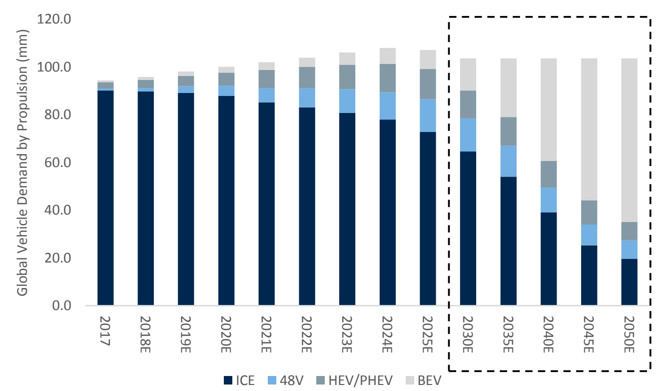
As we touched on in the automaker section, OEMs have an opportunity to re-imagine the supply chain and the functionality that is outsourced. Suppliers will always have the advantage of scale as they can sell across to multiple customers. So the onus is on them to come up with strong technology at a low cost. That means investment now. We also believe it is likely that suppliers may have to increasingly look to partnerships to fill competency gaps, quicken time to market and reduce capital spend. However, partnerships and JVs naturally could bring their own set of challenges including choosing the correct partners, cultural issues and governance.

Near-term, technologies like 48V could experience some of the best near-term growth (41% global CAGR through 2025), as they deal with trying to meet CO_2 targets amid lower diesel demand. Companies under coverage that could benefit from the 48V trend include DLPH, BWA, and LEA. However, the majority of future electrified platforms being planned are PHEVs or BEVs. In our view, batteries are a commodity. But PHEVs and BEVs will also need electric motors (which companies like BWA have invested in) and power electronics (DLPH, BWA, Conti, and Bosch). The key question is will these areas face increased competition from other strong engineering or technology companies? Meanwhile, we believe that many investors soured on axle makers (AXL, DAN, MTOR) in light of electrification. While risk is clearly present, we also see opportunity as their core competency is power to the wheels, which doesn't change and arguably can grab more value in EVs.

Will EVs make China an automotive powerhouse?

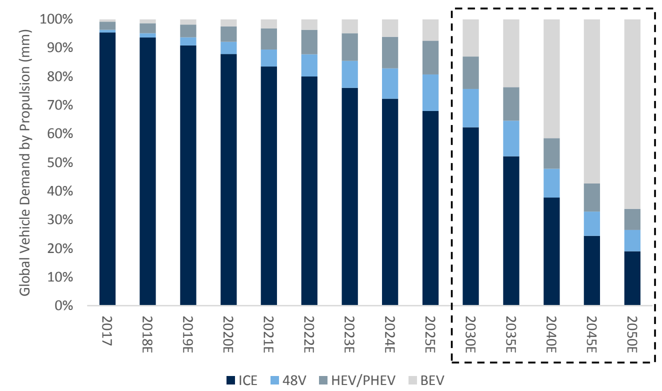
A final conclusion we reached is that EVs present a significant opportunity for China to assert itself within the automotive industry. Our view is informed by: 1) a government that is very supportive of EVs; 2) a lot of Chinese companies pushing EVs; 3) China appears to control a large portion of battery supply...; 4) …and the battery supply chain.

Exhibit 1: Global Unit Demand by Propulsion



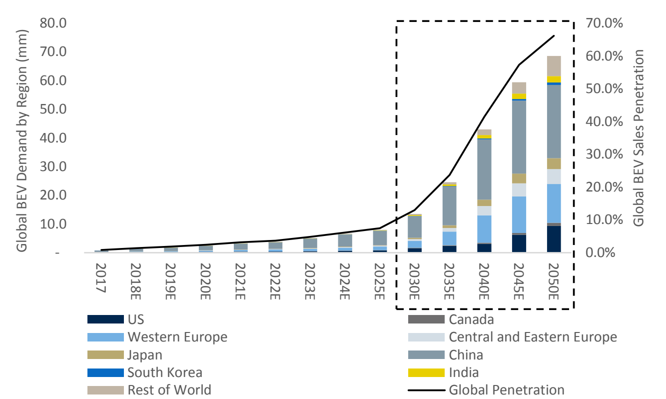
Source: IHS, OICA, Bloomberg, IEA, ACEA, CAAM, JAMA, Wards, and RBC Capital Markets estimates

Exhibit 2: Global Market Demand Share by Propulsion



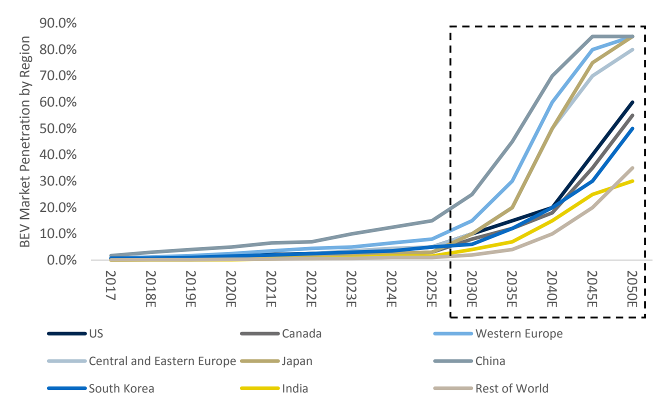
Source: IHS, OICA, Bloomberg, IEA, ACEA, CAAM, JAMA, Wards, and RBC Capital Markets estimates

Exhibit 3: BEV Sales and Penetration by Region



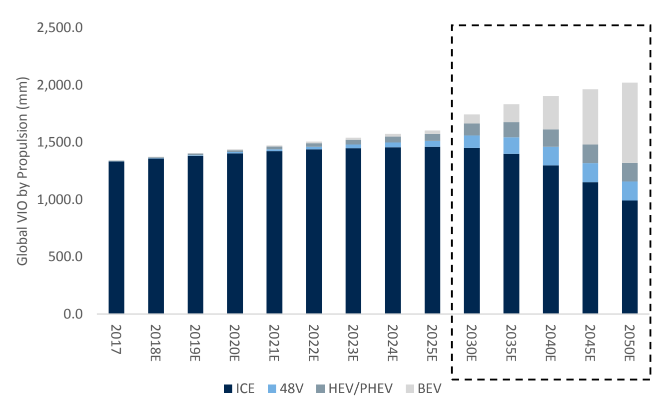
Source: IHS, OICA, Bloomberg, IEA, ACEA, CAAM, JAMA, Wards, and RBC Capital Markets estimates

Exhibit 4: BEV Market Penetration Trend by Region



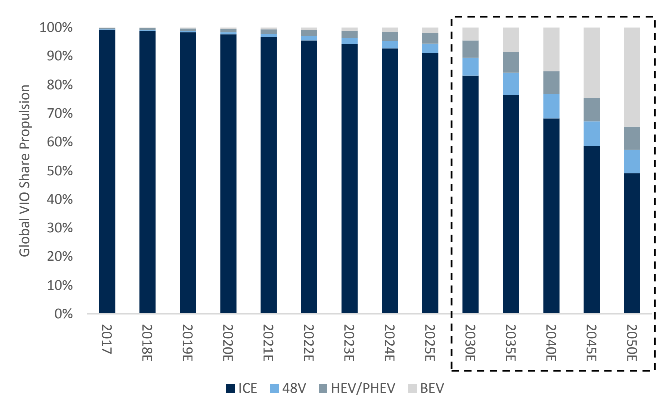
Source: IHS, OICA, Bloomberg, IEA, ACEA, CAAM, JAMA, Wards, and RBC Capital Markets estimates

Exhibit 5: Global VIO by propulsion



Source: IHS, OICA, Bloomberg, IEA, ACEA, CAAM, JAMA, Wards, and RBC Capital Markets estimates

Exhibit 6: Global VIO share by propulsion



Source: IHS, OICA, Bloomberg, IEA, ACEA, CAAM, JAMA, Wards, and RBC Capital Markets estimates

Electric vehicle basics

Powertrain electrification has a range of technologies

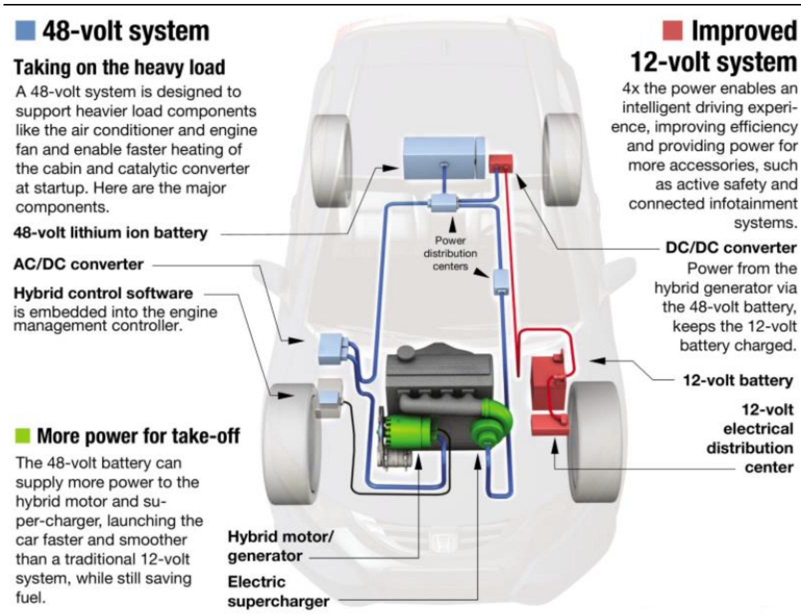
There are a number of different applications to electrify the vehicle powertrain. These include, in order of increasing electrification, 48 Volt (48V), Hybrid-Electric Vehicles (HEV), Plug-in Hybrid Electric Vehicles (PHEV) and pure Battery Electric Vehicles (BEV). We go into the definitions in more detail below, but every type of vehicle save the BEV still has an internal combustion engine (ICE) of some sort. To generalize, we sometimes refer to 48V/HEV/PHEV/BEV vehicles (in totality) as xEV.

More on what each technology is:

48 Volt (48V, Mild-hybrid)

Largely utilizes the same architecture as an ICE vehicle, but adds an extra 48-volt battery to the traditional 12-volt battery standard on today's vehicles. This extra battery capacity helps in start/stop situation and reduces the need for the engine to power tertiary vehicle functions (i.e. water pumps, air conditioning, infotainment, etc.). However, propulsion of the car cannot be powered by the extra battery capacity alone. Example: Audi A8.

Exhibit 7: 48 Volt summary

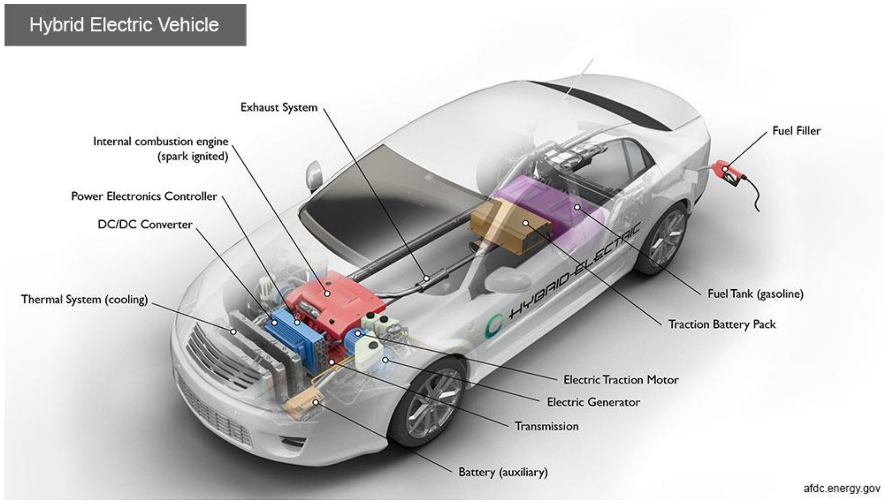


Source: Delphi Technologies and IHS Automotive

Hybrid Electric Vehicle (HEV, Full-hybrid)

These vehicles are more efficient than mild-hybrids as the battery and electric motor help to power the vehicle, rather than just providing the energy needed for accessories. Full-hybrids can be classified as series or parallel hybrids. A series hybrid uses the internal combustion engine as a generator that creates the electricity that turns the wheels of the vehicle via an electric motor in the axles. A parallel hybrid uses both the energy generated by the ICE and the electric motor to power the vehicle. Additionally, a full hybrid can operate like a pure BEV when energy requirements are minimal at low speeds. Example: Toyota Prius.

Exhibit 8: Full Hybrid summary

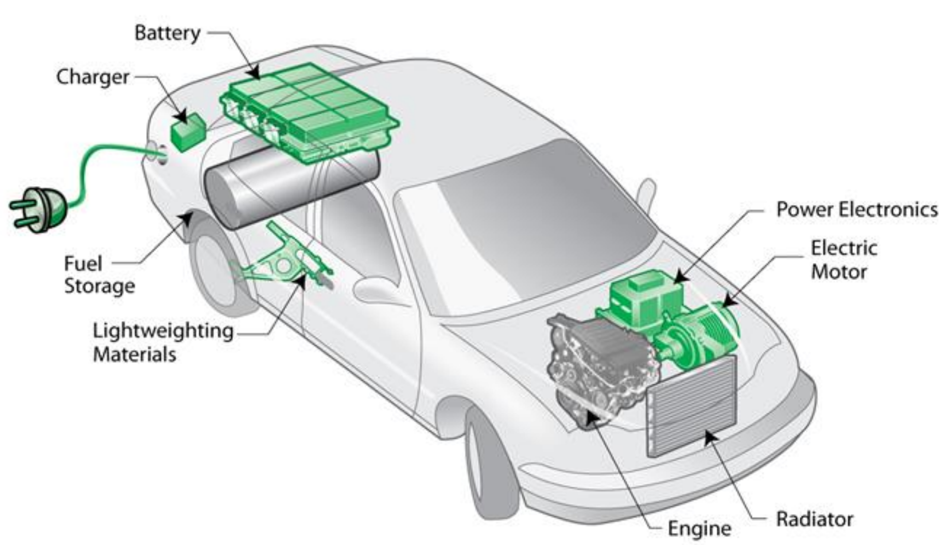


Source: Alternative Fuels Data Center

Plug-in Hybrid (PHEV)

Similar to full-hybrids, but have larger batteries that can be recharged by "plugging in." These vehicles can be powered by the electric motor and often run in "full electric mode" until the battery is depleted, at which time the vehicle switches to a series or parallel hybrid propulsion system. Example: Chevy Volt.

Exhibit 9: Plug-in Hybrid summary

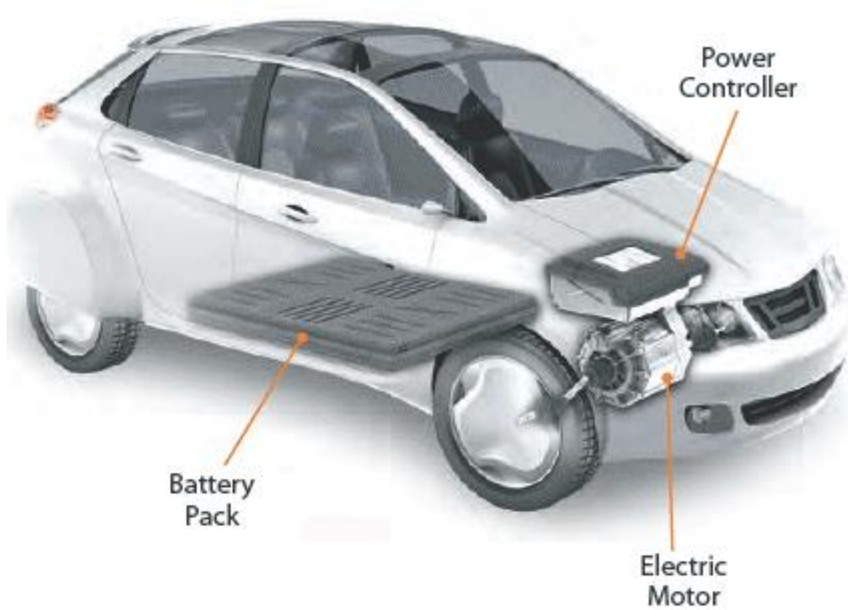


Source: Argonne National Laboratory

Battery electric vehicle (BEV)

Vehicles use one or more electric motors with an electric battery for propulsion ("pure" electric vehicle) and has no ICE. Examples: All Tesla's, Chevy Bolt.

Exhibit 10: Battery Electric summary



Source: The Union of Concerned Scientists

RBC Global EV forecast

RBC's take: BEV sales penetration ~7.5% by 2025, ~66% by 2050

We expect regulation, led by China and Western Europe, to help drive mid-term electric vehicle adoption and rapid growth off small base levels. We forecast 7.5% global BEV mix for new demand by 2025. However, we see a more meaningful inflection beyond 2025 as the cost of batteries declines leading to consumers choosing electric vehicles given their lower upfront cost and lower operating cost as well as a built out infrastructure. As such, we see global BEV new demand penetration reaching 66% by 2050.

We see the different electrification technologies as a progression (48V, HEV, PHEV, BEV), but a cannibalizing one. For instance, in our view, 48V technology can experience rapid mid-term growth, but is somewhat of a "band-aid" solution. This is because it is a quick and relatively inexpensive fix to get more fuel economy out of existing platforms (vehicle architecture does not need to be redesigned). However, the majority of new electrified platforms being planned will be PHEV or BEVs, especially as the technology progresses and the cost comes down. In that respect, even HEVs are very likely to cede share to PHEVs. Our forecast (detailed more in the next section) buckets HEV/PHEV, though the further out on the time axis we go, the more this trends towards PHEV vs. HEV. Once cost comes down and infrastructure is built out (and consumers become comfortable with BEVs) we further expect that PHEVs give way to BEVs. Generally, when investors and market participants are talking about electric vehicles, or in some government cases such as with China's New Energy Vehicle (NEV) policy, they are talking about a vehicle with a plug, or PHEVs and BEVs.

By 2025, we forecast BEV penetration in China at ~15%, Western Europe ~8%, and the US ~5%.

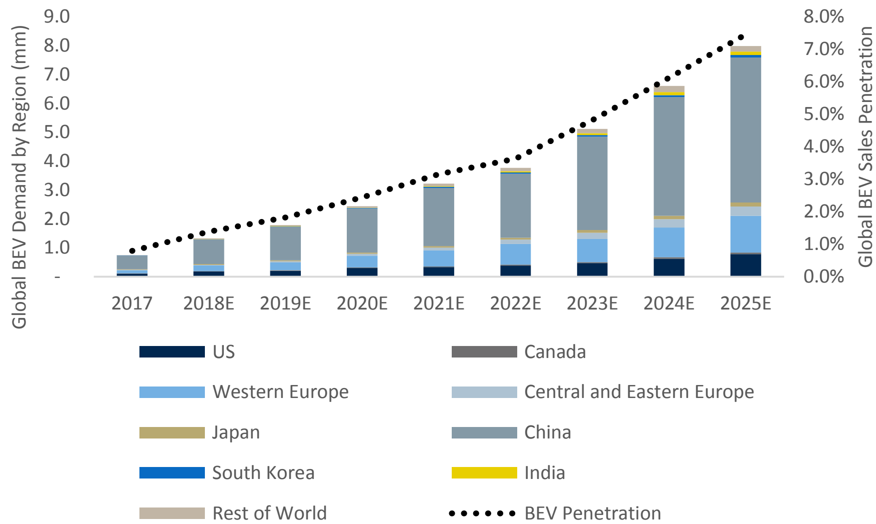
xEV market is nascent…

The global electric vehicle market is still in its infancy. We estimate that in 2017, there were ~750,000 BEVs sold globally, representing ~0.8% of global demand. However, this represented ~78% y/y growth. We estimate HEV/PHEV units at around 2.7 million in 2017, representing ~2.9% of global demand and ~21% y/y growth.

…but growing rapidly through 2025 driven by regulatory factors

We took a look at the global landscape and a number of key factors that we believe will drive mid-term xEV adoption, namely: government regulation, improving cost of ownership, increasing battery capacity and OEM targets. We forecasted ICE, 48V, HEV/PHEV and BEV sales and penetration across 9 key regions to come up with our global forecast. We end up with 7.5% BEV global penetration by 2025 or ~8mm units, representing a ~34% CAGR from 2017's levels. The growth will be driven by China and Western Europe where we expect BEV penetration to reach 15% and 8% market penetration, respectively. We model the US at ~5% BEV penetration. Our 7.5% global BEV penetration rate compares to IHS at ~5%.

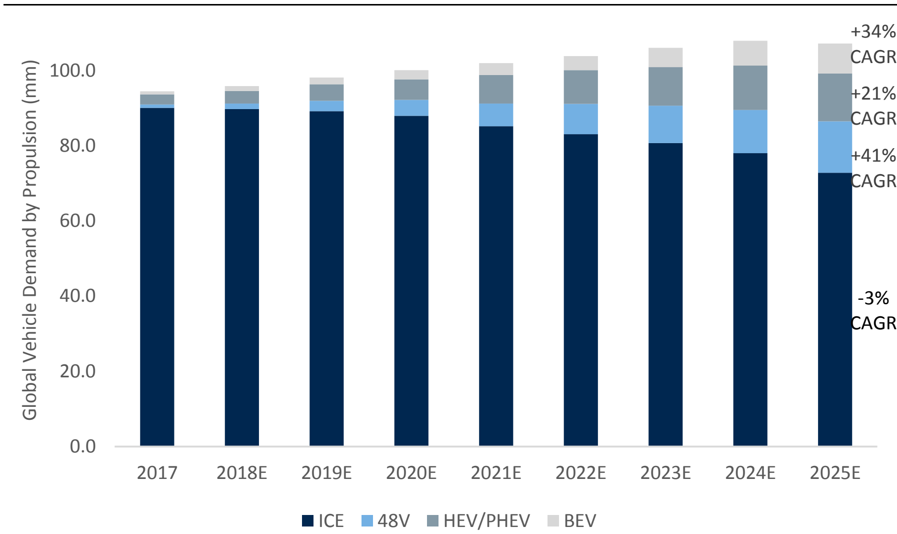
Exhibit 11: BEV global demand and market penetration forecast through 2025



Source: IHS Automotive, OICA, Bloomberg, IEA, ACEA, CAAM, JAMA, Wards, and RBC Capital Markets estimates

The other way to look at this is that ~92.5% of the world's vehicles will still have an ICE (of some sort) in 2025. However, we estimate that only ~68% will not have any form of electrification (pure ICE), with 48V technology and HEV/PHEVs each garnering about 12% share. From a unit perspective, we actually expect 48V to experience the greatest growth through 2025 at a ~41% CAGR. 48V is a quick, easier and less costly solution to help OEMs meet some near-term emission goals. However, it is most likely a "band-aid" solution, eventually giving way to PHEV and BEV, though it could be argued that eventually all remaining ICE vehicles will be 48V. Indeed, our conversations with industry participants indicate that conversations for new platforms/programs (which may only begin to be available to the public in 3-4 years) are for PHEV and BEV.

Exhibit 12: Global demand forecast by propulsion method through 2025 with 8-year CAGRs



Source: IHS Automotive, OICA, Bloomberg, IEA, ACEA, CAAM, JAMA, Wards, and RBC Capital Markets estimates

Tipping point in ~15-20 years, leads to mass BEV disruption

In our 2050 view, lower battery cost and stronger infrastructure cause BEV penetration to be consumer led, and reach ~66% global penetration

The view through 2025 is likely more relevant for most investment decisions and has a higher degree of certainty. However, we also thought it was useful to put on our "futurist" hats and think out through 2050. Within this longer-term horizon, we see much more significant change. It is likely that as battery costs continue to decline and the infrastructure build out continues, the regulatory driven environment gives way to a consumer led one. Economics and cost will drive decisions and BEVs can become more cost effective than ICE vehicles. Further, many governments have plans to ban ICE vehicles. As more BEVs get out there in a cost efficient manner, enforcement will come easier and other governments can join the fold, causing an even steeper inflection. The timing of the tipping point needs a wide error band. History has proven that humans are poor at judging exponential change. However, analyzing the change factors, we have a high degree of confidence in the end-state, even if the path and transition to that state has a high degree of variability and uncertainty. Still, the actions taken through the 2025 timeframe by different industry participants is likely to determine their success over the following quarter century.

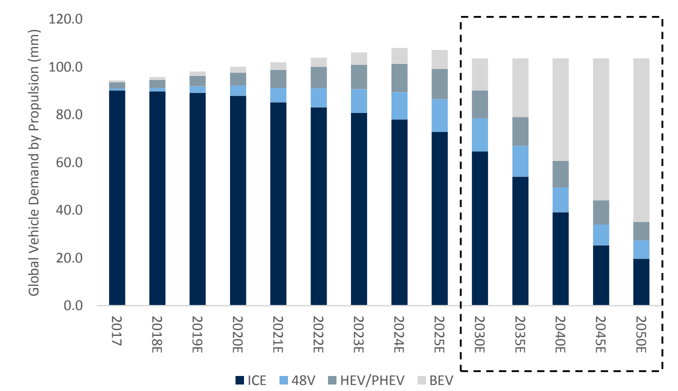
By 2050, we see ~66% BEV global penetration, representing a ~9% CAGR over a 25 year period from 2025. We see regions like China and Western Europe reaching 85% penetration. We forecast the US will be at 60% penetration.

Finding a longer-term third party projections is difficult and further, we found that some organizations that give longer-dated forecasts combine their PHEV and BEV forecasts. However:

- Our ~66% Global BEV penetration forecast compares to Energy Innovation's 2050 forecast at 65% BEV penetration.
- Our 60% US BEV penetration by 2050 compares to The US Energy Information Administration at 12%.
- By 2025, IHS estimates that BEVs will represent ~5% of total global vehicle sales vs. our estimate of 7.5%.
- Bloomberg New Energy Finance estimates EVs will account for 54% of new vehicle sales by 2040 (our 2040 BEV forecast is ~42% and HEV/PHEV is ~11%).
- ExxonMobil believes that HEV/PHEV and BEVs will account for ~40% of global sales by 2040, which compares to our estimate of ~52%.

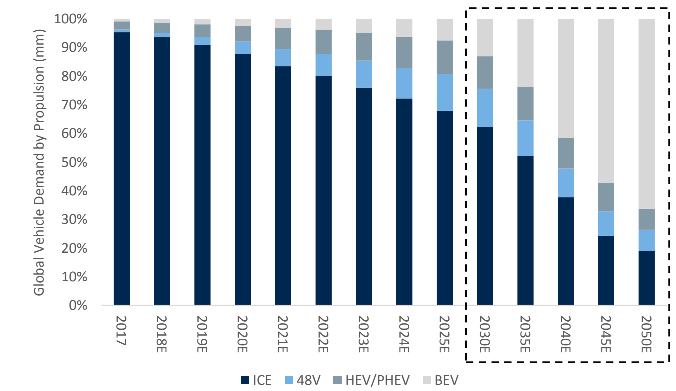
By 2050, we see pure ICE penetration at only 19% (~26.5% if we include 48V vehicles). HEV/PHEV is at ~7.5%, on the downside of their cycle (which we believe will peak in the 2025-2035 timeframe) as BEVs and infrastructure will have come far enough alone to favor BEV vs. PHEV.

Exhibit 13: Global Unit Demand by Propulsion



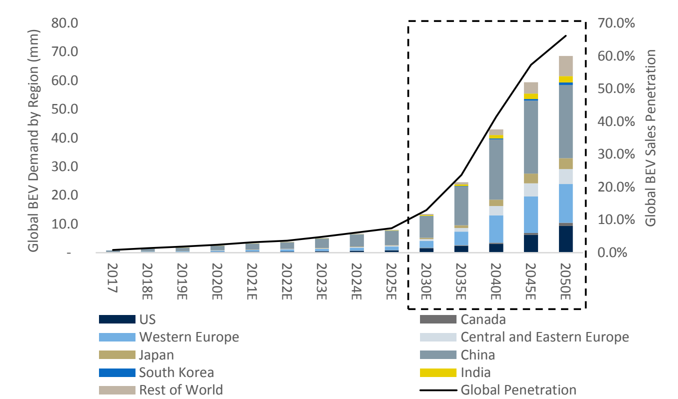
Source: IHS, OICA, Bloomberg, IEA, ACEA, CAAM, JAMA, Wards, and RBC Capital Markets estimates

Exhibit 14: Global Market Share Demand by Propulsion



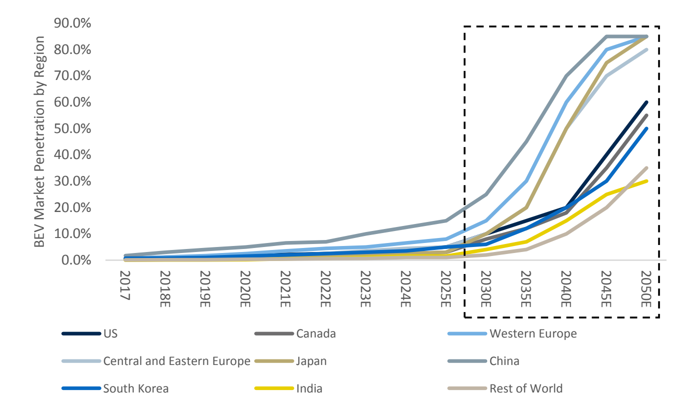
Source: IHS, OICA, Bloomberg, IEA, ACEA, CAAM, JAMA, Wards, and RBC Capital Markets estimates

Exhibit 15: BEV Sales and Penetration by Region



Source: IHS, OICA, Bloomberg, IEA, ACEA, CAAM, JAMA, Wards, and RBC Capital Markets estimates

Exhibit 16: BEV Market Penetration Trend by Region



Source: IHS, OICA, Bloomberg, IEA, ACEA, CAAM, JAMA, Wards, and RBC Capital Markets estimates

BEVs <2% of Global VIO by 2025, but ~35% by 2050

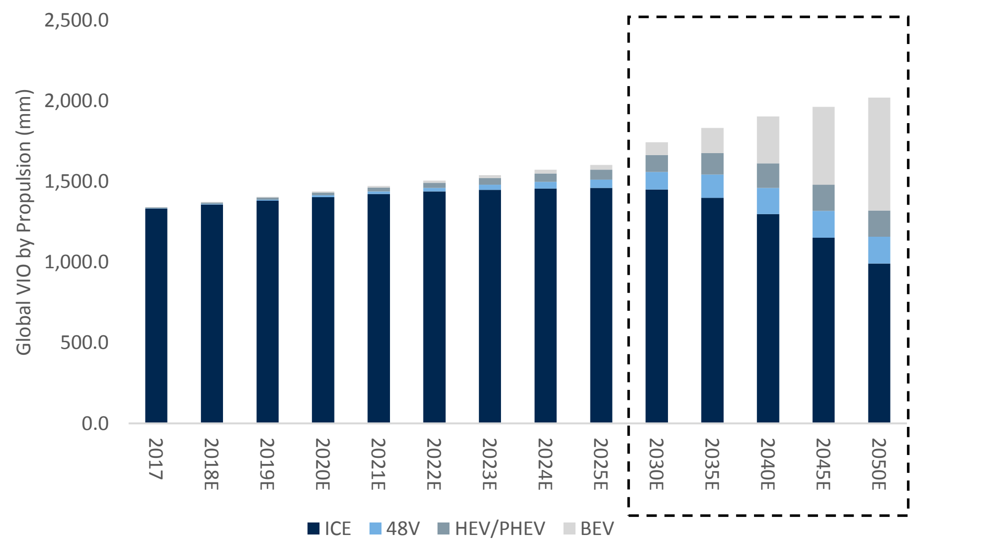
The above discussion focused on new demand mix, but to help judge the needed investment in infrastructure as well as the impact on other industries, we believe it is useful to look at the vehicles in operation (VIO), or said differently, the car parc or fleet.

In addition to mix forecasts, this involves a number of assumptions including:

- **Total demand.** We used our own and IHS' demand outlook through 2025. RBC US demand forecast only goes to 2022 after which we then used ~15.5 million units of demand (which is our view of equilibrium US demand). Thereafter (through 2050) we mostly held demand constant at more normalized levels, taking cycles out of the equation.
- **Scrap.** For ICE, 48V and HEV/PHEV we used normalized, regional scrap rates. For BEV, we generally lowered the scrap rate as a) it is believed that BEV vehicles may be able to put on more miles than ICE vehicles, potentially as much as 500,000 miles and b) to build in some conservatism.
- An issue we didn't fully address, but that could affect demand, scrappage and certainly VIO is the rise of autonomous and shared autonomous vehicles.

Net, our modeling shows that for global VIO by 2025, ~91% will be ICE, ~3% 48V, ~4% HEV/PHEV (so ~98% still have some sort of ICE), and ~2% BEV. By 2050, we model the global VIO to be ~49% ICE, ~8% 48V, ~8% HEV/PHEV (so vehicles having some sort of ICE down to ~65%), and ~35% BEV.

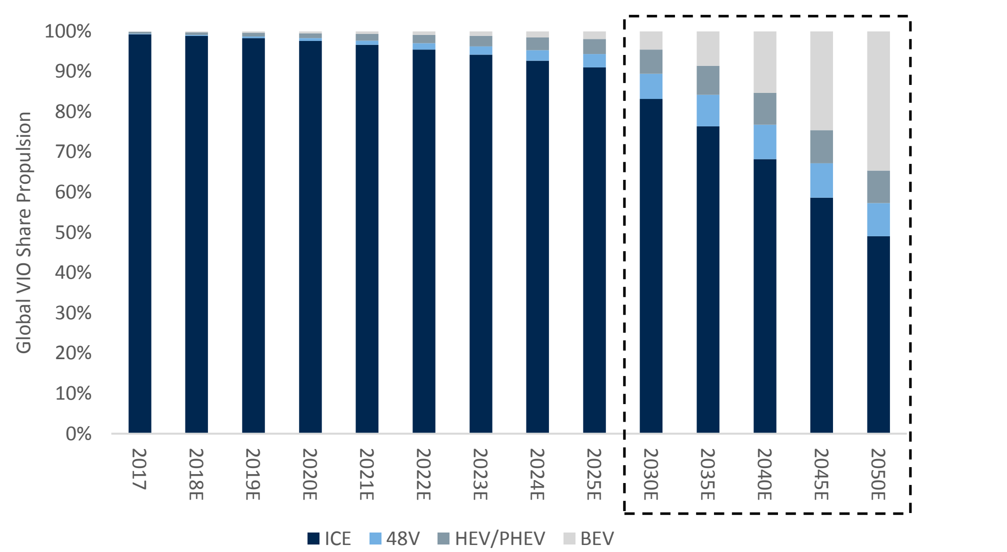
Exhibit 17: Global VIO forecast by propulsion method through 2050



Source: IHS Automotive, OICA, Bloomberg, IEA, ACEA, CAAM, JAMA, Wards, and RBC Capital Markets estimates

In the US, by 2025, we forecast ~95% of VIO will be ICE, ~1% 48V, ~3% HEV/PHEV (so ~99% still have some sort of ICE), and ~1% BEV. By 2050, we model US VIO to be ~58% ICE, ~4% 48V, ~13% HEV/PHEV (so vehicle having some sort of ICE down to ~75%), and ~25% BEV.

Exhibit 18: Global VIO share forecast by propulsion method through 2050



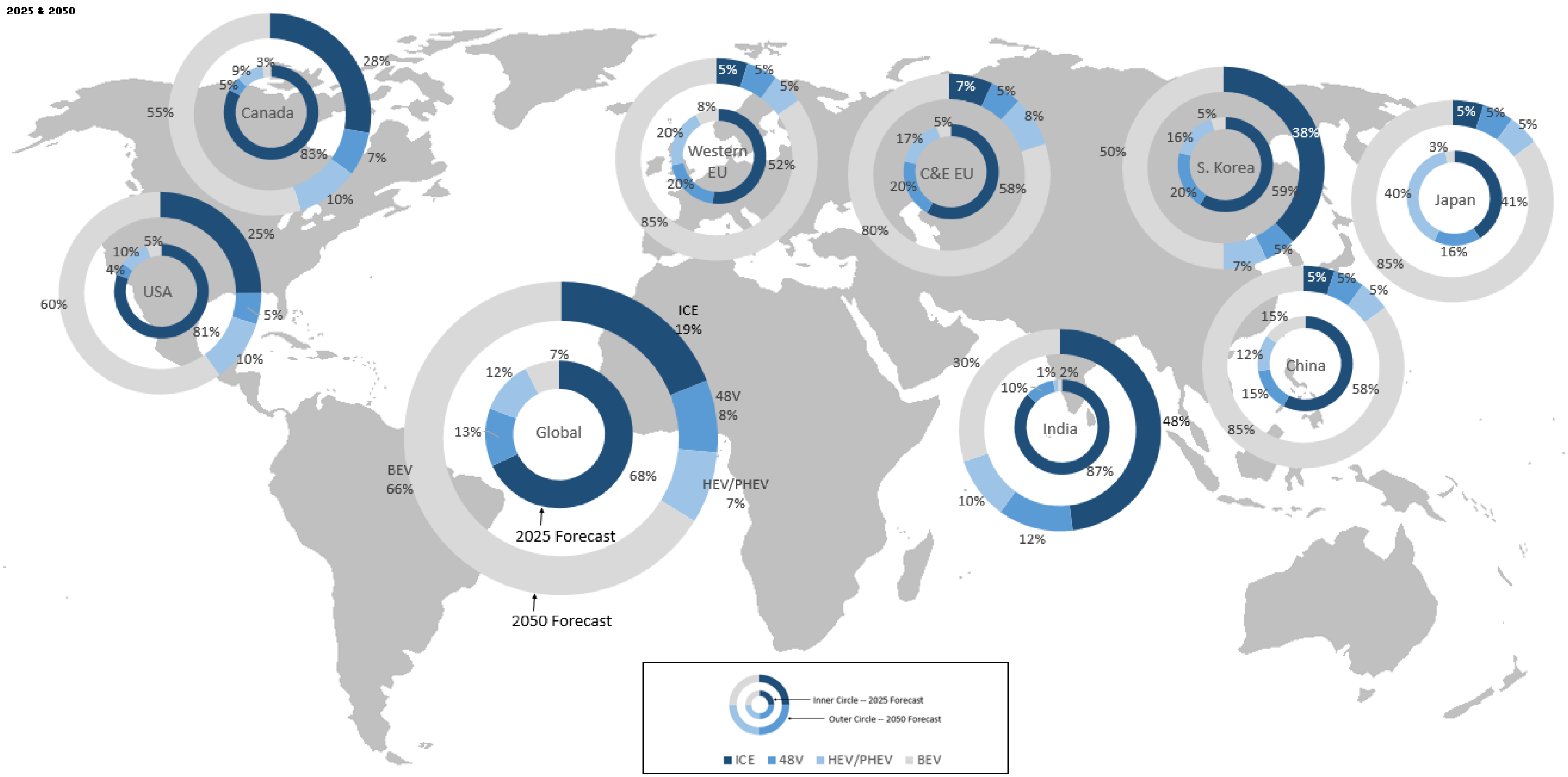
Source: IHS Automotive, OICA, Bloomberg, IEA, ACEA, CAAM, JAMA, Wards, and RBC Capital Markets estimates

As with our demand mix forecast, finding longer-range third party projections is difficult and further, we found that some organizations that give longer-dated forecasts combine their PHEV and BEV forecast. Our 2050 BEV VIO forecast is ~35%. We note the comparison versus other forecasts we found:

- BP, in their 2018 Energy Outlook, pointed to "electric cars" (defined as PHEV + BEV) as being 15% of the global car parc by 2040. Our equivalent forecast would be ~20%.
- The International Energy Agency (IEA), their Global EV Outlook 2017 points to a range of ~160-200 million electric vehicles (PHEV + BEV) by 2030. Our equivalent is likely slightly below the low-end of their range.
- Exxon Mobil, in their 2017 Outlook for Energy, points to full-hybrids as ~15% of the vehicle fleet in 2040 and "electric vehicles" (PHEV + BEV + FCEV) as ~9% of the fleet in 2040. Our "electric vehicles" forecast by 2040 is ~20% of the fleet.
- OPEC forecasts that BEVs and PHEVs will represent 12% of the global fleet by 2040. Our equivalent forecast by 2040 is ~20% of the fleet.
- The IEA estimates that the BEV and PHEV global car parc will be 9-20mm vehicles by 2020 (we estimate the HEV/PHEV and BEV parc to be ~25mm) and 40-70mm vehicles by 2025 (our estimate of HEV/PHEV and BEV parc to be ~91mm by 2025).

Please see all our assumptions and data for our analysis, including regional graphs in the appendix.

Exhibit 19: 2025 and 2050 Forecast of Global Sales Mix by Region



Source: US Energy Information Administration and RBC Capital Markets

Global regulations supporting EV adoption

Regulatory pressures raise ICE compliance cost

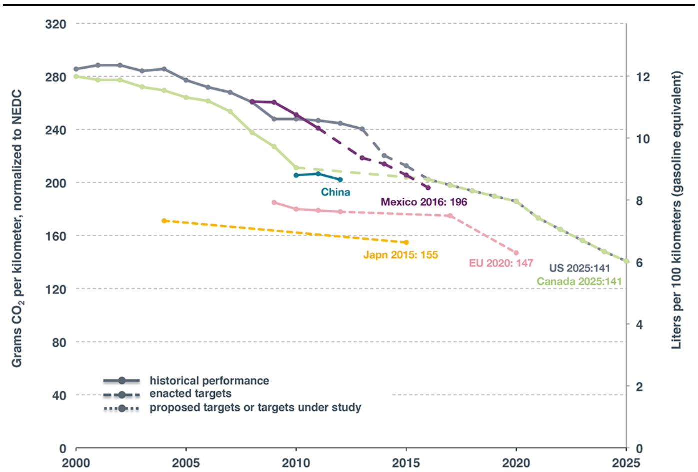
Our conversations with industry contacts and experts lead us to believe that BEVs are at drivetrain parity with an ICE at battery pack cost of $100-$150/kWh.

Across the globe, governments have started to target internal combustion engines in order to limit the dangerous pollutants that pose health and environmental risks. Two chief air pollutants in the crosshairs are Carbon Dioxide (CO_2) and Nitrogen Oxide (NOx). Carbon dioxide is a greenhouse gas, which traps heat within the earth's atmosphere rather than allowing it to escape into space. CO_2 may contribute to higher global temperatures, rising sea levels, and lower rainfall according to NASA. In the US, the transportation industry contributed 32% to total CO_2 emissions in 2015, making the auto industry a target of environmental protection. Nitrogen Oxide can be harmful to both the environment and the general population, as NOx contributed to smog and acid rain and can irritate human airways. In the US, transportation contributed over 50% of NOx emissions in 2015.

Many countries have instituted regulations to cut the emissions of these pollutants. The cost of compliance for an internal combustion engine (ICE) is hence increasing. Meanwhile, the cost of a BEV is decreasing, particularly as battery costs fall. The powertrain (ICE vs. BEV) is the meaningful change. Other elements of the vehicle should be equivalent (on a like for like vehicle basis). An ICE has an engine, transmission and exhaust and other elements, which we believe could cost $5-7k on an average vehicle. A BEV has a battery pack, electric motors and power electronics. The most expensive cost of a BEV today is the cost of the batteries. Our conversations with industry contacts and experts lead us to believe that BEVs are at drivetrain parity with an ICE at battery pack cost of $100-$150/kWh. If we assume an average BEV might have 50 kWh battery pack, that math works.

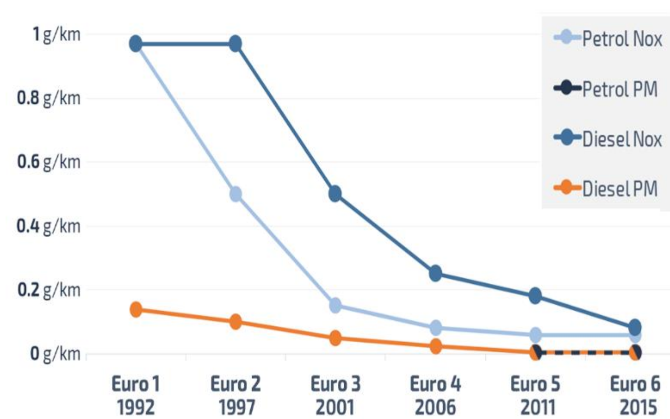
Another regulatory pressure pushing OEMs to move away from ICEs is changing testing methodologies, specifically in Europe. Since the 1980s, EU vehicle emissions were tested via New European Driving Cycle (NEDC). NEDC did a poor job of simulating real-world driving and favored stop-start engines to satisfy emissions requirements. In September 2017, the EU commissioned the Worldwide Harmonized Light Vehicle Test procedure (WLTP). Compared to NEDC, WLTP has more/longer cycles, more driving phases, and more complex shifting, among other differences. This puts any vehicles with ICEs at a substantial disadvantage vs. NEDC.

Exhibit 20: Global CO_2 emission regulations



Source: ICCT

Exhibit 21: Euro NOx and PM regulations



Source: ACEA

Some governments have gone further including potential ban of ICE vehicles

Some countries have gone a step further in promoting the adoption of EVs. The UK, France, and India have indicated bans on the sale and use of ICE vehicles by 2040 (UK and France) and 2030 (India). Additionally, both Germany and China have considered similar ICE bans. These markets accounted for ~46% of global sales in 2017. Additionally, while there has been no legislation banning ICEs in the US to date, California has proposed an ICE ban by 2040 (CA represents ~10% of US registrations). Some of these "bans" should likely be viewed as aspirational. For instance, India may have a difficult time adhering to that target given their infrastructure.

Additionally, to pressure OEMs, some countries have instituted EV sales quotas. The most notable quota program is in China. The program is currently expected to be implemented in 2019, and states that OEMs must earn credits for the sale of New Energy Vehicles (NEVs). The necessary credits are equivalent to 10% of sales in 2019 and rise to 12% in 2020 (though some vehicles are worth more credits than others so the real proportion of sales is lower). Additionally, China has established a target for new energy vehicles to comprise ~20% of new vehicle sales by 2025, and the Prime Minister has insinuated that the country could pursue an all-out ban of ICE vehicles by 2040.

Based solely on the government regulations, this would imply that xEVs would have to be ~8% of global demand by 2025, ~12% by 2030 and ~48% by 2040.

On the consumer side, the majority of governments offer some form of financial incentives, whether in the form of a tax credit or exemption from tolls and parking fees. These incentives are designed to offset some of the delta in price between electric vehicles and their ICE peers. Generally, these incentive programs phase out based on the total amount of electric vehicles sold in the country as the cost of an electric vehicle begins to level out with traditional ICE vehicles

BEV adoption will shift from regulation led to consumer led

Let's look at it from the consumer side – today

We took a look at the cost to own, for 5 years, a Chevy Bolt EV versus a Chevy Sonic Hatchback and a Chevy Cruze Hatchback. The reason we selected the Chevy Sonic is that it is actually built on the same platform (G2XX) as the Chevy Bolt EV. However, spec-wise, the Sonic falls short a little bit so we also went "one-up" to compare versus the Cruze.

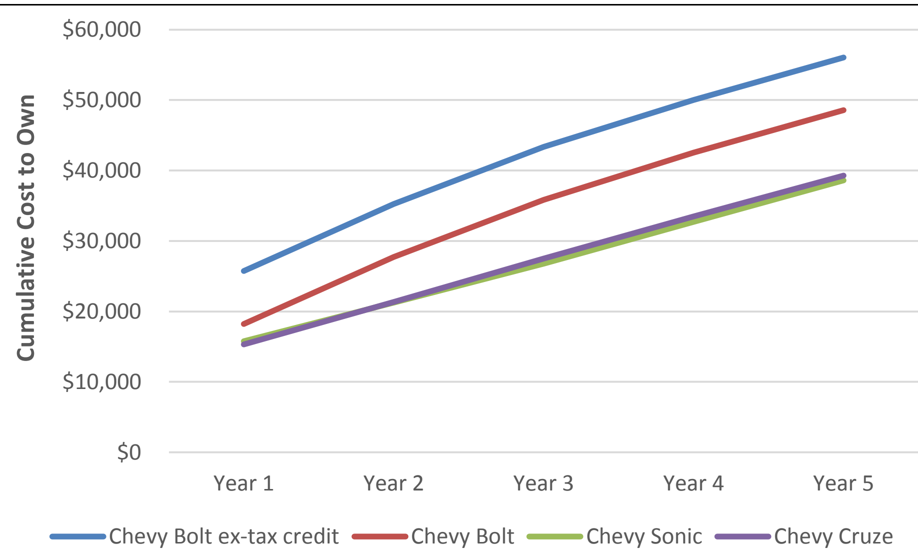
Exhibit 22: Key Specifications for Chevy Bolt EV, Chevy Sonic, Chevy Cruze

Chevy Bolt EV Premier		Chevy Sonic Hatchback Premier		Chevy Cruze Hatchback Premier
	vs.		vs.	
$41,780	**Starting MSRP**	$22,170	**Starting MSRP**	$24,820
Electric Motor	**Engine**	1.4L 4-cyl. Turbo	**Engine**	1.4L 4-cyl. Turbo
AWD	**Drive Type**	FWD	**Drive Type**	FWD
200	**Horsepower**	138 @ 4900 rpm	**Horsepower**	153 @ 5600 rpm
266 ft-lbs.	**Torque**	148 ft-lbs. @ 1850 rpm	**Torque**	177 ft-lbs. @ 2000 rpm
Single-Speed Fixed Gear	**Transmission**	6-Speed Automatic	**Transmission**	6-Speed Automatic
119 (MPGe)	**MPG (combined)**	30	**MPG (combined)**	31
5	**Max Seating**	5	**Max Seating**	5
102.4"	**Wheel Base**	99.4"	**Wheel Base**	106.3"
164.0"	**Overall Length**	159.8"	**Overall Length**	175.3"
16.9 ft³	**Cargo Volume**	N/A	**Cargo Volume**	22.7 ft³
36.5"	**Rear Leg Room**	34.6"	**Rear Leg Room**	36.1"
52.8"	**Rear Shoulder Room**	53.0"	**Rear Shoulder Room**	53.7"
37.9"	**Rear Head Room**	37.8"	**Rear Head Room**	37.3"

Source: Company website, RBC Capital Markets

What is immediately clear is the higher cost of the Chevy Bolt EV – the "EV premium." But what is also clear, is the improved efficiency, torque and horsepower that EVs offer. Using Kelly Blue Book, we calculated the cost to own the Chevy Bolt EV at $48,557 for 5-years. Note, that this includes the $7,500 tax credit in year one. Otherwise, the 5-year cost to own would have been ~$56k. This compares to $38,607 5-year cost to own for the Sonic and $39,282 5-year cost to own for the Cruze.

Exhibit 23: Cumulative cost to own each vehicle



Source: KBB.com, RBC Capital Markets

Exhibit 24: Chevy Bolt EV 5-year Total Cost to Own

Chevy Bolt EV Premier

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Fuel	$342	$324	$323	$329	$335	**$1,653**
Insurance	$2,095	$2,095	$2,095	$2,095	$2,095	**$10,475**
Financing	$1,090	$863	$629	$387	$138	**$3,107**
Fees & Taxes	($4,743)	$309	$298	$237	$225	**($3,674)**
Maintenance	$0	$506	$327	$445	$885	**$2,163**
Repairs	$0	$0	$676	$676	$676	**$2,028**
Depreciation	$19,436	$5,431	$3,760	$2,507	$1,671	**$32,805**
Total	$18,220	$9,528	$8,108	$6,676	$6,025	**$48,557**

Based on 15,000 miles per year, $3,907.20 down payment, 60-month loan, 3.19% APR

Source: KBB.com, RBC Capital Markets

Exhibit 25: Chevy Sonic 5-year Total Cost to Own

Chevy Sonic Hatchback Premier

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Fuel	$1,355	$1,285	$1,280	$1,305	$1,330	**$6,555**
Insurance	$1,531	$1,531	$1,531	$1,531	$1,531	**$7,655**
Financing	$584	$462	$337	$207	$74	**$1,664**
Fees & Taxes	$1,546	$194	$196	$155	$155	**$2,246**
Maintenance	$0	$488	$295	$642	$915	**$2,340**
Repairs	$0	$0	$548	$548	$548	**$1,644**
Depreciation	$10,739	$1,552	$1,330	$1,552	$1,330	**$16,503**
Total	$15,755	$5,512	$5,517	$5,940	$5,883	**$38,607**

Based on 15,000 miles per year, $2,093.70 down payment, 60-month loan, 3.19% APR

Source: KBB.com, RBC Capital Markets

Exhibit 26: Chevy Cruze 5-year Total Cost to Own

Chevy Cruze Hatchback Premier

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Fuel	$1,297	$1,230	$1,226	$1,249	$1,273	**$6,275**
Insurance	$1,531	$1,531	$1,531	$1,531	$1,531	**$7,655**
Financing	$644	$510	$371	$229	$81	**$1,835**
Fees & Taxes	$1,688	$207	$208	$164	$163	**$2,430**
Maintenance	$0	$525	$295	$735	$924	**$2,479**
Repairs	$0	$0	$577	$577	$577	**$1,731**
Depreciation	$10,176	$1,986	$1,985	$1,489	$1,241	**$16,877**
Total	$15,336	$5,989	$6,193	$5,974	$5,790	**$39,282**

Based on 15,000 miles per year, $2,308.2 down payment, 60-month loan, 3.19% APR

Source: KBB.com, RBC Capital Markets

However, there may be some faults with this data. One of the biggest factors was that KBB depreciated 79% of the Bolt EV value over 5-years while only 74% for the Sonic and 68% for the Cruze. This may be fair now to assume a lower residual value for EVs as there is a perception that the batteries may not hold up or that advancements in battery technology could result in greater range and energy density in newer models. But, as the market develops more experience with EVs, we believe this discount may subside. If for instance, we placed the Cruze depreciation curve on the Bolt EV, the 5-year cost to own the Bolt EV would decrease by ~$4,500. Further, KBB has maintenance only slightly lower for the Bolt than the other two vehicles. However, one of the promises of BEVs is that maintenance will be lower than ICE engines as there are fewer parts.

BEVs vs. ICEs – eventually

Declining cost curve for BEV vs. increasing for ICE

The cost curves of BEVs and ICEs will eventually cross leading to a consumer led tipping point for BEVs. This is because the ICE cost curve is upward sloping as more content is required to meet regulations. Meanwhile, the cost curve for a BEV is dominated by battery costs that are expected to decrease over time. The current "rule of thumb" is that EVs will be able to achieve "parity" with an ICE at $100-$150/kWh pack cost at almost any reasonable fuel level.

But there are other potential benefits that could tip the scales in favor of BEVs vs. ICEs.

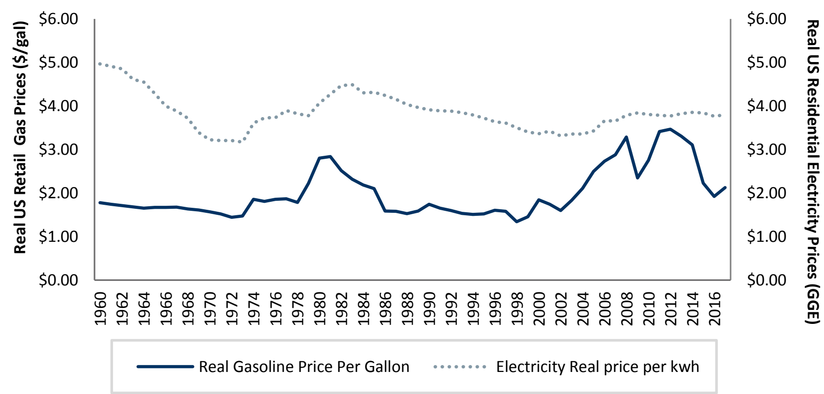
EVs have lower maintenance costs

For example, a Tesla powertrain has 18 moving parts and no exhaust system. A traditional ICE could have thousands of parts. An electric powertrain doesn't need regular maintenance as there are no fluids involved (good-bye oil changes) or belts. No filters are needed and brake wear on EVs is reduced. According to the Institute for Automobile Economics (IFA), a modern-day EV can save up to 35% in maintenance costs.

EVs can have greater fuel price stability and reduce energy dependence

The price of electricity in the US has been incredibly more stable than the price of gasoline. Further, electric vehicles can reduce energy dependence, especially if countries are able to use nuclear, solar, wind, hydro or geothermal generation.

Exhibit 27: Real US gasoline prices vs. electricity on a GGE basis, 1960-2017

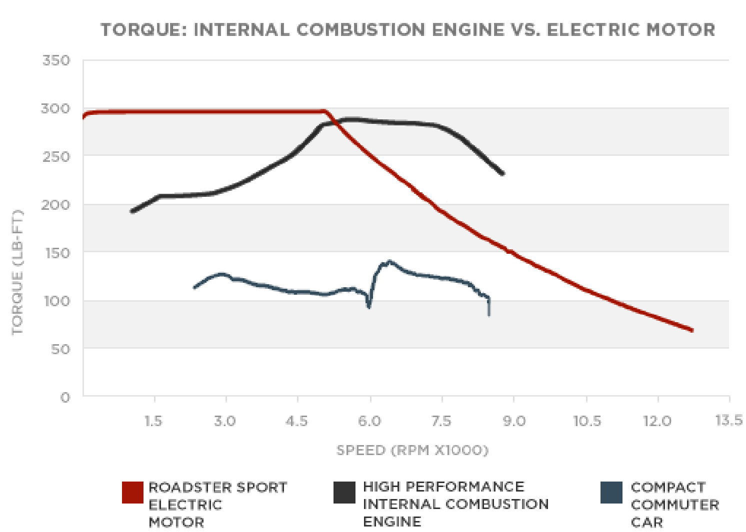


Note: Price is for Regular Leaded Gasoline until 1975 and for Regular Unleaded Gasoline thereafter.
Source: Energy Information Administration, RBC Capital Markets

EVs have better acceleration

Many say EVs are "more fun to drive". This is subjective, but they do have better acceleration. Electric motors have flat torque curves and thus achieve peak torque right off the bat. The drive is also very "smooth". A traditional ICE has to increase its RPM (which takes time) to achieve its peak torque potential. The Tesla Model S can do 0–60 mph in 2.5–4.2 seconds (depending on trim).

Exhibit 28: Torque/RPMs for a Tesla electric motor versus ICE engine

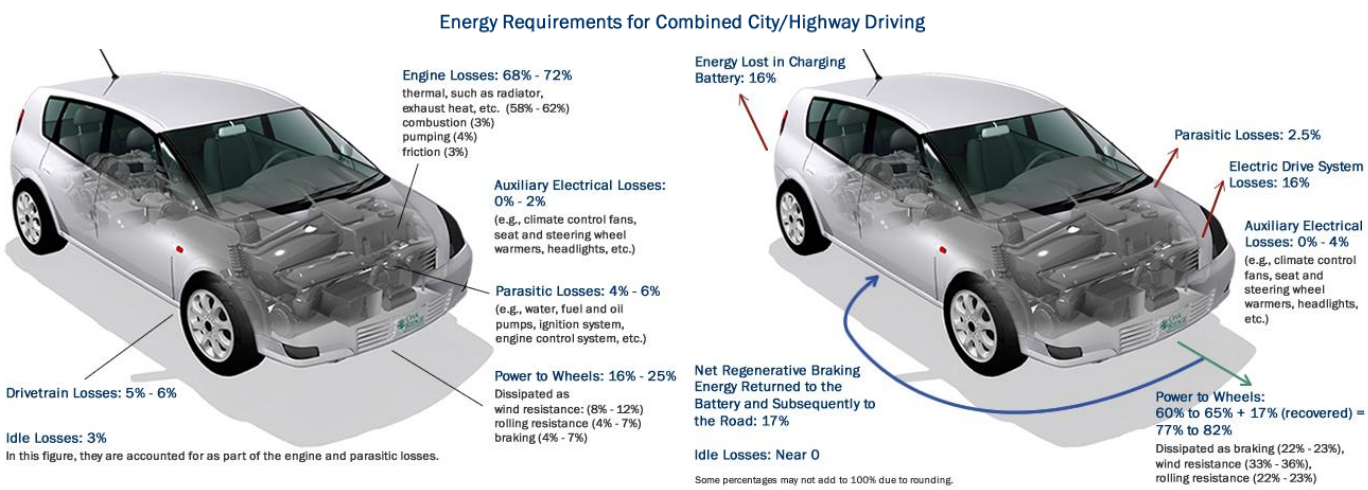


Source: Tesla Motors

EVs have better energy efficiency

According to the US EPA, electric vehicles convert 72%–94% of the energy used to power the vehicle to move it down the road. A gasoline-powered ICE only converts about 12%–30% of the energy stored in gasoline to move the vehicle.

Exhibit 29: Energy use for ICE vehicles (left) and BEVs (right)



Source: US Department of Energy

Environmentally friendly

EVs emit no tailpipe pollutants, but the source of the power plant generating that electricity does matter (i.e., coal, gas, nuclear, solar, hydro, wind, etc.). However, an ICE is essentially a one-way energy suck as once the oil is burned, it's gone. Theoretically, electric vehicles can be integrated into the electric grid, take power from the grid but also provide it back. We should note that there is a belief that EVs are not as "green" as perceived after considering the "long tailpipe." These arguments include that much electricity generation comes from coal and rare-earth materials that need to be mined.

Ultimately, the drivers to EV adoption vary by region

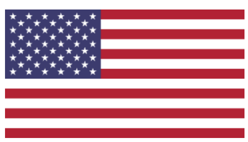
Regulatory vs. economic driven markets

Our analysis suggests that EV adoption in most regions/markets will be a function of regulations and economics. In a market more driven by regulation, consumers and OEMs will be pushed to shift to EVs as governments pass increasingly strict emissions regulations or sales quotas. In a market driven by economic factors, EV adoption will hinge on the price to produce, buy, and own the vehicle. Once an EV becomes a lower cost alternative to an ICE vehicle then both consumers and OEMs will shift to EVs. We believe that the transition to EVs will be relatively earlier in regulatory driven markets as deadlines and potential fines would likely force companies and consumers to shift before EVs become economically viable. While EV adoption in markets driven by economics may come at a later date, the EV penetration will likely accelerate faster than in a regulatory-driven market. Once EVs become more financially viable, we believe consumers and OEMs will have no incentive to purchase/produce ICEs.

Below we outline the driving factors for the United States, Europe, and China.

Exhibit 30: Factors influencing EV adoption by region

Drivers of Vehicle Electrification



Main Driver:	Economics	Regulations	Regulations
Influencing Factors:	- Vehicle Affordablity - Total Cost of Ownership - Government Incentives - Robo-Taxi Development	- Tougher CO_2 & NO_X Regulations - Rising Cost of Compliance - Tougher Testing Standards - Government Incentives - Cost of Ownership	- NEV Policy - Government Incentives - Cost of Ownership

Source: RBC Capital Markets

United States

In the US, regulations have been largely inconsistent as Corporate Average Fuel Economy (CAFE) standards have been altered, enacted, and eliminated. Currently, the EPA and automakers are working to establish future fleet emission targets after the most recent iteration of the standards was rejected. The California Air Resource Board (CARB) has instituted its own emission targets, and even pushed the state to ban ICEs by 2040, but the power and influence of CARB has been called into question recently by EPA Chief, Scott Pruitt. Therefore, we believe that US EV adoption will be a function of economic factors. EV adoption will be largely influenced by how affordable a vehicle is to purchase and own as well as the incentives offered by the government. Another interesting factor to watch will be how robo-taxis affect vehicle sales and total car parc. If robo-taxis become a cheaper option, and a realistic substitute to vehicle ownership, then we would expect to see slower EV adoption.

Exhibit 31: Top selling EV models in the US

Top Selling US Models	EV Type (PHEV, BEV)	2017 Unit Sales	y/y Change
Tesla Model S	BEV	26,500	-12.3%
Chevy Bolt	BEV	23,297	3923.7%
Tesla Model X	BEV	21,700	10.7%
Prius Prime	PHEV	20,936	NA
Chevrolet Volt	PHEV	20,349	-17.7%
Nissan Leaf	BEV	11,230	-19.8%
Ford Fusion Energi	PHEV	9,632	-40.3%
Ford C-Max Energi	PHEV	8,140	4.8%
BMW i3	PHEV/BEV	6,276	-17.7%
BMW X5	PHEV	5,349	-10.8%
BMW 3-Series	PHEV	4,141	NA
BMW 5-Series	PHEV	3,759	NA
Volkswagen E-Golf	BEV	3,534	-10.2%
Fiat 500E	BEV	3,336	-10.7%
Audi A3	PHEV	2,877	-32.8%
Chrysler Pacifica	PHEV	2,764	NA
Hyundai Sonata	PHEV	2,254	-24.9%
Volvo XC90	PHEV	2,196	9.0%
Kia Soul EV	BEV	2,157	24.8%
Ford Focus	BEV	1,817	101.7%

Source: hybridcars.com, RBC Capital Markets

Europe

Europe's regulatory environment favors the adoption of EVs, as Euro 6 regulations put strict limits on harmful pollutants that would cause OEMs to add costly content to its vehicles or shift to lower emission vehicles. Additionally, many countries have instituted their own financial incentives and bans on ICE vehicles in select cities or entire countries, with others considering similar action. Western Europe clearly leads the way in regard to regulations and EV adoption, but we expect Central and Eastern Europe to follow in its footsteps (likely 3-5 years behind).

Exhibit 32: Top selling EV models in Europe

Top Selling EU Models	EV Type (PHEV, BEV)	2017 Unit Sales	y/y Change
Renault Zoe	BEV	31,410	44.5%
BMW i3	BEV	20,855	38.5%
Mitsubishi Outlander	PHEV	19,189	-10.0%
Nissan Leaf	BEV	17,454	-7.3%
Tesla Model S	BEV	15,553	23.9%
Volkswagen Passat GTE	PHEV	13,599	3.7%
Volkswagen e-Golf	BEV	12,895	93.7%
Tesla Model X	BEV	12,630	243.2%
Mercedes GLC350e	PHEV	11,249	503.2%
BMW 225xe	PHEV	10,805	82.7%
BMW 330e	PHEV	10,117	16.4%
Volkswagen Golf GTE	PHEV	9,267	-18.2%
Audi A3 e-Tron	PHEV	8,356	21.0%
Volvo XC90 T8	PHEV	7,847	-17.1%
Mercedes C350e	PHEV	6,861	-32.2%
BMW 530e	PHEV	6,143	NA
Hyundai Ioniq Electric	BEV	6,117	NA
BMW X5 xDrive40e	PHEV	5,944	12.0%
Kia Soul EV	BEV	5,551	25.7%
Smart Fortwo ED	BEV	5,191	NA

Source: Clean Technica, RBC Capital Markets

China

China's regulations appear to be the most thorough in pushing for EV adoption. The country has set emission regulations, sales quotas on OEMs, tax incentives and rebates for consumers, and NEV sales targets (~20% of new vehicle sales by 2025). Additionally, China has indicated that they could pursue an altogether ban of ICEs, though no official date has been announced. The Chinese market has largely focused its EV options on low cost, city friendly, micro-vehicles that offer convenience for urban consumers.

Exhibit 33: Top selling EV models in China

Top Selling Chinese Models	EV Type (PHEV, BEV)	2017 Unit Sales	y/y Change
BAIC EC-Series	BEV	78,079	315.0%
Zhidou D2	BEV	42,342	365.8%
BYD Song	PHEV	30,920	NA
Chery eQ	BEV	27,444	71.3%
JAC iEV6S/E	BEV	25,741	NA
BYD e5	BEV	23,601	50.9%
Geely Emgrand	BEV	23,324	35.8%
BYD Qin	PHEV	20,738	-5.2%
SAIC Roewe eRX5	PHEV	19,510	28.8%
Zotye E200	BEV	16,751	27.3%
JMC E100	BEV	15,491	43.1%
BYD Tang	PHEV	14,592	-53.5%
Changan Benni	BEV	14,549	NA
BAIC EU-Series	BEV	13,158	NA
JMC E200	BEV	12,340	NA
Hawtai EV160	BEV	11,823	NA
SAIC Wuling E100	BEV	11,420	NA
Zotye Cloud	BEV	11,038	-32.8%
SAIC Roewe eRX5	BEV	10,436	NA
BYD e6	BEV	10,023	-51.4%

Source: Clean Technica, RBC Capital Markets

Battery costs will dictate EV adoption curve

As mentioned earlier, the cost of the battery is the largest factor in the cost of a BEV powertrain. The battery needs to have the right energy density, capacity and safety to meet consumer needs/demands. The cost of batteries is broadly expected to come down making BEVs more cost competitive versus ICEs. We see two major factors to consider, the components (chemistry) and industry capacity.

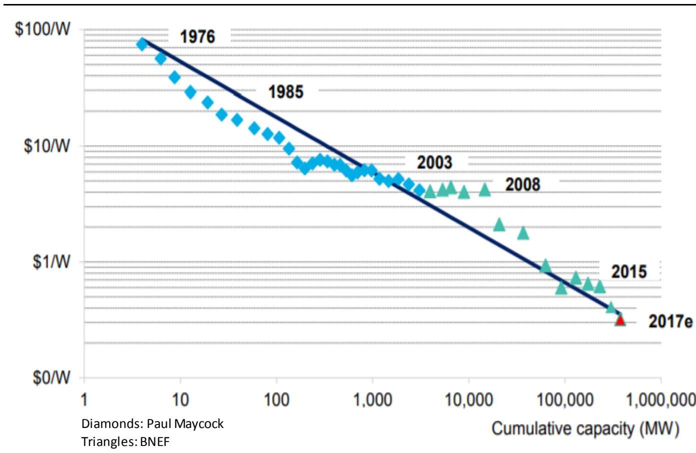
For the purposes of this report, we assume that all-in battery pack cost drops to ~$100/kWh by 2025 and $70/kWh by 2030.

Lithium-ion battery costs have declined significantly over the past 10 years. In 2005, lithium-ion battery costs were in excess of $1,500 per kWh. It is fairly difficult to know where prices are today, but we estimate somewhere in the $150-$200/kWh range. Some data points:

- In October 2015, GM indicated their cost at the cell level (via LG Chem) was $145/kWh. Based on what we know about pack assembly, we would put the all in back cost at $200-$220/kWh. In November 2017, GM confirmed they were on a path to get the cell cost below $100/kWh, which we believe would put the pack cost (assuming greater efficiencies as well) to around $125/kWh. In any event, they are talking about a >30% cost reduction and with higher energy density.
- In June 2017, Audi indicated a ~$114/kWh cell price.
- Bloomberg New Energy Finance has indicated that industry battery pack costs (including energy storage products) in 2016 stood at ~$273/kWh and $209/kWh in 2017.
- Tesla is a large player but hasn't disclosed battery costs in years. In early 2016, they mentioned they were at $190/kWh at the pack level. We believe Tesla is on a path to be below $100/kWh (all-in pack cost) around the end of the decade.

As R&D dollars increase and capacity increases, it is logical to assume that battery prices will continue to fall. The allegory is solar PV prices, which have fallen 95% since 1976 as capacity came on line.

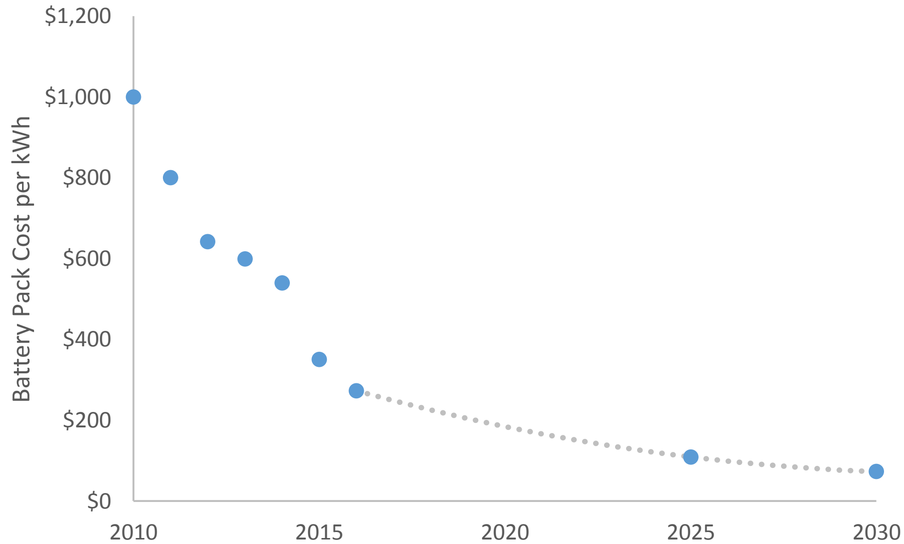
Exhibit 34: Solar PV prices vs. cumulative production capacity



Source: Bloomberg New Energy Finance, RBC Capital Markets

For the purposes of this report, we assume that all-in battery pack costs drop to ~$100/kWh by 2025 and $70/kWh by 2030.

Exhibit 35: Li-ion battery pack cost forecast to 2030



Source: Bloomberg New Energy Finance, RBC Capital Markets estimates

Battery component costs

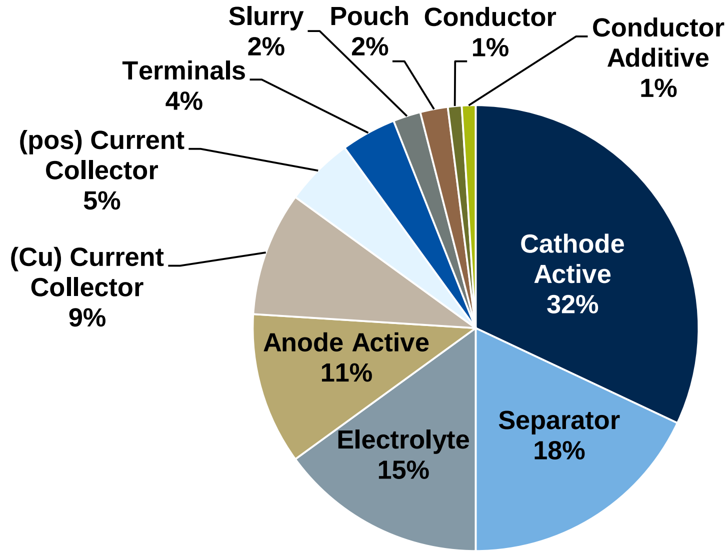
When we look at battery costs, it is important that we separate battery cells, modules, and packs. Battery cells are the basic battery units that charge and discharge. Battery modules are assemblies that combine cells and protect them from shocks, heat, and/or vibration. The battery pack is the final battery system installed in the vehicle. It combines battery modules, control systems, cooling systems, voltage management, etc.

Battery cell costs are separated into two buckets – material costs and production costs. We estimate that ~75% of costs come from materials (cathode, electrolyte, anode, separator, current collector, etc.), while the remaining ~25% of costs are from production (overhead, labor, and assembly). For total pack costs, we also need to factor in packaging, electronics, liquid cooling system, warranty, and other costs. However, almost all of these seem leverageable (hence lowering the cost per kWh) over time, especially with higher volume.

In terms of lowering total battery costs, we see a few levers to pull on both the material and production sides. On the material side, increased battery energy density lowers the absolute chemical material requirement per battery, which in turn should reduce battery cost. Increasing production in and of itself could also create economies of scale in purchasing cell materials. We see the majority of the cost improvements coming on the production side. Increased manufacturing capacity should help create economies of scale and allow battery manufacturers to gain fixed cost leverage and lower costs. We think standardization and improved processes will also come as EV battery production grows, which should lower production costs.

Battery cell material components

Exhibit 36: NMC battery material component breakdown



Source: National Renewable Energy Laboratory, RBC Capital Markets

Cathode (32% of cell material cost)

Positive electrode in the battery; consists of lithium and other chemical elements (nickel, manganese, and cobalt for an NMC battery). Lithium ions migrate to the cathode (from the anode) during discharge to create electric current. During the charging process, this process reverses.

Separator (18% of cell material cost)

The separator is a permeable membrane that isolates the cathode and anode in a battery. Ions move through the separator (via the electrolyte) between the cathodes and anodes.

Electrolyte (15% of cell material cost)

The electrolyte is a non-metallic, typically liquid, conductor and acts as a catalyst by which ions move between the anode and cathode.

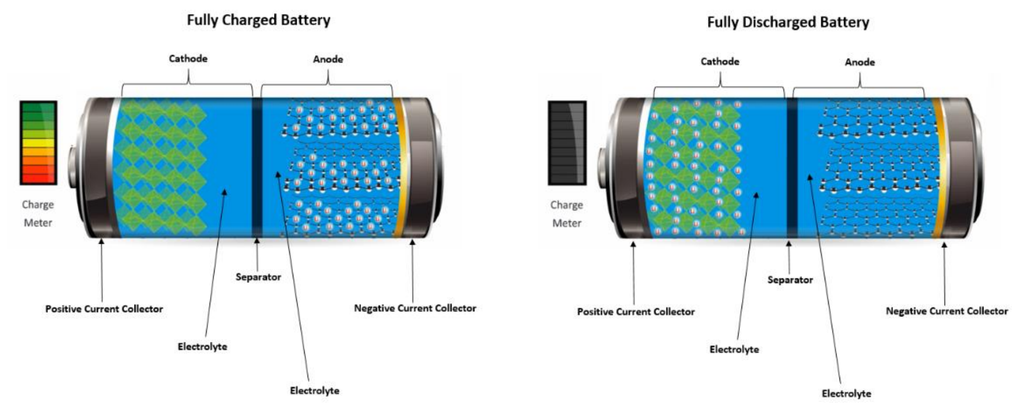
Anode (11% of cell material cost)

Negative electrode in the battery in which oxidation occurs. Lithium ions migrate away from the anode during discharge, thus helping to create electrical current. During the charging process, ions move toward the anode.

Current Collectors (14% of cell material cost)

Batteries have a positive current collector and a negative current collector. The movement of lithium ions from the anode to the cathode creates a charge at the positive current collector. The electrical current then flows to the vehicle. During the charging process, the electrical current flows to the negative current collector where the charge is stored.

Exhibit 37: Fully charged battery vs. fully discharged battery



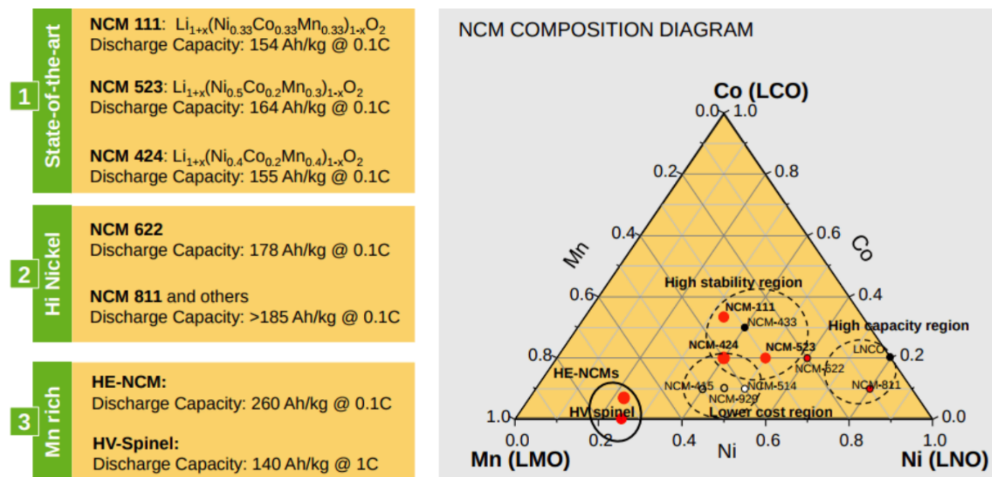
Source: US Office of Energy Efficiency & Renewable Energy, RBC Capital Markets

Current and future battery technology

Lithium Nickel Manganese Cobalt Oxide ($LiNiMnCoO_2$)

This chemistry is the most common form in electric vehicles, NMC or NCM, adds nickel to the LMO configuration (description below) to increase the energy generated and the life span of the battery (i.e. better acceleration and range). The reason this is the chemistry of choice is that these batteries use less cobalt than the other options while providing strong performance. The drawback of the NMC is that they produce a slightly lower voltage.

Exhibit 38: NCM battery chemistry profiles



Source: Argonne National Laboratory, BASF

We note that there are multiple cell chemistries, which in turn determine the characteristics of the battery. The chemistries determine stability, cost, and capacity of the battery.

- **NMC 111**: The initial chemistry used in NMC batteries, and it includes equal parts of Nickel, Manganese, and Cobalt. The 111 chemistry has higher stability characteristics than other make ups, making it a "safer" battery for commercial uses. However, its capacity limitations and cost weigh on its ability to be a long-term solution. Chemistry used in the Chevy Bolt and BMW i3.

- **NMC 622:** NMC 622 uses six parts Nickel, two parts Cobalt, and two parts Manganese. Higher Nickel concentration creates higher density, but the 622 chemistry can still handle the same amount of voltage as NMC 111. The cost also goes down given the lower Cobalt content. BMW aims to use NMC 622 batteries in its vehicles in 2021.
- **NMC 811:** The highest Nickel-concentrated chemistry, NMC 811 uses eight parts Nickel, one part Manganese, one part Cobalt. The higher concentration of Nickel increases energy density, and therefore capacity, which also increases range. The lower concentration of Cobalt lowers the general cost requirement. The risk in the 811 chemistry is the relative instability of the compound, causing safety concerns. Many mainstream battery makers have announced plans to make 811 batteries, including Samsung SDI (2019), LG Chem (late 2018), and CATL (2020). SK Innovation has already started producing 811 batteries. BMW is also looking to use NMC 811 in its BEVs by 2025.

Lithium Nickel Cobalt Aluminum Oxide ($LiNiCoAlO_2$)

This battery chemistry, also known as NCA, is similar to NMC in that it generates high energy and a long life span, but is less safe and more costly. This is the battery chemistry found in Tesla's vehicles (though Tesla Storage products and the future Tesla Semi product use NMC).

Lithium Cobalt Oxide ($LiCoO_2$)

These batteries are comprised of a graphite anode and a cobalt oxide cathode, and are generally found in cell phones, laptops, and other handheld electronics. This chemistry provides a high amount of energy per unit of mass, but provides low power and short lifespan making these batteries less attractive for electric vehicles. Additionally, cobalt is increasingly expensive, so alternative chemistries that mix cobalt with other, less expensive metals, is favorable.

Lithium Manganese Oxide ($LiMn_2O_4$)

These batteries, often referred to as LMO batteries, substitute lithium manganese oxide for cobalt oxide as the cathode. This provides the battery with further stability in a range of high or low temperatures and safety at the expense of shorter life and cycle. LMO batteries allow for fast charging and high-current discharging. They are often found in power tools, hybrids, and electric vehicles.

Lithium Iron Phosphate ($LiFePO_4$)

The cobalt is removed in this battery, and is replaced by iron phosphate, which is a cheaper option. Additionally, iron phosphate is much more stable than cobalt oxide, making it safer, and the calendar life of the battery longer. However, the downside is that the energy capacity is low and has high levels of self-discharge (which reduces the life of the battery).

Lithium Titanate ($Li_4Ti_5O_{12}$)

Lithium Titanate serves as the anode in this chemistry (as opposed to graphite in a typical lithium ion battery), while NMW can serve as the cathode. The advantages of this battery are a long life span, ability to be fast charged, and great low temperature performance. However, the energy delivered from the battery is low and it is more expensive than other battery chemistries.

Solid-State Batteries

Solid-state batteries replace the liquid electrolyte used in today's lithium ion batteries with a solid, non-flammable electrolyte. This reduces the safety risks associated with current technology, mainly the potential for vehicles to blow up due to short-circuiting. In terms of performance, solid-state batteries could have double the energy density as current technology. This allows for increased energy generation, faster recharging, longer useful life, and lower commodity requirements (translating into lower prices). However, none are automotive production ready.

Lithium-Air Batteries

Lithium-air batteries rely on oxygen from the air to interact with lithium ions to power and recharge the vehicle. When a vehicle is driving, oxygen from the air reacts with lithium ions to form lithium peroxide. During the charging process, oxygen is released back to the atmosphere and the lithium ions move back to the anode. Lithium-air batteries have the potential to achieve 10x the energy density as current day batteries, but life cycle is poor. While research for the technology is still nascent, finding a way to extend lifecycle would meaningfully accelerate adoption of the technology.

Battery capacity being added which should drive cost lower

We estimate that there was ~143 GWh of EV battery production capacity at the end of 2017, with most of that concentrated in Asia. By 2025, we see current announcements that suggest ~346 GWh of capacity. Note, that this may not be comprehensive and further announcements are likely to occur.

Asia (63% of 2017E Capacity; 51% of 2025E Capacity)

Asia has dominant share of global EV battery production, with close to 63% of all capacity, or ~90 GWh of production. This is not a surprise to us. 1) Asian countries have historically dominated battery production since the 1980s electronics boom, giving producers there better economies of scale. 2) China's aggressive NEV policies have spurred far greater BEV demand than in other regions. The largest players in the region include NEV manufacturer BYD (20 GWh capacity), LG Chemical (17 GWh capacity), Panasonic (8.5 GWh capacity), and CATL (7.5 GWh capacity).

In the region, we forecast production capacity growing ~+96% from ~90 GWh in 2017 to ~176 GWh in 2025. Chinese battery manufacturer CATL announced that it plans to grow its capacity by almost 7x to 50 GWh in 2020 from 7.5 GWh in 2017. Tianjin Lishen plans to grow its production capacity from 3 GWh in 2017 to 20 GWh in 2020. The largest remaining single capacity addition comes from Chinese OEM BYD. BYD is planning to grow its battery production capacity from 20 GWh in 2017 to 34 GWh in 2020. LG Chem plans to add 8 GWh in China by 2020, while Samsung SDI and Panasonic plan to add 2 and 3 GWh respectively in China. Note, the reduction in Asian share is largely a function of us taking Tesla's claim of 105 GWh capacity at Gigafactory 1 at face value. Initial Gigafactory capacity was 35 GWh.

North America (33% of 2017E Capacity; 34% of 2025E Capacity)

North American battery production capacity in 2017 stood at ~47 GWh (33% of global capacity), concentrated between three main players. The majority of the capacity comes from Tesla's Gigafactory with 35 GWh of capacity. However, we note that "functional" capacity is likely less than the headline 35 GWh. After Tesla, Automotive Energy Supply Corp (AESC) supplies the most battery production capacity with ~8 GWh. AESC is the former Nissan/NEC battery JV that supplies the current Nissan Leaf with its batteries. Nissan recently sold it to Chinese PE firm GSR Capital as it looks for new battery partners. The remaining capacity comes from LG Chemical's production facility in Holland, Michigan (3 GWh).

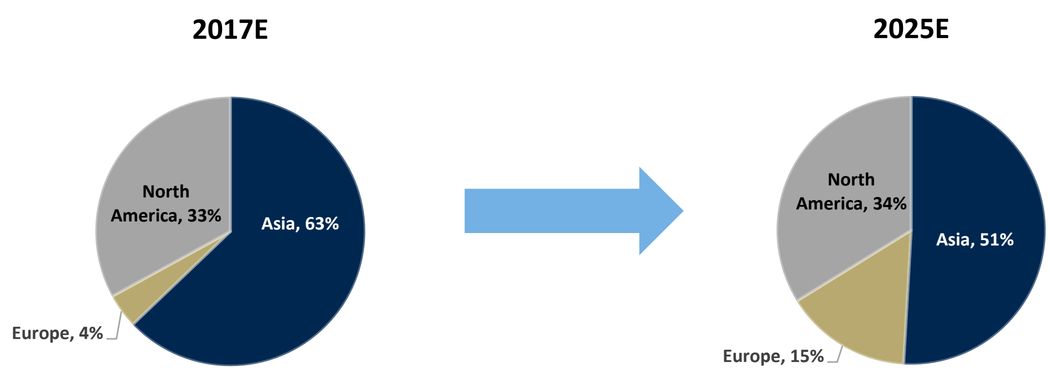
We expect NA capacity to grow from ~47 GWh in 2017 to ~117 GWh (34% of global capacity) by 2025. Tesla is the main driver. Initial Gigafactory expectations were for 35 GWh, with car cell capacity initially earmarked at 2/3, and power/storage taking up the remaining 1/3 (though we believe production allocations are flexible). At the 2016 shareholder meeting, CEO Elon Musk mentioned that this capacity could be triple initial expectations to 105 GWh. While functional capacity to date is likely below the 35 GWh, we do assume it grows over time to 105 GWh.

Europe (4% of 2017E Capacity; 15% of 2025E Capacity)

Europe has relatively small battery capacity, with only ~6 GWh of capacity. AESC offers the highest capacity with ~0.4 GWh in the UK, mainly focused on Nissan production. Even though the EU's push for green vehicles is further along than most areas (ex-China), it does not require extensive battery production given proximity to Asia.

We expect Europe capacity to grow from ~6 GWh of capacity in 2017 to ~53 GWh (15% of global capacity) in 2025. Swedish start up North Volt (run by ex-Tesla supply chain execs) is aiming to add 8 GWh of capacity by 2020, and an additional 24 GWh to reach 32 GWh of total capacity by 2023. The remaining ~15 GWh of capacity additions stem from traditional Asian battery manufacturers expanding production footprint into Europe. SK Innovation announced plans to build a 7.5 GWh capacity production facility in Hungary, which is expected to begin production in early 2020. Samsung SDI also announced a 2.5 GWh capacity facility in Hungary, with production starting in 2H18 and ramping to full capacity in 2019. LG Chem plans to add 5 GWh of capacity to its Wroclaw, Poland facility.

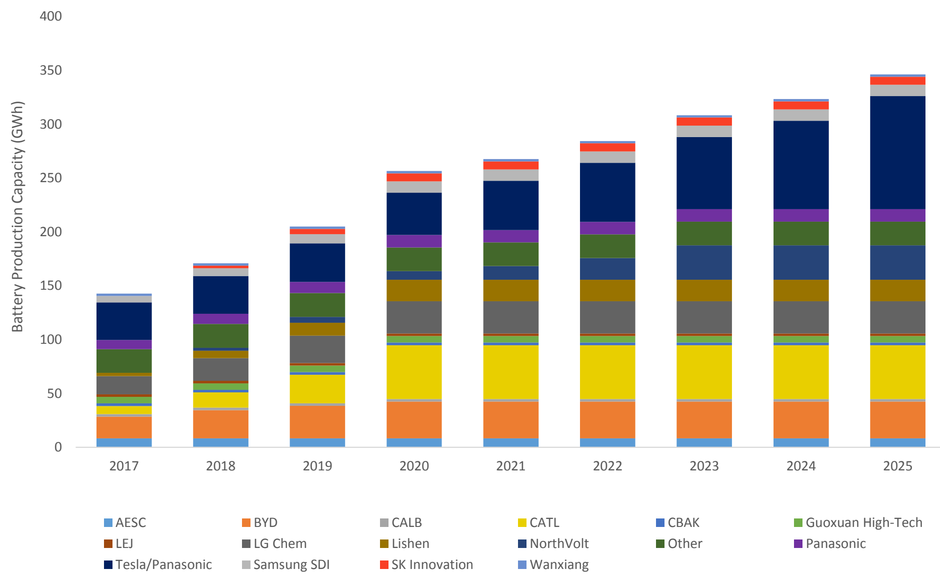
Exhibit 39: Estimated global capacity mix shift 2017 to 2025



Note this assumes (by 2025) Tesla can increase Gigafactory 1 capacity to 105Gw as they have indicated.
Source: RBC Capital Markets estimates

Note, our analysis beyond 2017 is based solely on announced battery capacity expansion plans. It's more than likely capacity can exceed the levels we propose here, but quantification is tricky without company announcements.

Exhibit 40: Estimated battery production capacity by manufacturer

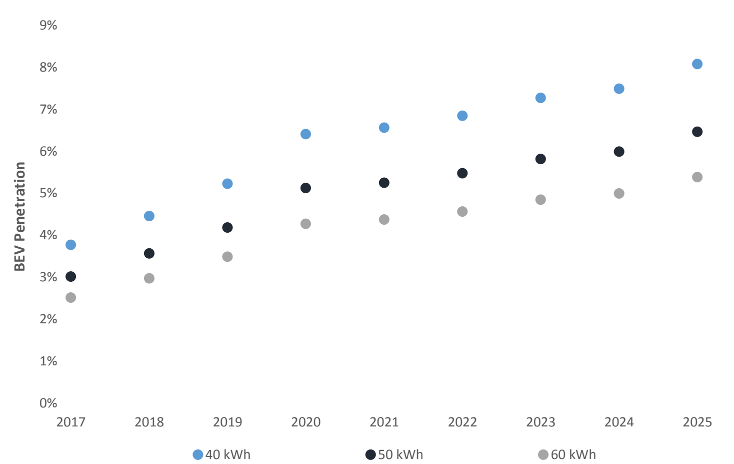


Note this assumes (by 2025) Tesla can increase Gigafactory 1 capacity to 105Gw as they have indicated.
Source: Company reports, RBC Capital Markets estimates

Announced battery capacity expansion plans support ~7% BEV sales mix by 2025

We estimate that based on announced battery production expansion plans, BEV units can reach 6.5% of global units, or ~6.9mm units, by 2025 assuming a 50 kWh battery and solely BEV production. For reference, 2017 capacity implied ~2.9mm potential BEV units or ~3.0% of total global sales. However, capacity was not fully utilized in 2017, as BEV units were only ~750k.

Exhibit 41: BEV units based on announced battery production capacity

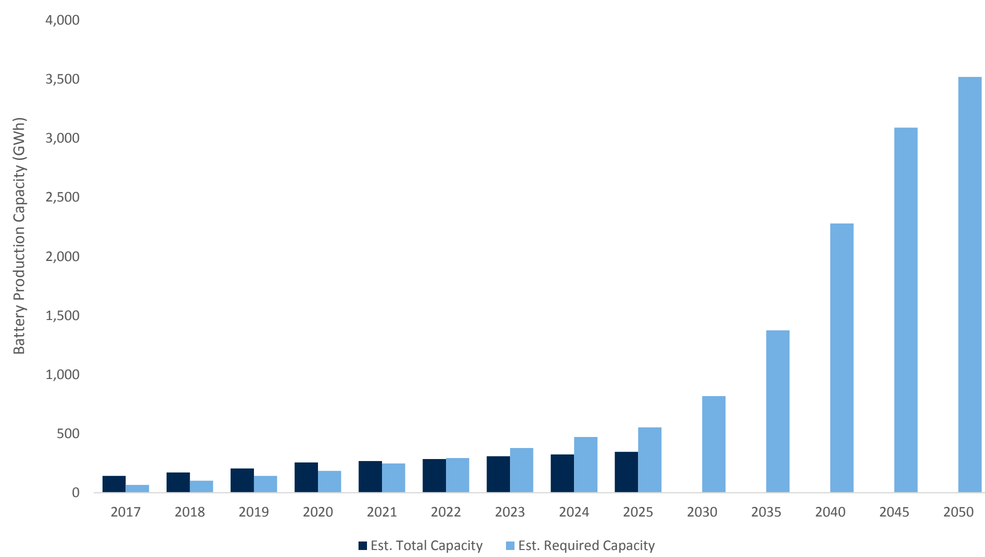


Source: Company reports, RBC Capital Markets estimates

It's important to note that this analysis is only based on *announced* capacity expansion plans. We think it is likely that more announcements that are meaningful come out in 2019+ focused on capacity expansion for the early-mid 2020's. Our battery capacity figures are likely lower than actual future capacity given we aren't making assumptions outside of what is already known. We considered this when creating our forecast.

We also note that the 6.5% number is looking at the world as if only BEVs were produced using announced capacity. In reality, a mix of 48V, HEV, PHEV, and BEV vehicles will be built. We estimate that a 48V battery requires ~2kWh and HEV/PHEV at 10kWh. In 2025, we estimate xEV penetration of 32%. This would require ~550 GWh of battery capacity, above announced capacity of ~346 GWh by 2025.

Exhibit 42: Required battery capacity implied by RBC xEV forecast



Source: Company reports, RBC Capital Markets estimates

Mainstream xEV adoption over the long term requires increased battery capacity. Based on our xEV forecast, announced capacity additions will only be sufficient to supply xEVs through 2021. In 2022 and beyond, battery production needs to ramp meaningfully higher. By 2050, our estimates imply ~3,500 GWh of required battery capacity – that's equivalent to ~34 of Tesla's Gigafactory 1, assuming 105 GWh/Gigafactory of capacity is reached. Without significant investment in battery factory expansion, xEV adoption will be hindered.

Automaker strategies shifting toward electrification

How are automakers impacted by electrification?

Traditional (incumbent) automakers are clearly impacted by the shift to electrification. Historically, they faced a bit of an innovator's dilemma situation with EVs as it puts their legacy infrastructure, which generates profits today, at risk.

But OEMs seem to have finally embraced their electric future. Generally, OEMs are accelerating their electrification efforts in the hopes of delivering a profitable and desirable electric vehicle. However, where they differ is the scope and breadth of their targets. Many OEMs have set targets on the amount of sales, number of models, and amount of investment by a specific target date.

We think about the impact of electrification to traditional automakers in three broad strokes: R&D, production and supply chain.

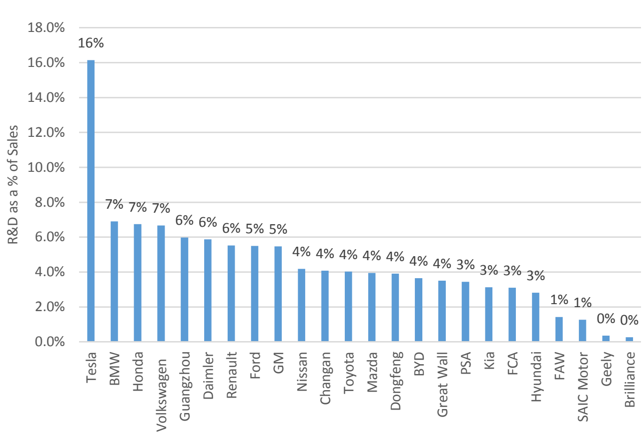
Research & Development

We believe traditional automakers are quickly ramping up R&D efforts to be able to participate in the electrification of the powertrain. For instance:

- Volkswagen has set a target of spending $84bn to bring 300 electric vehicle models to market by 2030.
- Ford will spend $11bn to bring 40 hybrid and fully electric vehicles in its model line-up by 2022.
- Daimler indicated it will spend €10bn for electrification.

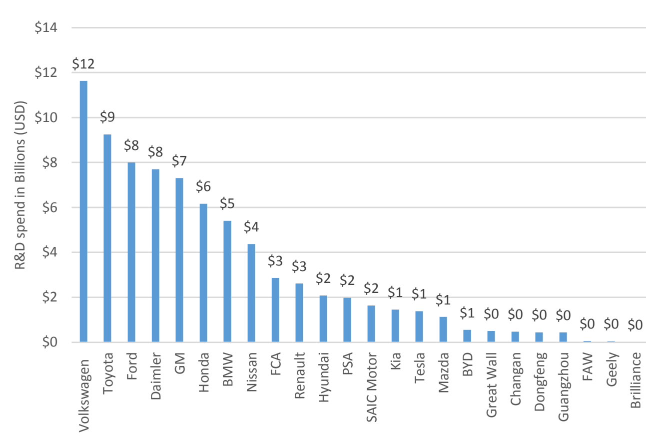
Total R&D investment may not be the perfect measure to understand what automakers are spending on electrification considering there are other factors at play (including large investment in autonomous). However, we believe it is instructive to look at the sheer dollar spend on R&D because a significant portion of this is going to electrification. Effectively, the OEM game now is to leverage the traditional ICE products to fund this transition.

Exhibit 43: R&D Expense as a Percent of Sales



Note: As of FY17 for all except Nissan, Changan, Kia, FAW which are as of FY16; accounting treatment of R&D may differ between companies
Source: Company reports, FactSet, and RBC Capital Markets

Exhibit 44: Absolute R&D spend in USD

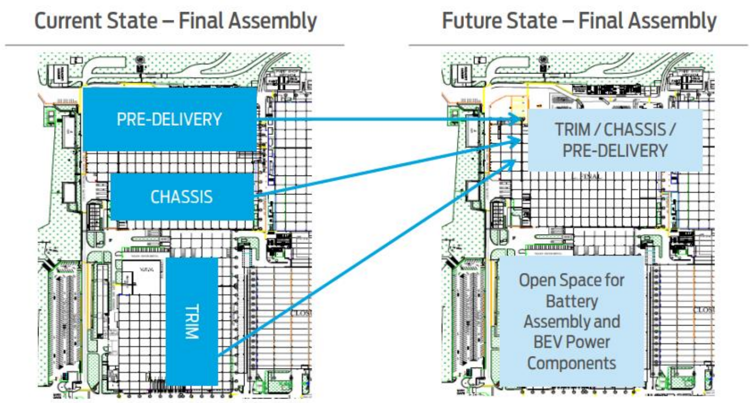


Note: As of FY17 for all except Nissan, Changan, Kia, FAW which are as of FY16; accounting treatment of R&D may differ between companies; spend translated to USD at 2017 average
Source: Company reports, FactSet, and RBC Capital Markets

Production

Redesigning a vehicle architecture for BEVs means a company can re-imagine their manufacturing footprint. The product simplification that comes with BEVs could lead to capital efficiencies. For instance, Ford has indicated that their next system of battery electric vehicles in the final assembly area will have a 50% reduction in footprint, a 50% reduction in capital investment, and a 30% improvement in hours per unit or labor savings.

Exhibit 45: Ford BEV plans call for improved floor space and capital efficiency



Source: Ford

Some investors are concerned about the impact to profits given lower operating leverage on traditional ICE products. Further, they fear write-downs of legacy assets. We are less certain as it appears that at least part of OEMs' recent capex is flexible to be re-used for EV assembly. Further, while we are forecasting a steep inflection in BEV demand, this isn't for 15-20 years and we believe average life of equipment is under 10 years. Thus, as long as OEMs invest and buy smart from here, they may have a path to manage the transition.

Supply Chain

In the current ICE world, much of the know-how, and hence value-add has been outsourced to the supply base. This is a reason why supplier margins and ROIC are greater than automakers'. However, EVs offer an opportunity for automakers to re-insource and capture value.

Perhaps the most critical decision the OEMs have to make is deciding **who ends up doing what on an EV?** Today's supply and value chains are fairly well established. But these are upended with EVs. New suppliers (such as battery and electric motor companies) may enter the fray while others (fuel systems, transmissions, exhaust) leave. OEMs need to decide how they will design EVs but also how much they do internally versus leveraging a supply base. In the current ICE world, much of the know-how, and hence value-add has been outsourced to the supply base. This is a reason why supplier margins and ROIC are greater than automakers'. However, EVs offer an opportunity for automakers to re-insource and capture value. Further, BEVs are "simpler" than ICE. So what is outsourced may be more standardized/commoditized. This could upend how investors think about OEMs vs. suppliers. This (along with pricing) may ultimately decide what margins on future electric vehicles look like.

Current automaker targets

The final factor we looked at is what have different automakers set as targets. We did take a caveat emptor approach to this since automakers are notoriously optimistic. Further, sometimes the term electrification gets thrown around loosely to include 48-volt technology, hybrids, plug-in hybrids and full battery electric vehicles. We tried to delineate when possible. Nevertheless, we did find the exercise useful to show the direction of adoption. The majority of the world's largest automakers have outlined a strategy as it pertains to EVs, which gives us further insight into how quickly the world will adopt EVs. Below, we highlight the most significant sales, new vehicle models, and EV investment targets by OEM.

Exhibit 46: OEM xEV targets and timeline

	Vehicles		Electrified Models			Investment	
	Number	Time Frame	xEVs	BEVs	Time Frame	Amount	Time Frame
BAIC	All sales	2025	Total Fleet	-	2025	$15bn	-
BMW	15-20% of sales	2025	13	12	2025	-	-
Changan	All sales	2025	Total Fleet	-	2025	-	-
Daimler	100,000	2020	40	>10	2022	€10bn	2022
Dongfeng Motor	30% of sales	2022	20	-	2022	60bn RMB	2023
Ford	-	-	40	16	2022	$11bn	2022
GM	1,000,000	2026	-	20	2023	-	-
Honda	2/3 of sales	2030	-	-	-	-	-
Hyundai/Kia	-	-	31	-	2020	-	-
Jaguar Land Rover	-	-	Total Fleet	-	2020	-	-
Nissan	30% of sales	2022	20	-	2022	$9bn	2022
PSA	-	-	Total Fleet	4	2025	-	-
Toyota	~50% of sales	2030	Total Fleet	10	Early 2020s	-	-
Volvo	50% of sales	2025	All New Models	-	2019	-	-
VW	3,000,000	2025	Total Fleet	-	2030	$84bn	2030

Source: Company reports, RBC Capital Markets

If we take company goals at face value (and there are no market share shifts), then we estimate that would mean xEV penetration would be ~16% by 2025. Further, OEM targets would imply that xEV penetration would reach ~25% by 2040.

OEM strategies: the here, the plan, the future

Below we outline each of the largest global OEM's electrification strategies and stated targets, as well as where they currently stand in the EV competition.

BMW

Today: BMW has established the BMW i sub-brand to develop and manufacture electric vehicles. The brand launched two vehicles in 2013-14: the i3, with a PHEV and BEV model designed for urban driving, and the i8, a PHEV luxury sports car priced well over $100,000. BMW has begun to transfer what it has learned from BMW i to its core portfolio of vehicles through the iPerformance model designation, which is applied to its plug-in hybrid models. BMW now offers PHEV options of its popular 3, 5, and 7 Series as well as its X5 model. We estimate BMWi PHEV/BEV share at 11% in the US in 2017. This compares to ~18% BEV/PHEV market share in Europe in 2017.

Exhibit 47: Details of BMW's BEVs and PHEVs

BMW BEVs		% of 2017 US BEV/PHEV Sales	Battery Pack Size (kWh)	Battery Type	Range	Base Price	Top Speed	Horse Power	Charging Time (hours)
i3*		3.2%	33	NMC-LMO	114	$44,450	91	170	5

BMW PHEVs		% of 2017 US PHEV Sales	Battery Pack Size (kWh)	Battery Type	Range	Base Price	Top Speed	Horse Power	Charging Time (hours)
X5 xDrive40e iPerformance		5.9%	9.2	NMC-LMO	14	$63,750	75	111	3
330e iPerformance		4.6%	7.6	NMC-LMO	14	$45,600	75	87	2.2
530e iPerformance		4.1%	9.2	NMC-LMO	16	$52,650	87	111	3
740e xDrive iPerformance		0.8%	9.2	NMC-LMO	14	$90,700	87	111	2.7
i8		0.5%	11.6	NMC-LMO	18	$147,500	75	189	2

*The i3 comes in a BEV and PHEV model, the presented information is related to the BEV
Source: Company data and RBC Capital Markets

Strategy: BMW's electrification strategy is broken up into three phases: (1) pioneering, (2) electrification of the core portfolio, and (3) scalability and flexibility. BMW appears focused on transitioning the portfolio to PHEVs through its iPerformance badge, before rolling out full BEV models. By 2021, BMW will offer an ICE, PHEV, and full BEV version of each of its existing models. Looking even further ahead, the OEM expects to generate 15-20% of total sales from electric vehicles by 2025, and introduce 25 new electric models (12 of which being BEVs).

Going Forward: As BMW electrifies its core portfolio, we expect to see further PHEV versions of its existing models be introduced under the "i" badge. This process has already started as BMW recently introduced the BMW iX3 concept, a BEV crossover, which will have a 70kWh battery (~249 miles of range). BMW is also planning a meaningful upgrade to the BMW i3's range (possibly as much as 25%) so as to better compete with its longer-range competition. Additionally, BMW will offer an electric MINI in 2019, the iX3 in 2020, and the iNEXT in 2021 (BMW's autonomous electric car concept).

Daimler

Today: Daimler currently offers two BEVs, the Mercedes B-Class and the Smart forTwo EV, and three PHEVs: the S550, GLE 550e, and the C350e. These vehicles generate minimal sales, for Mercedes and relative to the BEV and PHEV market, likely due to their high price range even for the luxury segment (outside of the smart car).

Exhibit 48: Details of Daimler's BEVs and PHEVs

Daimler BEVs		% of 2017 US BEV Sales	Battery Pack Size (kWh)	Battery Type	Range	Base Price	Top Speed	Horse Power	Charging Time (hours)
B Class		0.7%	28	NCA	87	$39,900	101	177	3.5
Smart forTwo EV		0.5%	17.6	NMC	58	$23,900	81	80	3

Daimler PHEVs		% of 2017 US PHEV Sales	Battery Pack Size (kWh)	Battery Type	Range	Base Price	Top Speed	Horse Power	Charging Time (hours)
C350We		0.9%	6.2	NCA	8	$47,900	80	80	2
GLE 550e		0.5%	8.7	NCA	10	$66,700	80	116	2
GLC 350e		NA	8.7	NCA	21	$49,990	87	114	2.5

Source: Company data and RBC Capital Markets

Strategy: Daimler appears to be taking a balanced approach to electrification and the future of mobility as they are investing in more efficient ICEs, PHEVs, BEVs, and fuel cell vehicles. The company has set a target to invest €10bn to electrify its fleet and an additional €1bn in a global battery production network. This broad strategy to address all propulsion methods is intended to cover all mobility needs for the customer base, and highlights Daimler's belief that ICE and EV powertrains will coexist in the future.

Going Forward: The next BEV from Daimler is expected to begin production in 2019 with the EQC, an all-electric SUV. The new EQC is expected to have a 70 kWh battery (~250 miles of range) and should compete directly with Tesla's Model X. Ultimately, by 2022, Daimler is targeting to release 10 all new electric vehicle models, along with an electrified option on all of their current models, bringing the total to 50 EV models.

FCA

Today: FCA does not have a significant electric vehicle presence in the market today. The company currently offers just one BEV and PHEV model in the US, the Fiat 500e and the Chrysler Pacifica, respectively. Both of these vehicles represent a small portion of BEV/PHEV sales in the US today, though we note the Pacifica has only been available since May 2017.

Exhibit 49: Details of FCA's BEVs and PHEVs

FCA BEVs		% of 2017 US BEV Sales	Battery Pack Size (kWh)	Battery Type	Range	Base Price	Top Speed	Horse Power	Charging Time (hours)
Fiat 500e		3.2%	24	NMC	84	$32,995	88	111	4

FCA PHEVs		% of 2017 US PHEV Sales	Battery Pack Size (kWh)	Battery Type	Range	Base Price	Top Speed	Horse Power	Charging Time (hours)
Chrysler Pacifica		3.0%	16	NMC	33	$39,995	110	114	2

Source: Company data and RBC Capital Markets

Strategy: FCA has been tight-lipped about what their strategy is going forward, but management has indicated that they will be releasing a 2022 plan that will include more in-depth electrification plans. But from a high level, it appears that the company will focus on hybrids and PHEVs to meet European regulations as diesel vehicles continue to lose favor. With regard to full electric options, FCA appears to be focused on the luxury segment with its Maserati brand. Ultimately, FCA intends to electrify half of its portfolio by 2022.

Going Forward: Again, there is limited news on upcoming electric vehicle releases, but CEO Sergio Marchionne has stated that he will switch the entire Maserati portfolio to all electric over the next two models.

Ford

Today: Ford's EV platform appears to be still in its early stages. Ford has a strong hybrid portfolio, offering hybrid versions on some of their popular nameplates. However, they have more limited PHEV and BEV options. The Focus Electric is a pure BEV that has a relatively low base MSRP when compared to its peers, but also comes with a standard range of just 115 miles. The model has proven largely unpopular with the US consumer as the vehicle only accounted for ~1.7% of total US BEV sales in 2017. Ford has had more success in its hybrids and PHEVs. The Fusion and C-Max Energi PHEVs both have ~20 miles of all electric range and comprise ~20% of total US PHEV sales combined.

Exhibit 50: Details of Ford's BEVs and PHEVs

Ford BEVs		% of 2017 US BEV Sales	Battery Pack Size (kWh)	Battery Type	Range	Base Price	Top Speed	Horse Power	Charging Time to 80% (minutes)*
Focus Electric		1.7%	33.5	NMC-LMO	115	$29,120	84	143	33

Ford PHEVs		% of 2017 US PHEV Sales	Battery Pack Size (kWh)	Battery Type	Range	Base Price	Top Speed	Horse Power	Charging Time (hours)
Ford Fusion Energi		10.6%	7.6	NMC-LMO	21	$31,305	85	188	7
Ford C-Max Energi		9.0%	7.6	NMC-LMO	20	$27,120	85	141	7

*Ford estimated time to reach 80% battery capacity at a DC fast charger
Source: Company data and RBC Capital Markets

Strategy: When CEO Jim Hackett took over the reins at Ford, he began shifting the focus toward the future of mobility, and stated that he plans to shift more resources toward the development of EVs, shifting spending (~$500mm) from ICE investments to electrification efforts. Hackett has noted that they are shifting the way they think about EVs, from a compliance standpoint to a more performance centric mindset. Ford's mid-term electrification strategy seems more dependent on hybrid technology, as the company plans to offer hybrid versions of their largest nameplates (F-150, Mustang, etc.). Ford intends to invest $11bn in electrification and introduce 40 electrified vehicles, of which 16 will be BEVs, through 2022. In China, Ford offers the Mondeo Energi PHEV (essentially the Fusion Energi), and will be capitalizing on its JVs with Zotye and CAF to deliver hybrid and BEVs to China. Ultimately, Ford intends to have two unique BEV platforms, one for Zotye and one for Ford.

Going Forward: Ford is utilizing the brand name of its existing top selling nameplates (i.e. F-150, Mustang, Explorer, Escape, and Bronco) to drive interest in its hybrid technology. Ford is hoping to deliver an optimal experience in these hybrids that replicate the experience that consumers have grown accustomed to in their current ICE iterations. Ford's first EV will be introduced in 2020, starting with a performance utility vehicle (potentially named the Mach 1), and will introduce six more fully electric vehicles by 2022.

GM

Today: GM invested in creating standalone xEV vehicles in the Chevy Bolt BEV and the Volt PHEV. These two vehicles are top BEV and PHEV sellers in the US (the Bolt and Volt represented ~22% of 2017 BEV and PHEV sales in the US, respectively). The Bolt is a small and reasonably affordable EV and beat Tesla's Model 3 to market for a reasonably priced mass offering.

Exhibit 51: Details of GM's BEVs and PHEVs

GM BEVs		% of 2017 US BEV Sales	Battery Pack Size (kWh)	Battery Type	Range	Base Price	Top Speed	Horse Power	Charging Time to 80% (minutes)*
Chevy Bolt		22.3%	60	NMC	238	$37,495	93	200	30

GM PHEVs		% of 2017 US PHEV Sales	Battery Pack Size (kWh)	Battery Type	Range	Base Price	Top Speed	Horse Power	Charging Time (hours)
Chevy Volt		22.4%	18.4	NMC-LMO	53	$34,095	102	149	13
Cadillac CT6		0.2%	18.4	NMC-LMO	31	$75,095	150	265	9

*GM estimated time to reach 80% battery capacity at a DC fast charger
Source: Company data and RBC Capital Markets

Strategy: CEO Mary Barra has stated that GM will produce profitable electric cars by 2021 through its low cost and flexible EV architecture and its battery technology. GM has developed its own battery chemistry and is targeting cell cost of <$100/kWh vs. today's cost of $145/kWh. Additionally, the company has set its sights on achieving 300 miles of range, a point at which they believe range anxiety is eliminated. Additionally, in order to accelerate acceptance of electric vehicles, GM will incentivize and invest in order to create the necessary infrastructure to support EVs. Ultimately, the company expects to sell 1mm EVs globally by 2026, and management consistently states that GM is committed to an all-electric future.

Going Forward: GM set a goal to offer a total of 20 all electric (BEV and fuel cell) models by 2023. The first two new vehicles will hit the market by May 2019, and will be hatchbacks based on the Bolt's platform, with one sold under the Buick brand. The remaining 18 vehicles will be based on new platforms and will span several segments, including minivans, sports cars, SUVs, etc. GM recently introduced a BEV concept at the Beijing Auto Show, the Buick Enspire, which GM stated will get up to 370 miles on a single charge and will be fast and wireless charging enabled. GM did not state when they expect to bring the car to market.

Honda

Today: We believe that Honda is playing catch up on the electrification front, as the company previously focused its efforts on hydrogen fuel cell vehicles. The company now offers BEV, PHEV, and fuel cell options on its Clarity model, which launched in 2017. The Clarity was originally designed as the OEM's fuel cell vehicle.

Strategy: In order to expedite its electrification efforts, Honda has established an EV division within its R&D department to develop new electric vehicles. Honda is targeting to generate two-thirds of their sales from electric vehicles by 2030, focusing on hybrids and PHEVs. Additionally, Honda expedited these targets for its European operations, stating that alternative energy vehicles should account for two-thirds of Honda European sales by 2025. Again, Honda stated that the focus here will be on hybrid systems. In China, Honda expects to launch more than 20 EVs by 2025

Going Forward: Honda released its new Urban EV concept at the 2017 Frankfurt Auto Show, which gained positive reviews for the unique design. The compact, super-mini BEV will begin taking orders in Europe soon, though limited details on the car have been released, including price and range, which could be meaningful as Honda indicated the price of the car would likely put it in the premium category. There has also been no indication of whether this model will be available outside Europe. Honda will release a new hybrid model for Europe in 2018. Additionally, Honda showed off its China only BEV concept, the Everus, at the Beijing Auto show and it should be available for sale by the end of 2018.

Hyundai Motor Group (Hyundai Motor and Kia Motors)

Today: Hyundai Motor Group has historically focused its efforts on fuel cell technology, but as electrification has gained public and regulatory favor, the OEM has quickly altered its strategy. In 2016, Hyundai Motor Group announced that they will be launching 26 electric vehicles by 2020 (which has since been increased). The results from this electrification have been encouraging. The company now has two BEVs (the Kia Soul EV and Hyundai Ioniq) and four PHEVs (Hyundai Ioniq and Sonata and the Kia Nitro and Optima). Additionally, in 2017, Hyundai Motor Group had the third highest market share in hybrid vehicles in the US, behind Toyota and GM.

Exhibit 52: Details of Hyundai/Kia's BEVs and PHEVs

Hyundai/Kia BEVs		% of 2017 US BEV Sales	Battery Pack Size (kWh)	Battery Type	Range	Base Price	Top Speed	Horse Power	Charging Time (hours)
Kia Soul EV		2.1%	30	NMC	111	$33,950	145	109	4.5
Hyundai Ioniq Electric		0.4%	28	NMC	124	$29,500	104	118	4.25

Hyundai/Kia PHEVs		% of 2017 US PHEV Sales	Battery Pack Size (kWh)	Battery Type	Range	Base Price	Top Speed	Horse Power	Charging Time (hours)
Hyundai Sonata		2.5%	9.8	NMC	27	$34,600	75	67	2.7
Kia Optima		1.7%	9.8	NMC	29	$35,210	75	66	3

Source: Company data and RBC Capital Markets

Strategy: The OEM has increased its target to 31 new eco-friendly models by 2020 from just 26 previously. The motor group believes that ICE vehicles will continue to be a "strong presence" in the market until 2025, at which point hybrids will begin to take meaningful share. Therefore, Hyundai Motor Group has invested in developing more fuel-efficient engines, while focusing its efforts on hybrids and PHEVs. At Hyundai Motor, they have stated they will develop a full range of small to large, premium EVs (CUVs and SUVs with 4WD). Additionally, Hyundai will develop its first dedicated architecture for BEVs, which will allow them to create multiple models. Turning to Kia Motors, they will deliver 16 EVs by 2025 (five new hybrids, five PHEVs, five BEVs, and one fuel cell).

Going Forward: Hyundai Motor Group has a number of EVs and PHEVs that are expected to hit the market in the near term. Starting with Hyundai, the Kona EV has a short and long-range option that is expected to hit the market in Korea and Europe late in 2018 before coming to the US. In 2021, Hyundai expects to release its premium Genesis EV and then a long-range EV (>300 miles of range) after 2021. At Kia, the Niro EV will be launched within the next year or so. Pricing has not been stated yet, but the vehicle will have 238 miles of range so will likely compete with the Chevy Bolt.

Jaguar Land Rover

Today: JLR has begun to offer electrified vehicles with one PHEV model in their current lineup, though there are several new models that the company will introduce over the next 12 months (more on this below). Jaguar currently offers the F-Pace, a luxury SUV PHEV.

Strategy: JLR has established the target of offering an electrified option (so ranging from mild-hybrid to full BEV) on each vehicle offered by the company by 2020. The company intends to offer a completely new electric lineup that will be headlined by the Jaguar i-Pace and E-Type Zero, launching in 2019.

Going Forward: In 2019, Land Rover will offer the Range Rover PHEV (with a Sport option) and a Land Rover PHEV competing in the Luxury SUV segment, at a price point higher than the current Jaguar F-Pace at >$78,000. Turning to the BEV option, Jaguar will introduce the i-Pace in July in Europe and will be available in the US in 2H18. The i-Pace is a highly anticipated SUV that will likely compete directly with TSLA's Model X and potentially the Model 3, though the price is slightly higher at $69,500. Finally, Jaguar has shown an E-Type Zero concept that borrows many of Jaguar's classic finishes but upgraded with a battery electric powertrain and modern finishes.

PSA

Today: PSA has a fairly limited selection of EVs with Peugeot offering the iOn (super-mini BEV) and the Partner Tepee Electric (minivan BEV) and Citroen offering the C-Zero (another super-mini BEV), and the newly acquired Opel offering the Ampera-e (otherwise known as the Chevy Bolt) though PSA licenses this technology from GM. These vehicles have proven to be largely unpopular, as none cracked the top 20 in sales in 2017 in Europe.

Strategy: CEO Carlos Tavares announced that PSA would offer electric options on each of their models by 2025. PSA and Dongfeng have established a JV to create a common EV platform, which should help PSA achieve its targets. The Common Modular Platform (e-CMP) will allow the two to design more spacious, multi-purpose EVs with fast charging solutions and ~270 miles of range (though this is by European standards so likely lower by EPA standards). Additionally, PSA established the Efficient Modular Platform (EMP2) dedicated to compact and premium PHEV models that will have ~37 miles of range in all electric mode. Overall, it appears that PSA is focused on the development of PHEV models.

Going Forward: PSA will develop four BEVs by 2021, with the first coming to market in 2019 from the e-CMP platform with Dongfeng. Additionally, the EMP2 will produce seven new PHEV models that will be gradually introduced to the market from 2019 to 2021.

Renault/Nissan

Today: Nissan's current strategy centers on the Nissan Leaf, which has emerged as a strong competitor in the BEV market, though we note its US market share is significantly lower than Tesla and GM. The Leaf competes as a low cost EV option with a competitive range (151 miles). In Europe, the Renault ZOE is the top selling BEV, with ~21% market share in 2017. The vehicle is significantly more affordable than its competitors (£14,245 vs. average of next five competitors of ~£46,000), while offering 149 miles of range.

Strategy: Renault/Nissan have set aggressive targets for the advancement of their electric vehicles, calling for EVs to comprise 30% of their sales by 2022. Unlike most other OEMs, Renault/Nissan set BEV targets, as opposed to EVs (which often includes hybrids, PHEVs, and hydrogen fuel cell). The company will offer 12 BEV models across their global markets. In China, Nissan and JV partner, Dongfeng, have announced that they will launch up to 20 EV models across their brands by 2022 and invest 1tn Yen to advance their technology in China.

Going Forward: Nissan announced that it will be offering a new BEV in China by the end of 2018, the Sylphy EV, Nissan's first mass production EV in China. The vehicle will likely have a range of ~210 miles per charge. However, looking ahead, Renault/Nissan does not have many EVs in the pipeline. Nissan has shown the IDS concept to the public, as a fully electric vehicle capable of Level 5 autonomous driving. But the car seems a long way from production; we wouldn't expect to see it on the roads until at least 2025.

Toyota

Today: Toyota has had great success with its Prius lineup, which offers hybrid and PHEV models. However, Toyota still does not offer an EV after it discontinued the RAV4 EV in 2014. So despite the strong results from the Prius lineup, Toyota is currently lagging behind its global competitors as the market trends towards electrification.

Strategy: Historically, Toyota has focused on developing hydrogen fuel cell vehicles, releasing the Mirai lineup. The Mirai has seen little demand likely due to the high price and the lack of required hydrogen fuel stations, even compared to EV charging stations (only 34 in the US). It appears that Toyota saw that the market was shifting toward EVs rather than hydrogen fuel cell, and switched their strategy at the end of 2017. The company now aims to sell more than 5.5mm electric vehicles (1mm EVs and fuel cell vehicles) by 2030. This is a significant transition in strategy for Toyota and will likely help to accelerate the adoption of EVs globally, given the OEM's meaningful market position.

Going Forward: Toyota will likely offer an EV at the full spectrum of segment and price ranges as all Toyota and Lexus models will offer an electric option by 2025. Further, Toyota plans to offer dedicated hybrid, PHEV, BEV, and fuel cell models along with electric options on its existing models. Geographically, Toyota will introduce 10 new BEV models in China in the early 2020s (including the Corolla and Levin PHEV models, and the IZONA SUV), seemingly to tap the fastest growing EV market in the world first. Toyota then plans to expand into Japan, India, the US, and Europe gradually thereafter.

Volkswagen

Today: Volkswagen's current electric offering is fairly limited with just one PHEV (Audi A3) and BEV (e-Golf) model for sale in the US. VW's e-Golf is a solid, affordable EV offering but its range comes in at just 125 miles, below its key competitors, the Bolt and Model 3.

Exhibit 53: Details of Volkswagen's BEVs and PHEVs

VW BEVs		% of 2017 US BEV Sales	Battery Pack Size (kWh)	Battery Type	Range	Base Price	Top Speed	Horse Power	Charging Time (hours)
VW e-Golf		3.4%	35.8	NMC	125	$30,495	85	134	1
VW PHEVs		**% of 2017 US PHEV Sales**	**Battery Pack Size (kWh)**	**Battery Type**	**Range**	**Base Price**	**Top Speed**	**Horse Power**	**Charging Time (hours)**
Audi A3		3.2%	8.8	NMC	16	$39,500	80	102	2.5

Source: Company data and RBC Capital Markets

Strategy: The key strategy shift in VW came after it admitted to outfitting 11mm of its diesel vehicles with defeat devices to cheat emissions tests. These diesel vehicles were key to VW meeting emissions regulation. The scandal forced VW to shift to another strategy, one centered on EVs. VW now plans to offer electrified versions of each of its 300 models across all of the company's brands. Former CEO Matthias Mueller went as far as to say that as much as a quarter of all VW sales (~3mm vehicles) could be battery powered by 2025. Additionally, VW will invest €20bn by 2030 in EV technology, and an additional €50bn in the required batteries for its EVs. Further, while Audi and Porsche are included in VW's corporate EV strategy, the brands have established their own internal targets. Audi is targeting to release 20 electrified vehicles by 2025, of which 12 will be BEVs, and targets selling 800,000 EVs in 2025. While at Porsche, the brand has set a target to spend €6bn on electrification efforts, including development of electrification and hybridization of its models, new technologies, facility expansions, and charging infrastructure. Porsche is focusing on bringing to market PHEVs and BEVs.

Going Forward: Volkswagen has been relatively open about its future EV models with an ID lineup of three future vehicles. The first two to reach production will likely be the Crozz (a crossover) and the I.D (a hatchback similar to the Golf). Both models will likely reach production by 2020. The US will get the Crozz before the I.D. due to the popularity of crossovers, while the rest of the world will get the I.D. first. No specifics are set in stone for these vehicles yet, but the Crozz is expected to get >300 miles of range and the I.D. >250 miles. A little further out, VW is expected to release the Buzz, an homage to the microbus of the 70s. At Audi, the e-tron Quattro BEV is expected to be released for the European market by the end of 2018 and will have ~250 miles of range (95kWh battery pack) at a price of €80,000. This vehicle will be joined by the e-tron Sportback in 2019, and the e-tron GT and a premium compact car in 2020.

Volvo

Today: Volvo currently offers a number of PHEV options: the S90 (sedan), XC60 (SUV), XC90 (SUV), and V90 (wagon). The company has had success with the XC90 over the past two years, as the vehicle has over 2% PHEV market share in the US in 2017. Volvo introduced the XC60 and S90 to the US market in the back half of 2017 to consumer interest as the two vehicles represent an additional ~2% of the market.

Strategy: Volvo made a big splash in 2017, as the company announced that its lineup will go all electric from 2019. Every new model introduced from 2019 and beyond will have an electric motor, meaning that each model will range from a mild-hybrid to a full BEV. Volvo also announced that Polestar will become its own separately branded, high-performance EV company. Ultimately, the company expects BEVs to account for 50% of sales by 2025.

Going Forward: The company has five new fully electric cars in the pipeline that it will launch between 2019 and 2021, three of which will be Volvo branded and the remaining two will be Polestar vehicles. The remaining vehicles to be launched will be 48V, hybrids, or PHEVs, consistent with its stated strategy. The Polestar 1, a PHEV two-door sedan with 93 miles of range, is expected to start production in the middle of 2019. The details of the next two Polestars are less clear, though Volvo has confirmed that Polestar 3 will be an SUV. Additionally, Volvo has stated that they intend to bring a BEV version of the XC40 SUV to the market, but has not laid out a timeline for that vehicle. Further, Volvo has plans to launch two more PHEVs: the S60 and V60.

Chinese OEMs

In the largest EV market in the world, many Chinese OEMs have focused on producing extremely low priced vehicles that are often two-seaters and stripped of all frills. For example, the Zhidou D2 EV and the Cherry eQ are both minicars and are designed for urban environments at prices below $10,000. Larger and more traditional looking vehicles are becoming more popular, though, with BAIC's EC-series taking over as the most popular vehicle in the region. Looking ahead, BAIC and Changan have both stated that all of their sales will be comprised of EVs by 2025 (well ahead of China's target of eliminating ICEs by 2040), and Dongfeng is targeting 100,000 sales of EVs by 2020.

The China NEV market is a very dynamic one. By the time this is printed, the information may be obsolete. To give a sense of the change, at the recent 2018 Beijing Auto Show, 174 new EV models were shown.

Are suppliers prepared for the electric revolution?

How are suppliers impacted by electrification?

Electrification can be very disruptive for the existing supply chain, particularly those who participate in the powertrain and exhaust arenas. At a high level, we would expect margin pressure driven by increased competition and lower volumes on ICE products, combined with higher investment dollars for innovation. However, the devil will be in the details with the timing of these two factors. The goal for these suppliers is to have the legacy business run strong and fund as much of the growth as possible. Ultimately, we see the need for powertrain consolidation.

Because of regulation on CO_2 and NOx, there is an increasing cost to make ICE and exhaust more compliant. This, in isolation, would be a positive for suppliers. However, electrification begins to impede some of that benefit. Even as 48V and HEVs become more prevalent, those vehicles should (especially HEVs) require a smaller ICE offering the suppliers less content opportunity. Then as PHEV and especially BEV penetration picks up, the whole ecosystem of what is needed in the vehicle could change.

The easiest place to start is what is a supplier providing today and what will an EV need in the future.

- **Out:** Fuel systems, transmissions, exhaust systems and other powertrain products.
- **Unchanged:** Seats, safety, interiors and body-in-white.
- **Evolved:** Braking systems (move to regenerative braking) and axles (to e-Axles).
- **Winners:** Thermal management, simple gear reduction.
- **New:** Electric motors, batteries, and power electronics (inverters, converters, on-board chargers, CPUs).

But as we touched on in the automaker section, OEMs have an opportunity to re-image the supply chain and the functionality that is outsourced. Suppliers will always have the advantage of scale as they can sell across to multiple customers. So the onus is on them to come up with strong technology at a low cost. That means investment now.

We also believe it is likely that suppliers may have to increasingly look to partnerships to fill competency gaps, quicken time to market and reduce capital spend. However, partnerships and JVs naturally could bring their own set of challenges including choosing the correct partners, cultural issues and governance.

Some companies have done a more pro-active job preparing for the future (such as BWA) while others remain content believing that ICE mix will still be the vast majority of vehicles for the foreseeable future. The issue with the latter strategy is that even if they are correct, the market is likely to continue to punish the multiple believing there is terminal value risk. From a capital markets perspective, perception of strategy is very important.

Different technology paths provide different growth trajectories over different time-frames

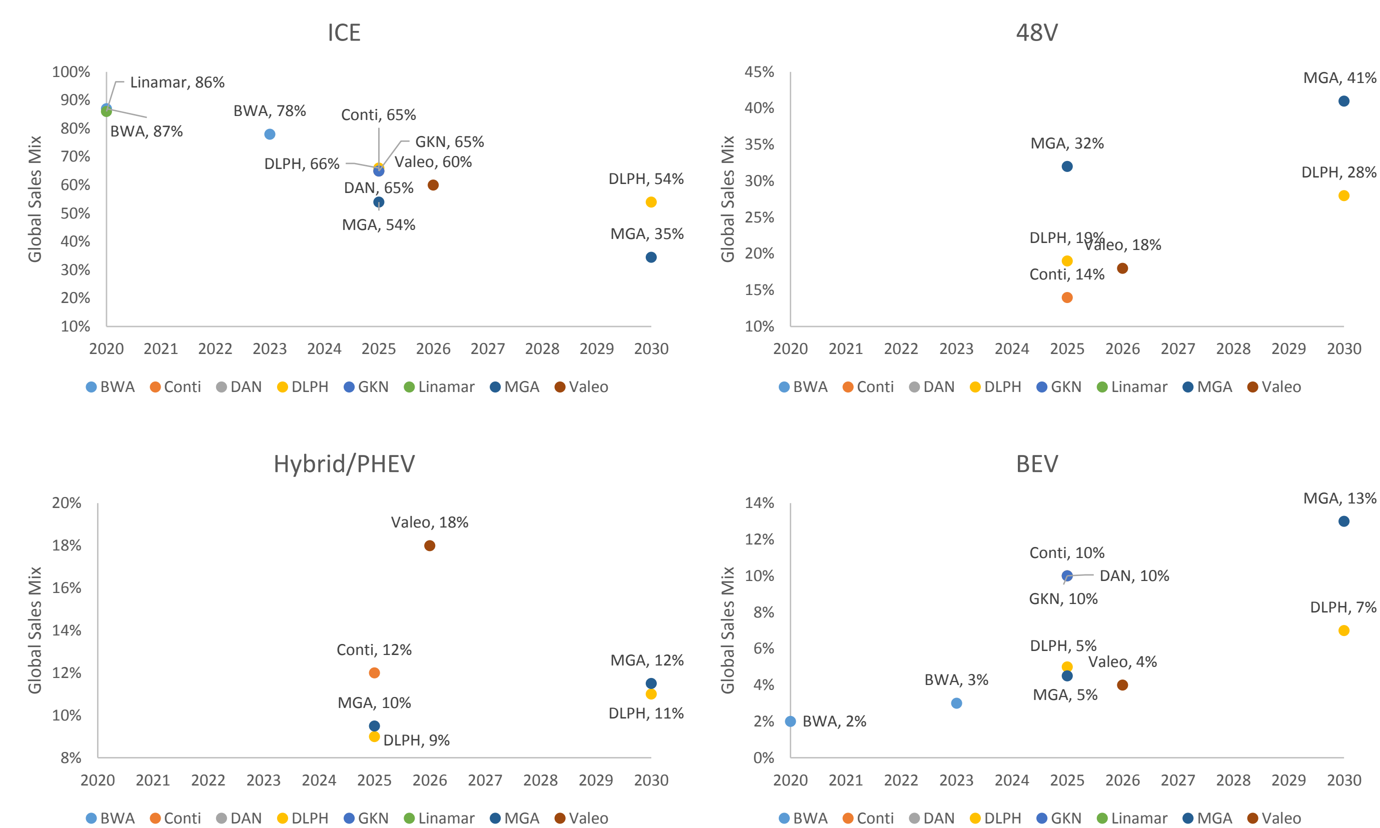
Because we see the different electrification technologies as a progression (48V, HEV, PHEV, BEV) there could be strong growth opportunities for select technologies. 48V is a good example of a technology that can experience rapid mid-term growth meaningfully impacting financials, even if it is somewhat of a “band-aid” solution. This is because 48V is a quick and relatively inexpensive fix (incremental $1,000-2,000/vehicle) to get more fuel economy out of existing platforms (vehicle architecture does not need to be redesigned). We believe that particularly larger vehicles will be the first to adopt 48V. Companies under coverage that could benefit from the 48V trend include DLPH, BWA, and LEA. Smaller vehicles could be quicker to look towards HEV/PHEV and BEVs.

However, we believe that going forward, the majority of new planned electrified platforms will be PHEV or BEVs. The main components needed will be batteries, electric motors and power electronics. Each can experience strong growth. At a high level, we believe batteries are commodities. Electric motors and power electronics are likely to experience strong growth in the mid-term, but the ultimate attractiveness depends on level of insourcing and new potential competitors.

What are supplier timelines?

In order to come to our EV sales forecast, we also looked at what the key suppliers to the world's OEMs are forecasting as far as EV penetration. What became clear while looking at each supplier's forecast was that there appears to be a general consensus that pure ICE mix will trend lower, while BEV mix will trend higher. The true variance seems to be 48V and hybrid/PHEV market penetration. Magna expects 48V to fill the majority of the void left from decreasing ICE mix, with market penetration rising to ~32% in 2025 and ~41% in 2030, while hybrid/PHEV penetration lags. However, names like Continental and Valeo expect hybrid/PHEV vehicles to absorb ICE's market share, with 48V failing to gain much traction with consumers.

Exhibit 54: Supplier global EV penetration forecast



Source: Company reports and RBC Capital Markets

Supplier content in an electrified world

As the bidding process commences for electric vehicle platforms, suppliers are positioning their portfolios to remain key players in the vehicle of the future. We see opportunities for suppliers to provide batteries (discussed more in-depth later), e-motors, e-axles, electrical architectures and power electronics.

e-Motors

The e-motor in an electric vehicle performs essentially the same functions as an engine in an ICE – it propels the vehicle. For now, it seems some OEMs tend to prefer to have control over the design and development of the e-motor given that it is replacing the engine so they view it as similar in terms of importance. To date, this is very varied. Tesla does it themselves, GM we believe is both developing some of their own competency and using the supply base (likely pursuing both strategies to learn) while other automakers strictly outsource. The level of outsourcing likely determines the ultimate attractiveness of this product. We believe it is likely that 50% of electric vehicle motors could be insourced, while 50% go to the supply base.

There is also some debate among investors as to whether this will be a commodity (even among suppliers). Companies like BWA have invested in electric motors while companies like DLPH explicitly stated they don't want to enter the market. Both views could be correct, it depends on the time frame.

In our view, electric motors are likely to experience a good period of very strong growth. However, ultimately, we could see more companies enter the fray. There are a number of industrial motor companies that have, to date, not invested in auto because the market wasn't there, but it looks more attractive if our forecast of the world is correct. Their challenge will be getting the product to automotive grade. But some motor players, like Nidec, have already made early moves.

A word on Electric Motor Configurations

There are five different basic engineering architectures used for vehicles with an electric motor: P0, P1, P2, P3, and P4. The key cost considerations for each architecture are the impact to the typical existing ICE configuration and the additional battery and electric motor expense. Each of the architectures has their own set of advantages and disadvantages. Below are brief descriptions of each architecture:

- **P0:** In this architecture, the electric motor replaces the 12V alternator in the belt drive attached to the ICE. This is a low cost way to add in the extra motor without having to change the configuration of the ICE engine. However, this architecture is not as energy efficient when boosting torque or regenerating energy because the electric motor is attached to the ICE with a belt (which can withstand limited torque). All said, this architecture is relatively cheap, readily available, but not very efficient in regard to generating torque or recuperating energy.
- **P1:** The electric motor is connected to the crankshaft, allowing the motor to act as a generator when the vehicle decelerates, and as an engine starter during acceleration. This architecture requires the electric motor to withstand a significant amount of torque as it is connected to the ICE, but it can generate higher torque than P0 as there is no belt connector to the ICE. However, the P1 architecture does require meaningful changes to the vehicle's design.
- **P2:** The electric motor is connected on the other side of the clutch to the transmission (or not directly connected to the ICE), which reduces the torque and therefore increases the energy efficiency. The electric motor/battery are now connected or integrated to the

transmission. The main benefit of the architecture is the increased energy recuperation, but it does cost more to integrate the system into an ICE vehicle.

- **P3:** The electric motor is connected on the output shaft of the transmission (between the axle and transmission). P3 provides some of the highest energy recuperation potential and can generate the highest electric power. Again, this architecture causes significant redesign of the ICE configuration, making it more costly than the P0 architecture.
- **P4:** This architecture shares many of the same advantages and disadvantages as P3, but differs in the placement of the electric motor. In P4, the electric motor is connected to the rear axle or wheel hubs. This placement of the electric motor allows this architecture to be used for pure BEVs and hybrids. Similar to P3, P4 provides high-energy recuperation and electric power.

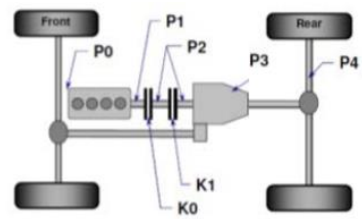
Exhibit 55: Snapshot of P0-P4 mild hybrid architectures

P0 configuration

- Low cost integration
- BSG on front end accessory drive (FEAD)
- Torque limited

P1 Configuration

- Crankshaft mounted
- High torque density
- Axial length restrictions



P2 configuration

- Side attached BSG or ISG
- Higher cost and architectural changes
- Additional hybrid functions
- Eliminate engine drag loss

P3 & P4 Configurations

- P3: eMotor torque on gear output
- P4: eMotor torque directly on axle drive
- Highest recuperation potential

Source: Continental

e-Axles

An e-axle combines powertrain components (typically the motor, power electronics, and transmission) into one unit that drives the vehicle's axle. Combining the powertrain components requires fewer total parts in the vehicle and simplifies the cooling system. An e-axle also creates more space in the vehicle. Thus, the e-axle lowers the overall cost of the total powertrain.

We believe that many investors have soured on axle makers (AXL on light vehicles, DAN on light, commercial and off-highway vehicles, and MTOR on commercial vehicles) in light of electrification. While risk is clearly present, we also see opportunity. At a high level, if the goal is to propel the vehicle from point A to point B, in an ICE world this was done with power generation from the engine through the transmission and sending power to the wheels. In a BEV world, the engine is removed and a much simpler transmission is needed leaving value up for grabs. What is still needed is sending power to the wheels (via a battery and motor). But in most BEV configurations, the motor is located much closer to the wheels. So the axle manufacturers have an opportunity to design and configure a strong "e-Axle" product that is of increasing importance to their customers.

Electrical Architectures

The electrical architecture consists of the vehicle wiring, wire harnessing, electrical distribution system, connectors, and overall system design in an electric vehicle. As voltage (and electrification levels) increase in the vehicle, electrical architectures become more complex and costly. Thus, suppliers focused on electrical architecture add value by reducing the amount of wiring required in the vehicle, while also allowing vehicles to handle higher voltages.

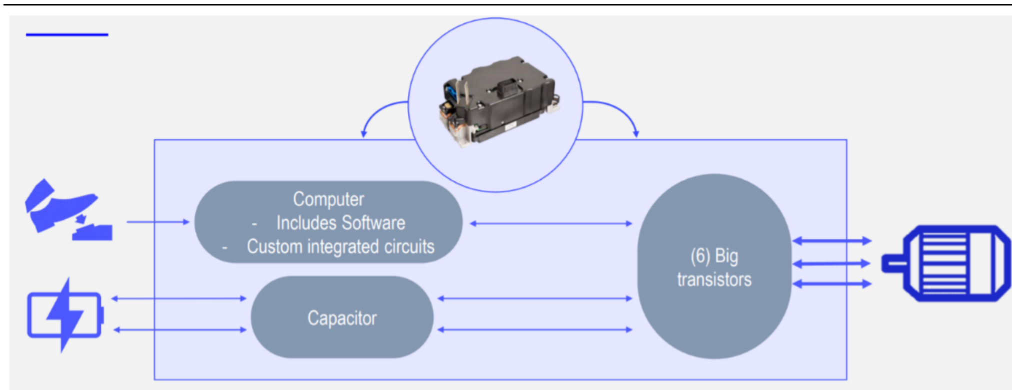
Power Electronics

Power electronics monitor, control, and direct the flow of power in vehicle propulsion and charging. As levels of electrification and vehicle complexity increase, energy and power management becomes an increasingly important part of vehicle design. Power electronics components include (but are not limited to): inverters, DC/DC converters, on-board chargers, battery management systems, and hybrid control units.

Similar to e-Motors, it appears some companies, like Tesla, want to insource power electronics. However, our view is that this appears to be an area more automakers are willing to outsource. Our high-level assumption is that 70% may choose to outsource.

As such, power electronics (inverters, converters, on-board chargers) looks to be a growth area for companies like DLPH, BWA, Conti and Bosch. However, power electronics, similar to motors, also potentially faces competition from other strong engineering or technology companies. The main impediment for these new entrants is to get to automotive grade.

Exhibit 56: Inverter components



Source: Delphi Technologies reports

We view the inverter as a key power electronic component in xEVs. The inverter takes the signal from the pedal and controls the power to the motor in proportion to how far the pedal is pushed down. It converts DC from the battery to AC that the motor runs on. The inverter also allows the motor to act as a generator, enabling regenerative braking. From a sourcing perspective, power electronics are currently sourced independently from other xEV components. However, according to Delphi Technologies, power electronics suppliers are involved early in xEV development as they help with electrical architecture design and component packaging.

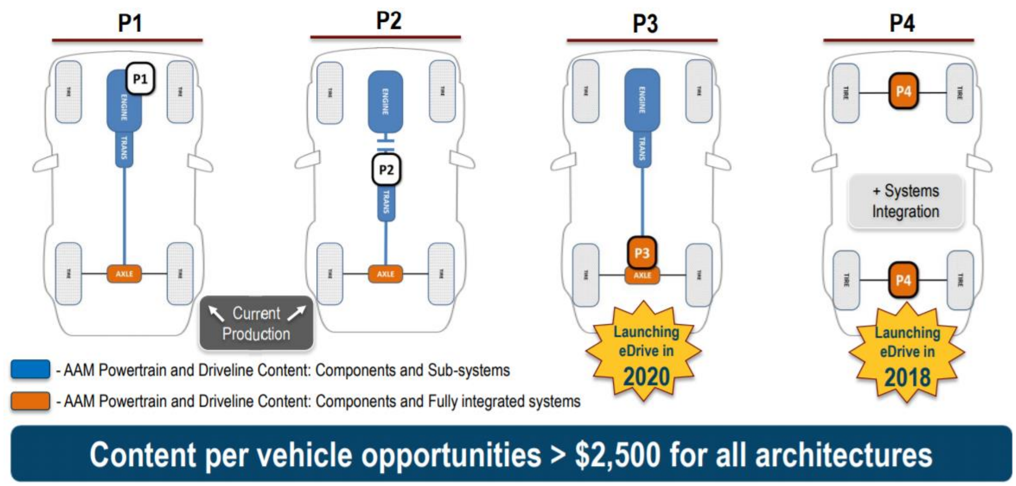
How are suppliers approaching electrification?

Many tier 1 suppliers have developed products tailored to electric vehicles, ranging from mild-hybrids to full BEVs. These suppliers have taken note that the electrification trend is upon them and have decided either to develop their capabilities in house, or acquire competitors.

American Axle

American Axle's eAAM technologies provide hybrid and electric driveline components and systems to OEMs. The eAAM technologies include eBoost, eDrive, electric AWD, electric traction control, brake regeneration, coast regeneration, and load point shifting. The company is also capable of providing full eAxle systems. American Axle's eAAM portfolio rounds out with systems integration capabilities on P3 and P4 architectures.

Exhibit 57: AXL eAAM opportunities



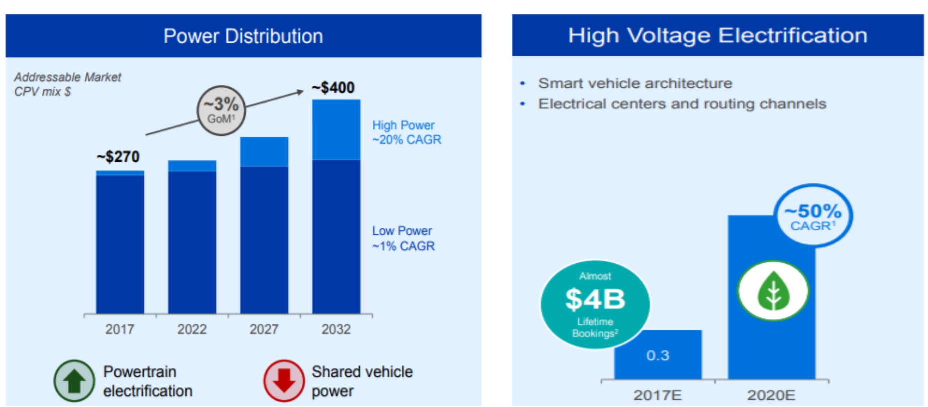
Source: American Axle company reports

American Axle expects its eAAM products to account for ~$100-200mm of 2021 revenue based on the two eAAM awards it has today. In 2018, AXL will be launching a European BEV program (P4 architecture) with eAAM content (specifically eDrive) with $2,500 CPV. AXL will be launching another xEV program (P3 architecture) with eDrive content in 2020.

Aptiv

While Aptiv is exposed to various secular trends in auto, its electrification specialization is in high voltage electrical architecture. The company provides wire harnessing, portable plug-in chargers (20% global share, management calling for 40% share in 2022), high voltage power distribution, specialty harnesses, and connectors.

Exhibit 58: APTV electrical architecture opportunity



Source: Aptiv Company reports

In the near term, APTV expects high voltage revenue to increase +60% y/y from 2017 to 2018. 1Q18 high voltage revenue was up +64% y/y and the company was awarded seven new high voltage programs in the quarter. High voltage bookings currently sit at ~$6bn, with ~$1bn of that coming in 2017 and ~$300mm in 1Q18. Over the medium term, the company expects its high voltage electrification business to grow at a 50% CAGR from ~$300mm in 2017 to ~$1bn in 2020E. This is driven by share gains, CPV growth, and increased xEV program launches. We estimate Aptiv's high voltage/high power CPV grows at a ~17% CAGR over the next 5 years, and a ~21% CAGR over the next 15 years.

BorgWarner

BorgWarner offers propulsion system solutions and solutions across the entire propulsion spectrum. For HEVs/PHEVs, BWA offers eBoosters (electrically-assisted charging system that uses two flow compressors to control thermal output and allows the use of smaller turbochargers), power electronics, electric AWD, electric drive motors, integrated belt alternator starters, and more. On booked content, average 48V/HEV/PHEV CPV is $240 in 2020, while the company estimates 2020 share of hybrids coming in at 36%. On RBC's xEV forecast, this would imply ~$1,050mm of revenue from hybrids, while IHS assumptions imply $950mm of revenue. For 2023, average 48V/HEV/PHEV CPV is $225, while the company estimates 2023 share of hybrids coming in at 42%. On RBC's xEV forecast, this would imply ~$2.4bn of revenue from hybrids, while IHS assumptions imply $1.8bn of revenue. If we were to look at BWA's potential CPV on hybrids, assuming all of their content was sourced on a vehicle, we think it could be >$3,300.

Exhibit 59: BWA hybrid products and CPV

Source: BorgWarner company reports

For BEVs, BWA provides eGearDrive (transmission), electric drive motor, power electronics, full electric drive modules, and electric AWD. In July 2017, BWA acquired SevCon, which bolstered the power electronics portfolio, specifically in controllers and charging technologies.

Exhibit 60: BWA BEV products and CPV

Source: BorgWarner company reports

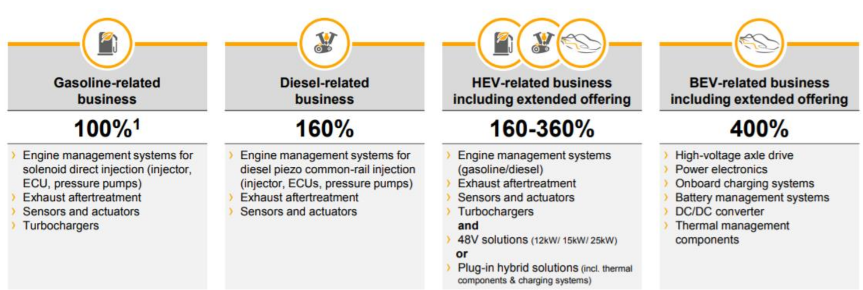
On booked content, average BEV CPV is $285 in 2020, while the company estimates 2020 share of BEVs coming in at 26%. On RBC's xEV forecast, this would imply ~$180mm of revenue from BEVs, while IHS assumptions imply ~$160mm of revenue. For 2023, average BEV CPV is $285, while the company estimates 2023 share of BEVs coming in at 29%. On RBC's xEV forecast, this would imply ~$420mm of revenue from BEVs, while IHS assumptions imply $190mm of revenue. If we were to look at BWA's potential CPV on hybrids, assuming all of their content was sourced on a vehicle, we think it could be >$3,500.

BWA has taken meaningful steps to make its business "powertrain agnostic." For the 2018-2020 backlog, BWA has 45% coming from PHEVs/HEVs and 5% coming from BEVs. We expect xEV content to grow as a percent of the backlog as BWA's win rate on xEV platforms is accelerating beyond its historical 15% rate.

Continental

Continental, a German supplier that specializes in chassis and safety, interiors, powertrain, tires, and technology. Continental has a suite of product offerings for mild-hybrids (both 12V and 48V) as well as for hybrid and battery electric cars. For 12V hybrids, the company offers dual volt battery managers (manages connection of power supply and flow) and power net stabilization (supports the 12V powerboard during start-stop). Turning to 48V hybrids, Conti has belt-driven starter generator with inverter (for P0), DC/DC converters, and auxiliary products. Finally, for hybrids and BEVs, offers several products related to power electronics, axles, smart actuators (for transmissions), as well as other auxiliary products.

Exhibit 61: Continental relative CPV vs. gasoline ICE engines



Source: Continental company reports

Looking ahead, Continental expects ICE vehicles to comprise ~65% of new vehicle sales in 2025. Of the remaining ~35% of sales, mild-hybrids comprise the next largest portion at ~14%, then BEVs at ~10%. Continental estimates its CPV on HEV business is 1.6x-3.6x that of its gas ICE content, while its BEV CPV is 4x that of its gas ICE business.

Dana

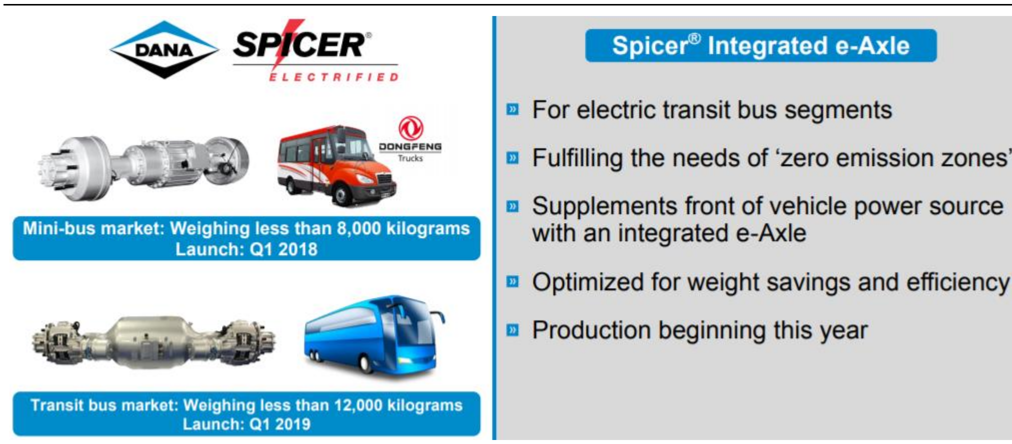
Dana specializes in drivetrain systems and thermal management solutions for the light vehicle, commercial vehicle, and off-highway markets. Dana has a number of products for electric vehicles, under the Spicer Electrified portfolio, which offers integrated motor, control, and e-drive technologies.

Exhibit 62: Select product offerings across end markets

Source: Dana company reports

The portfolio is applicable to each of Dana's end markets, and recently introduced their e-Axle for electric buses. For light vehicles, Dana offers battery, power electronic, and engine cooling systems for hybrid and electric vehicles. In CVs, Dana offers an e-Drive axle that the company recently announced would be featured on a city delivery vehicle designed by both Dana and Workhorse. Additionally, Dana's Spicer PowerBoost hydraulic-hybrid system is a complete solution for off-highway vehicles that reduces fuel requirements by 20-40%. Finally, DAN also introduced an integrated e-axle solution for the mini-bus market in 1Q18, and will launch an e-Axle for the transit bus market in 1Q19.

Exhibit 63: Overview of Spicer e-Axle product line



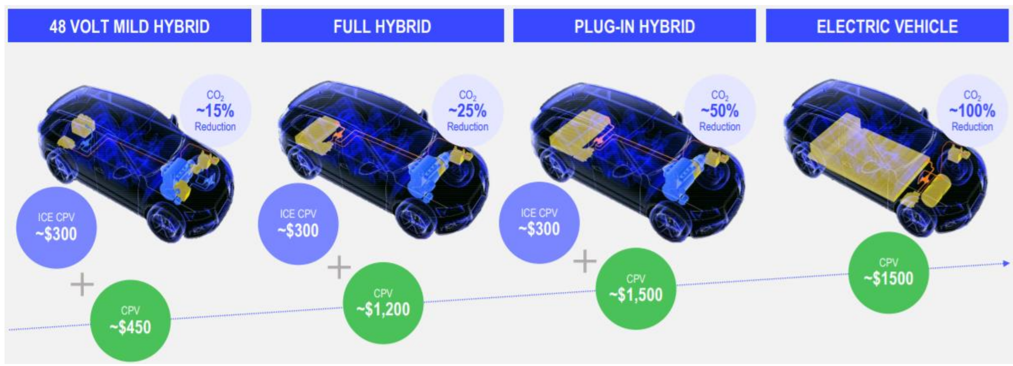
Source: Dana company reports

Looking ahead, Dana expects ICE vehicles to comprise ~65% of new vehicle sales in 2025. Of the remaining ~35% of sales, hybrids (mild, full, and plug-in) comprise the next largest portion at ~25%, then BEVs at ~10%.

Delphi Technologies

Delphi Technologies focuses on gas and diesel propulsion systems, but has a nascent Power Electronics portfolio. Delphi's power electronics offerings span across 48V through BEV architectures. Products include controllers and software, DC/DC converters, inverters, combined inverter/converter (CIDD), battery controller, and on-board chargers. Delphi also plays an important role in electrical architecture planning – OEMs often send axle makers to Delphi to figure out packaging and component placement in the vehicle. This position as both a part supplier and an integrator/planner allows Delphi to achieve relatively higher content than power electronics peers.

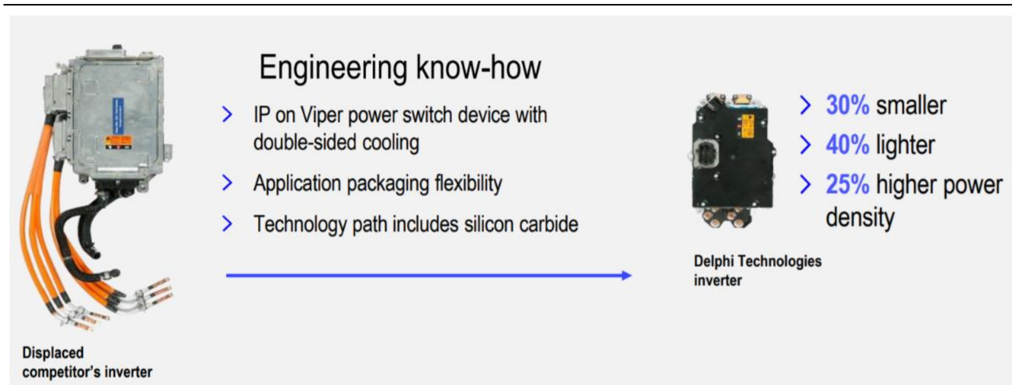
Exhibit 64: DLPH electrification CPV opportunity



Source: Delphi company reports

Delphi currently has $4bn in lifetime power electronics bookings ($2bn of which came in 2017 alone). Management is guiding 2018 power electronics revenue to be ~$250mm, up 50% y/y from RBCe ~$165mm in 2017. Management is guiding the power electronics business to grow at a ~35% CAGR through 2020, implying revenues can reach ~$410mm in 2020. In terms of CPV opportunity, 48V provides an incremental ~$450 CPV, HEVs an incremental ~$1,200 CPV, PHEVs an incremental ~$1,500 CPV, and overall BEV content is ~$1500 (so net $1,200). This is assuming the vehicle is fully outfitted with DLPH content.

Exhibit 65: DLPH inverter technology advantages



Source: Delphi company reports

The company's differentiating factor in power electronics, especially in PHEVs and BEVs, is its inverter. As discussed before this is a key part of xEV functionality. DLPH's inverter CPV alone is ~$700-$800. While a relatively high price tag to other power electronics components, Delphi's Viper inverter technology is automotive grade (challenging to achieve) and provides 25% higher power density than competitors while also being 30% smaller and 40% lighter.

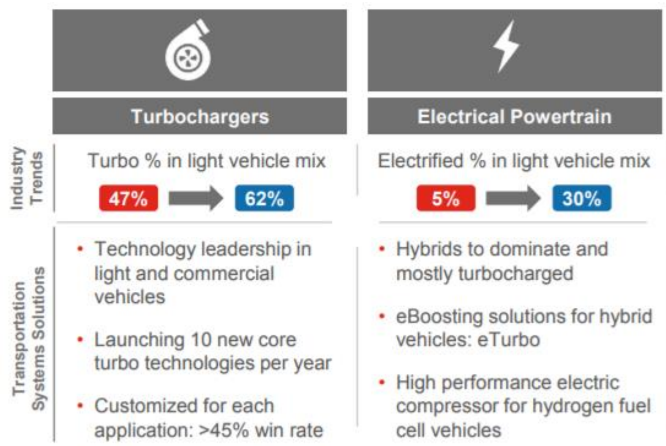
Delphi's advanced position in the inverter market also keeps it relatively insulated from emerging competitors such as industrial inverter manufacturers.

When we apply RBC's propulsion penetration model to DLPH's potential incremental CPV assumptions, we estimate Delphi's incremental xEV TAM grows from ~$12bn in 2020 to ~$40bn in 2025 and ~$100bn in 2050. While average CPVs likely come in lower than Delphi's CPV assumptions, it still shows the massive opportunity for the company to capitalize on.

Honeywell

Honeywell's Transportation Systems business is the number two turbocharger player behind BWA. On the electric side, HON supplies electric compressors (boosters), electrically assisted turbochargers (eTurbo), and fuel cell compressors.

Exhibit 66: Honeywell electrification opportunities



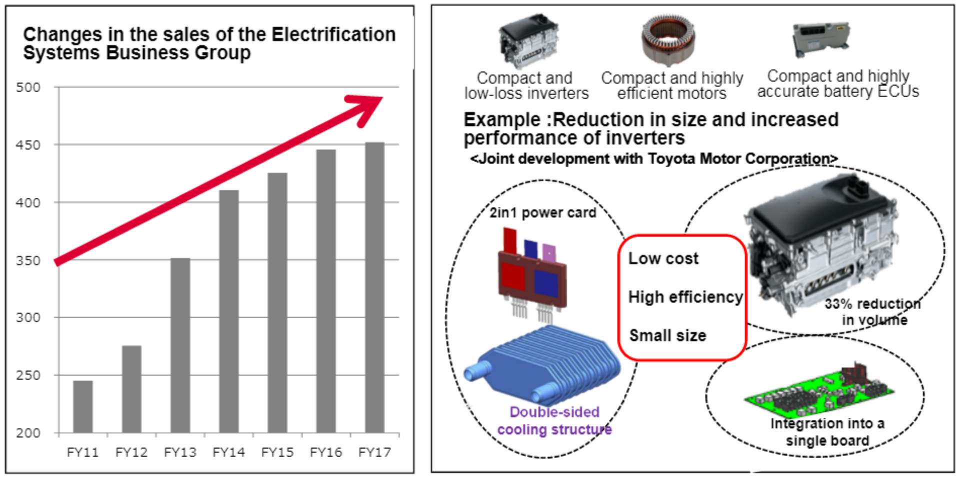
Source: Honeywell company reports

In both the turbocharger and electrical powertrain businesses, Honeywell has >45% win rate. Honeywell is planning to spin off its Transportation Systems business ($3bn in 2017 revenue) in 3Q18.

Denso

Denso is a global supplier of light vehicle technology, systems and components based in Japan, and has an extensive offering of solutions for hybrid and electric vehicles. Denso has a number of products designed for hybrids: inverter power control units (regulates the amount of current from the battery to the electric motor), motor generators, battery monitoring units, DC-DC converters, system main relays (acts as a switch between the battery packs and electric circuit), battery current sensors (measures the flow of electricity), electronic control unit (computer that controls how much power comes from the engine and the electric motor).

Exhibit 67: Denso electrification content



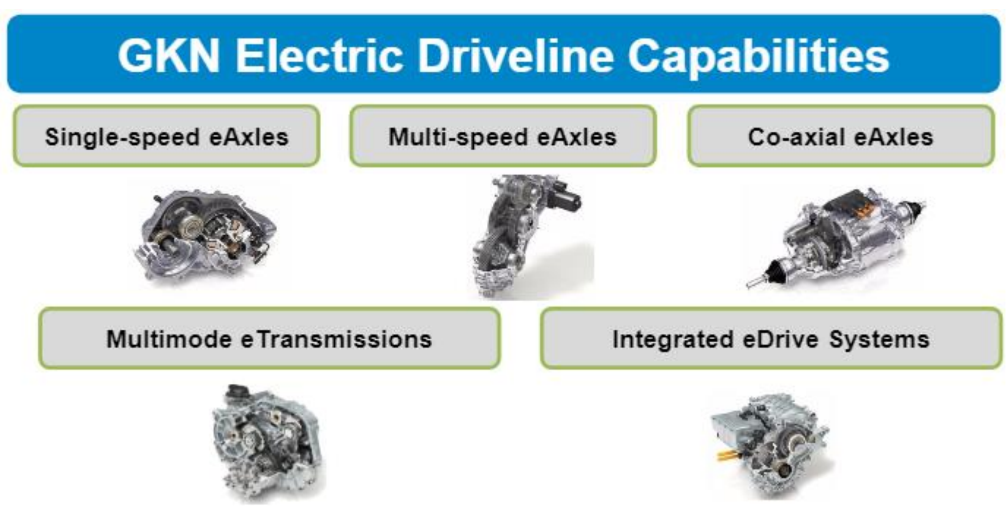
Source: Denso company reports

Additionally, Denso is partners with Mazda and Toyota to jointly develop basic structural EV technologies for a variety of vehicle types. Further, the three companies will establish another company that will research the common EV architecture and verify the vehicle performance realized from the architecture.

GKN

GKN is based in the UK, and is a leading manufacturer of components for light vehicle and off-highway driveline components. We believe that GKN's eDrive solution is a market leader. GKN offers eTransmissions for mild-hybrids, co-axial (BEVs), multispeed (HEV), and single-speed (mild-hybrid) eAxles (has produced >700,000 eAxles to date), and an integrated eDrive solution for PHEVs. The company currently has nine programs in production, with another eight programs yet to launch globally.

Exhibit 68: GKN electrification products



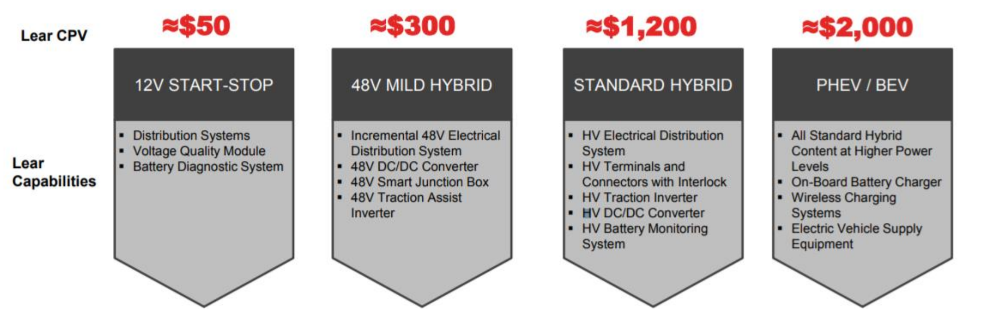
Source: DAN company reports

Looking ahead, Continental expects ICE vehicles to comprise ~65% of new vehicle sales in 2025. Of the remaining ~35% of sales, mild-hybrids comprise the next largest portion at ~14%, then BEVs at ~10%.

Lear

Lear's E-Systems business supplies electrical architecture solutions and power electronics components across the xEV spectrum. On the electrical architecture side, LEA provides electrical distribution systems, wire harnessing, system optimization solutions, and connectors. On the electrical architecture business, LEA has ~10% share. Lear's power electronics solutions include DC/DC converters, traction assist inverters, battery monitoring systems, control modules, on-board battery chargers (BEVs and some PHEVs), and wireless charging systems.

Exhibit 69: LEA electrification CPV opportunity



Source: Lear company reports

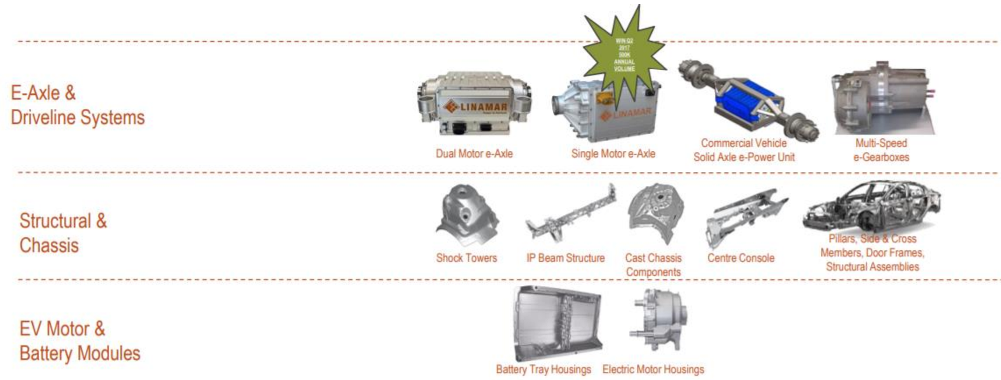
Increased electrification presents a meaningful opportunity to Lear's E-Systems business. 48V provides ~$300 CPV and HEVs provide ~$1,200 CPV, while PHEVs and BEVs provide ~$2,000 CPV. Looking forward, ~$270mm of LEA's $1.3bn 2018-2020 E-Systems backlog comes from electrification and the company is currently quoting ~$500mm in electrification programs beyond 2020. Historically, LEA's win rate has been 20-25% on electrification platforms.

Lear is having success bidding on 48V platforms, as it will be launching on 29 48V nameplates between 2018 and 2019. The company sees 48V having the potential to make up ~30% of electrification strategy in regions like Asia and Europe. Lear's CPV on 48V platforms is ~$300 when it supplies the electrical distribution system, DC/DC converter, smart junction box, and traction assist inverters. Based on the RBC xEV penetration forecast we believe that 48V TAM for LEA grows almost 5x from ~$265mm in 2017 to ~$1.3bn in 2020. For all xEVs, we estimate Lear's incremental TAM grows from ~$15bn in 2020 to ~$40bn in 2025 and ~$150bn by 2050 – a significant opportunity.

Linamar

Linamar machines and assembles engines, transmissions, and driveline components for light and commercial vehicles (as well as off-highway and agriculture) based in Canada. The company currently develops components for EVs and has two e-Axle programs, with one in Europe and the other in China. The e-Axles are fully integrated with an electric motor, controller, axle, and gearbox.

Exhibit 70: Linamar BEV content



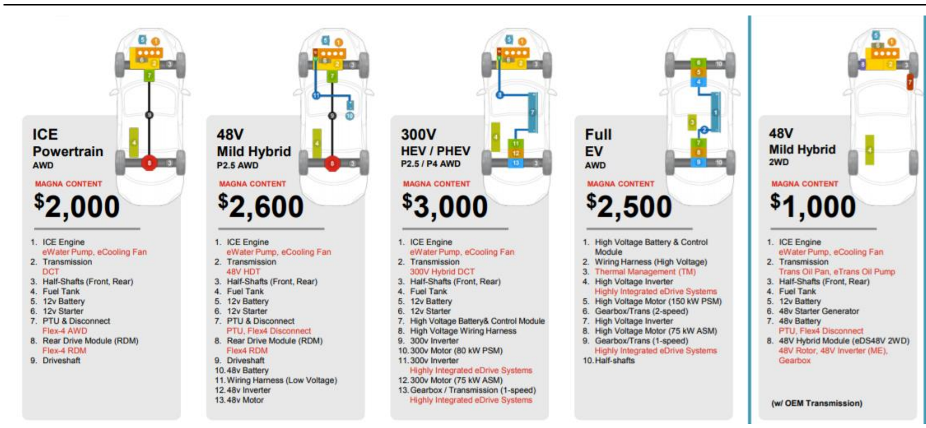
Source: Linamar company reports

Ultimately, Linamar expects the two e-Axle programs to be on one million electric powertrain systems by 2025, when they expect global BEV sales to reach 4-5mm units and ~21% of market penetration by 2030.

Magna International

Headquartered in Canada, Magna is a global supplier of panels, seats, bumpers, engines, doors, chassis, and interior and exterior components. Additionally, Magna designs and integrates complete systems, including the assembly of an entire vehicle. Magna recently introduced its etelligentDrive system at CES 2018, which is a suite of products for hybrids, PHEVs, and BEVs. For hybrids and PHEVs, Magna offers a selection of transmissions for PHEVs and BEVs, and Magna offers three eDrive options. Additionally, Magna produces several components for electric vehicles including water pumps, oil pumps, thermal management, cooling fans, etc.

Exhibit 71: Magna xEV CPV



Source: Magna company reports

Magna estimates that just 30-37% of vehicle sales will be ICE by 2025, and by 2030, only 16-21% of sales will be ICE. The majority of the share goes to mild-hybrids, which Magna estimates will comprise 46-59% and 48-66% of sales in 2025 and 2030, respectively. Magna expects EV penetration to begin to accelerate in 2025-2030 as share rises to 9-17% in 2030 from 4-5% in 2025.

Valeo

French supplier Valeo, manufactures driver assistance systems, powertrain systems, thermal solutions, and visibility systems (lighting and wipers). Valeo has been on the forefront of efficiency, inventing stop/start technology through the use of a 12V battery in 2004, which the company still provides today. One step further, the supplier also provides a solution for 48V with a battery, DC/DC converter, a starter generator, and an optional 48V electric supercharger. Turning to PHEVs, Valeo offers transmissions, inverters, battery chargers, DC/DC converters, crankshaft motor generator, gearbox motor generator, and an electric rear axle drive. Finally, under the Siemens eAutomotive JV, Valeo supplies solutions for full BEVs. The JV has developed inverters, battery chargers, electric motors, and DC/DC converters.

Exhibit 72: Valeo relative CPV

Source: Valeo company reports

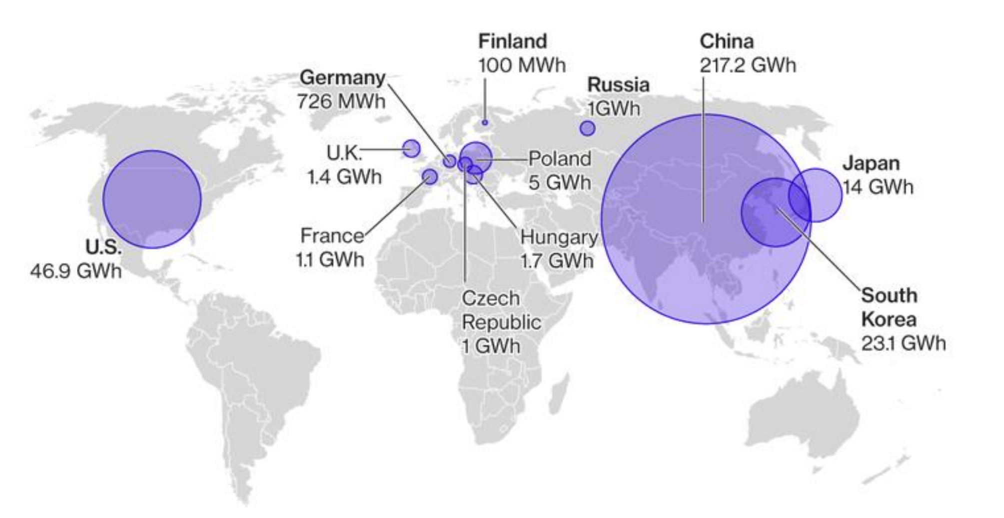
Valeo expects ICE sales penetration to decrease to 60% by 2026, with PHEVs and mild-hybrids gaining the majority of the share, with both representing 18% of sales. The supplier expects BEVs to represent 4% of global sales by 2026.

EVs as the medium for China auto takeover?

As we assess the global landscape for electric vehicles, we see significant potential for China to assert itself within the automotive industry. Our view is informed by:

1) **A government that is very supportive of EVs.** This is in part driven by air quality concerns, which are notoriously bad in China, but also likely a desire to become more energy independent. Recall, China established a target for New Energy Vehicles (NEVs, or PHEV/BEV) to comprise ~20% of new vehicle sales by 2025. The country's vice minister of industry has stated that the government has begun researching a potential ban of ICE vehicles. The country has moved to a more western style of incentives to stimulate the push.
2) **A lot of Chinese companies pushing EVs.** The 2018 Beijing auto show featured 174 EV models, 124 of them developed in China and ~17% of all vehicles shown. Sure not all of these will be successful and see the light of day. However, the sheer volume dwarfs what other countries have done to date. Companies like BYD, Geely and SAIC have made significant investment and pushes into NEVs. While many of these vehicles will satisfy local demand, we believe they have global ambitions as well. Further, there are a number of Chinese startups that have stated intentions of selling vehicles in the US by the end of the decade, including NIO, Byton and SF Motors.
3) **China appears to control a large portion of battery supply…** A look at future battery capacity shows that China is expected to dominate EV battery supply. Based on the numbers we were able to gather, probably something approaching half of global supply by 2025. Note that this number is only at that level because we also assume Tesla can ramp their Gigafactory to 105GWh. If instead, we assume it only gets to 50GWh, China share would be closer to 60%. That would be more in line with what some other forecasters have gathered. For instance, Bloomberg shows China with ~69% of global existing and planned capacity led by CATL, which we believe, aims to have ~50GWh. With China dominating supply, it's easy to see how they can prioritize China automakers vs. global automakers. That being said, it does appear Beijing has also encouraged Chinese battery companies to invest in factories overseas.

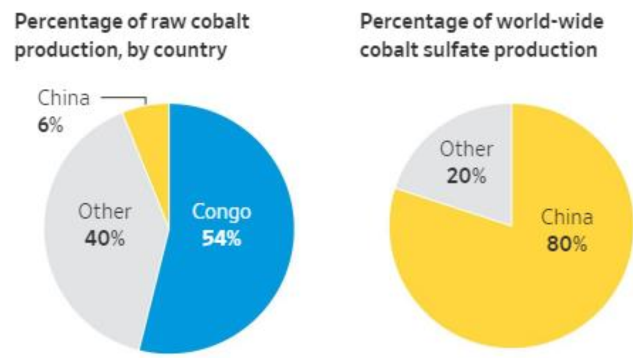
Exhibit 73: Global distribution of existing and planned battery cell production capacity



Source: Bloomberg, CATL IPO prospectus

4) **…and the battery supply chain.** In March 2018, Glencore Plc, the world's top cobalt producer, agreed to sell ~1/3rd of its cobalt output to Chinese supplier of battery chemicals GEM Co. And China already produces ~80% of the world's refined cobalt. China has also moved to secure significant portions of lithium supply and has invested in lithium mines.

Exhibit 74: China's focus on cobalt



Source: Wall Street Journal, U.S. Geological Survey (cobalt production); Benchmark Mineral Intelligence (cobalt sulfate)

The above leads us to believe that China has big plans to use the transition in the powertrain of the vehicle to make a move in automotive and become a global leader.

We also note that in April 2018, China announced it will remove foreign ownership limits for new energy vehicles (NEVs – i.e. PHEVs and BEVs) by 2018, commercial vehicles by 2020, and passenger vehicles by 2022. Previously (since 1994), foreign ownership was capped at 50%.

We believe there will be little near-term impact on existing domestic OEMs and foreign JVs. These JVs are likely costly and complex to unwind. Further, the government may not allow renegotiation of current JVs anyway. The most relevant near-term impact could be for Tesla which plans to expand production to China, a critical market for them to hit their longer- term volume goals.

Longer-term, there are more meaningful implications.

1) The government could have enacted this change because they felt better about the ability of domestic players to compete on a domestic and global stage. Domestic Chinese brand market share has been rising in recent years, a trend we expect to continue as future China growth is driven by penetration in Tier 3-6 cities that have no brand history. That being said, this will require Chinese companies to improve their domestic brands (many Chinese companies have foreign JV partner brands and their own standalone brands). We believe this policy could cause needed consolidation in China, either from some brands going away or M&A.
2) As vehicles shift to electric and autonomous, this could be more positive for the global OEMs. A lingering concern for the global OEMs has always been IP protection. Now, theoretically, these global OEMs could set up new entities in China for their electric and autonomous ventures (although our understanding is that the Chinese government must still grant permission for a new company to produce and/or add new capacity). Even if the global OEMs choose not to start new entities (and they may), the threat of doing so could give them more leverage vs. their partners. Bigger picture, this should raise the level of competition and innovation in China for electrification and autonomous which may be their ultimate goal, as we believe they would like to be global suppliers of the technology.

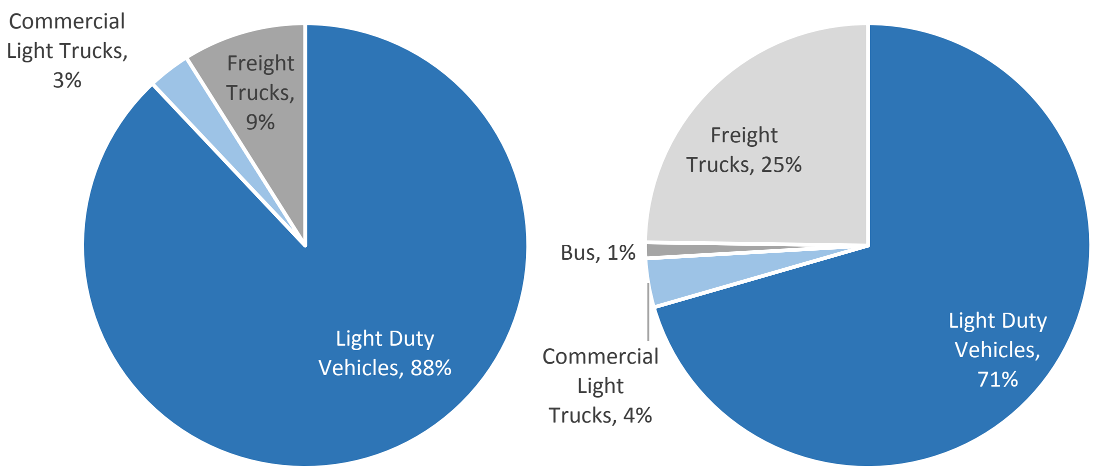
3) The bigger global trade picture. The US outlined tariffs on up to $60bn worth of Chinese goods. In response, China increased tariffs on a number of US goods. On the one hand, the removal of the automotive investment restrictions could be viewed as an olive branch towards reducing tensions. Let us not forget that Chinese OEMs still view the US market as a green field opportunity. For instance, China's Guangzhou Automotive Group (GAC) has indicated they intend to enter the US market in 2019 and the brand appeared to get good interest at the recent National Automobile Dealers Association (NADA) show. Despite the interest and intention, Chinese brands entering the US may have seemed like a tough pill to swallow amid the current environment. With China easing domestic restrictions maybe the global playing field looks a little more level. While initial US sales of Chinese brands would likely be imported (from China and/or Mexico), if the brands grow, US manufacturing will be needed (see Japanese/Korean OEMs as case studies). The current US administration is clearly focused on more US manufacturing so Chinese brands entering the US market could be a driver. However, this would raise the level of competition on U.S. soil.

The electrification of commercial and off-highway vehicles

Current electrification trends in CVs

The majority of miles driven in the US are by passenger vehicles, however, unsurprisingly commercial vehicles also drive a considerable amount of miles per year. In 2009 (unfortunately the most recent data we have), commercial trucks accounted for ~12% of total highway miles traveled. However, from an energy consumption standpoint, commercial vehicles comprise a much larger portion, representing ~28% of total energy consumption.

Exhibit 75: Commercial vehicles share of on highway miles (left) and fuel consumption (right)



Source: US Energy Information Administration and RBC Capital Markets

Therefore, recent efforts to electrify commercial vehicles has gained momentum. Many commercial vehicle OEMs have introduced electric or hybrid concepts, including Navistar, Volkswagen, Volvo, and new market entrants Tesla and Workhorse. Additionally, many suppliers have begun developing products to electrify commercial trucks, including Meritor, Cummins, WABCO, and Allison Transmission who have all taken steps toward investing in their electric portfolio.

Cost of ownership to drive Commercial Truck electrification

Aside from the fuel consumption or city limitations factors that may drive commercial vehicle electrification, we see one major driving factor and that is total cost of ownership/operation. Fleet managers have always bought on cost, and if they can be convinced electric trucks are cheaper to own/operate, and they don't sacrifice capability, then the shift to electric trucks will occur.

CV purchasing decisions tend to be purely economic (cost of ownership and utilization). In thinking about electric CVs, we need to consider how replacing a traditional powertrain and the associated fuel with a battery impacts the range, weight, utilization and cost. We believe Class 8 long-haul trucks generally need to have a range of ~600 miles/day which could require a ~1,200kWh battery pack which at $100/kWh is $120,000. That is nearly the cost of the entire truck today though there is an offset from the traditional diesel powertrain (~$25-$30k). However, assuming ~6.5MPG, 100k miles/year at current prices means annual fuel costs can approach ~$45k/year. Charging costs should be meaningfully lower. Further, the American Transportation Research Institute estimates that repair and maintenance cost on a diesel CV is ~$0.15/mile or ~$15k per year. The maintenance on an electric CV should be meaningfully less. If it can be reduced by 35% that's another $5k annual savings. So assuming a 600-mile range truck costs ~$230k, the breakeven versus the diesel truck could be 2-3 years. Turning to reliability, there are far fewer moving parts in the electric powertrain, reducing the number of things that could potentially go wrong while hauling. A final (and unknown) factor will be resale value.

Looking at it through an economic lens, we see a number of use cases that are likely to drive electrification in commercial trucks.

1. **Anything on a "loop."** Vehicles with specific routes and then return to depots (think distribution centers) seem ripe to adopt electric vehicles. Battery requirements can be smaller given range requirements and recharging infrastructure can be installed at the depots.
2. **Buses.** This may actually be the best use case for electric commercial vehicles. In fact, in China, PHEV/BEV buses are already ~20% of total bus sales. While electric buses have higher upfront costs, they should have lower operating costs (no oil changes, emissions after-treatments and less maintenance). Charging can also be dealt with (if necessary) via pantograph (overhead) or wireless charging along pre-defined routes. Additionally, the range demands are often not an issue. Additionally, e-Buses help with urban air quality, pollution and noise issues.
3. **Medium-duty trucks that drive a moderate amount of miles (100-150 miles).** Recall, the cost of the battery is the largest expense. In this use case, we see the capability of the battery being enough to support this mileage required while the cost of the battery is not impeding the upfront cost. According to the Bureau of Transportation Statistics, 50% of total freight (in tons) was transported within 100 miles. In short-distance deliveries, trucks should be able to travel to their delivery and make it back to the hub, within their range, where they can plug back in and charge for the next delivery. Of course, regional differences in diesel fuel and electricity costs will impact the equation (so Europe may be more likely before US).
4. **Long-haul.** Given the size of the vehicles and the battery pack required, this is likely the last segment to be impacted by electrification (though one of the first segments Tesla appears to be going after).

Exhibit 76: Timing of electric vehicle total cost of ownership parity vs. diesel

Application segment	Segment perspective	Example use cases	Range of TCO parity,[1] year
Regional light-duty-truck (LDT) hub-and-spoke delivery	First truck segment to reach total-cost-of-ownership (TCO) parity, lowest entry barrier for battery electric vehicles (BEVs)	Regional grocery delivery for shops and restaurants	2017
Urban LDT stop-and-go delivery	Second truck segment to reach TCO parity due to low share of battery cost	Urban last-mile distribution with central hub and many stops	2017–21
Regional medium-duty truck hub-and-spoke delivery	Third segment to reach TCO parity due to balanced capital and operating expenditure	Grocery store chain with logistics center for several branches	2017–23
Urban heavy-duty city bus	In China and US, buses reach earlier TCO parity than truck segments due to lower share of battery cost in total capital expenditure	Typical city bus or school bus with dozens of stops	2020–23
Long-haul heavy-duty truck point to point	Parity for average users around 2030, due to large battery need, but up to 7 years earlier in beneficial use cases	International or continental freight logistics	2023–31

[1]Depending on region; example shown: Europe.

Source: McKinsey Center for Future Mobility

Headwinds to CV electrification

The cost of the battery clearly needs to come down to make the cost of ownership work. But assuming it does, the other issue is infrastructure. Little infrastructure exists today, though bigger picture, the required charging infrastructure may not be as onerous as for passenger cars. The trucks generally run on the same routes, so recharging stations could be built along these corridors. Further, charging infrastructure can be placed at depots to charge when not in use. Speed of charging could be another impediment to fleet operators embracing electric commercial vehicles, though perhaps battery swapping can overcome this deficiency until charging speeds get faster.

Off-highway an early adopter of electric vehicles

The off-highway market has been an early adopter of electric vehicles, particularly in mining and aircraft ground support applications. Starting with mining equipment, electric vehicles provide an opportunity for the mining company to drive efficiencies and limit costs. An obvious advantage to electric mining equipment is that EVs do not produce the toxic exhaust that an ICE vehicle would emit, thus saving mining companies from having to install costly ventilation systems. Additionally, EVs are more efficient at transferring energy to movement. According to ABB, a large industrial conglomerate specializing in automation and electrification, electric drivetrains are 90% energy efficient, compared to diesel drivetrains, which are only 45% energy efficient. Further, much like light and commercial vehicles, the electric drivetrain is much simpler than an ICE configuration, reducing the expected maintenance expense. Turning to aircraft ground support vehicles, the low speeds (and therefore low torque requirements) and frequent start/stops make this market well suited for EVs. Further, less reliance on gas prices provides a benefit from the standpoint of large airline carriers. Delta has already begun to convert its support vehicles to an electric drivetrain, and as of 2016, 15% of its ground support vehicles were electrified.

Looking broadly at the off-highway industry, it is more difficult to forecast when off-highway machines will transition to electric drivetrains due to the wide-ranging uses and purposes of these machines. Volvo's Director of Emerging Technologies, Jenny Elfsberg, believes that electrification is the future, but will require the industry to reinvent many of the machines as vehicles become more specialized, automated, and electric. Eric Hendrickson, Parker Hannifin's Business Development Manager Vehicle Electrification, appears to agree saying that machines will have to be more efficient and right-sized to do the required work. He estimates that mass adoption will take 10-15 years, which seems to be largely reliant on the progression of battery and autonomous technology.

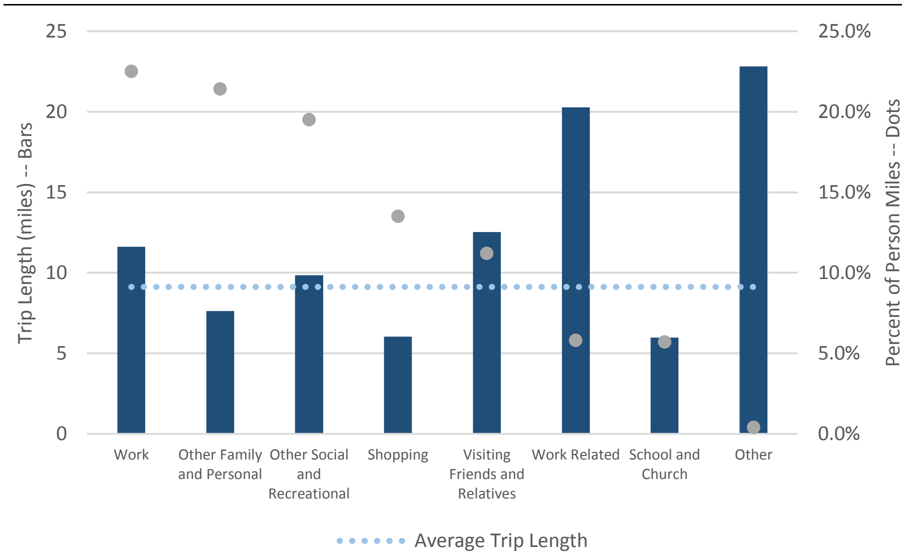
EV infrastructure

Infrastructure requirements

The charging infrastructure in the US is still in its infancy, and stands as a major hurdle for mass adoption of EVs. Currently, there are 17,678 charging stations (47,546 charging outlets), of which 2,302 are fast charging stations, in the US compared to 168,000 gas stations (at an estimated eight pumps per station, that's ~1.3mm pumps). But this isn't necessarily a fair comparison as we estimate there are ~269mm ICE vehicles in operation, or ~99.3%, compared to just ~400k BEVs so inherently there will be fewer charging stations to support EVs.

Another aspect of EVs that makes discussing the necessary infrastructure challenging is the fact that the majority of charging for EVs will be done from home. So even considering the average range of a BEV today, which is ~115 miles, the vast majority of everyday trips can be done without accessing a second party charging station. The average trip length is just 9.12 miles, so round trip is <20 miles which would be more than covered by at home charging alone. The only time second party charging will be necessary is for longer trips that are not as common. And when you consider improvements in range that are coming down the pipeline, the necessity of charging away from home decreases even further.

Exhibit 77: Average trip length is only 9.12 miles



Source: Federal Highway Administration, and RBC Capital Markets

To ultimately estimate how extensive and expansive the charging network would have to be in the US depends greatly on the penetration of plug-in vehicles and the mindset of the consumer (how accessible charging must be to ease anxiety). However, the US Department of Energy's National Renewable Energy Laboratory (NREL) attempted to do just that. The NREL concluded that ~8,000 fast charging stations would be necessary in US cities and towns. This amount would allow a BEV to be no more than three miles from a charging station if the stations are uniformly spread out. This would allow for efficient inter and intra city travel, and serve as a safety net for any emergency charging, easing range concern. Below are the NREL's assumptions used to come to their conclusions.

Exhibit 78: NREL assumptions

Variable	Central Scenario
PEV Total	15M (linear growth to 20% of LDV sales in 2030)
PEV Mix (range preference)	Mix PHEV20 10% PHEV50 35% BEV100 15% BEV250 30% PHEV20-SUV 5% BEV250-SUV 5%
Share of PEVs in Cities (w/ pop. > 50k)	83% (based on existing HEVs)
PHEV:BEV Ratio	1:1
PHEV Support	Half of full support
SUV Share	10%
% Home Charging	88%
Interstate Coverage	Full Interstate
Corridor DCFC Spacing	70 miles
DCFC Charge Time	20 minutes (150 kW)

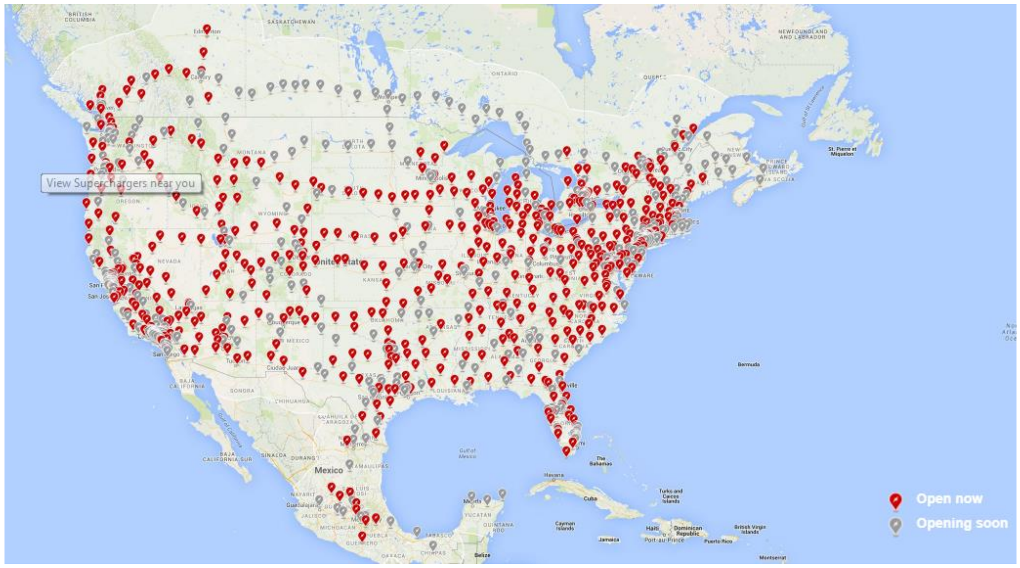
Source: The US Department of Energy's National Renewable Energy Laboratory (NREL)

To undertake the task of building out the necessary infrastructure, several OEMs and other companies have pledged investments. Below is a summary of their initiatives:

Tesla

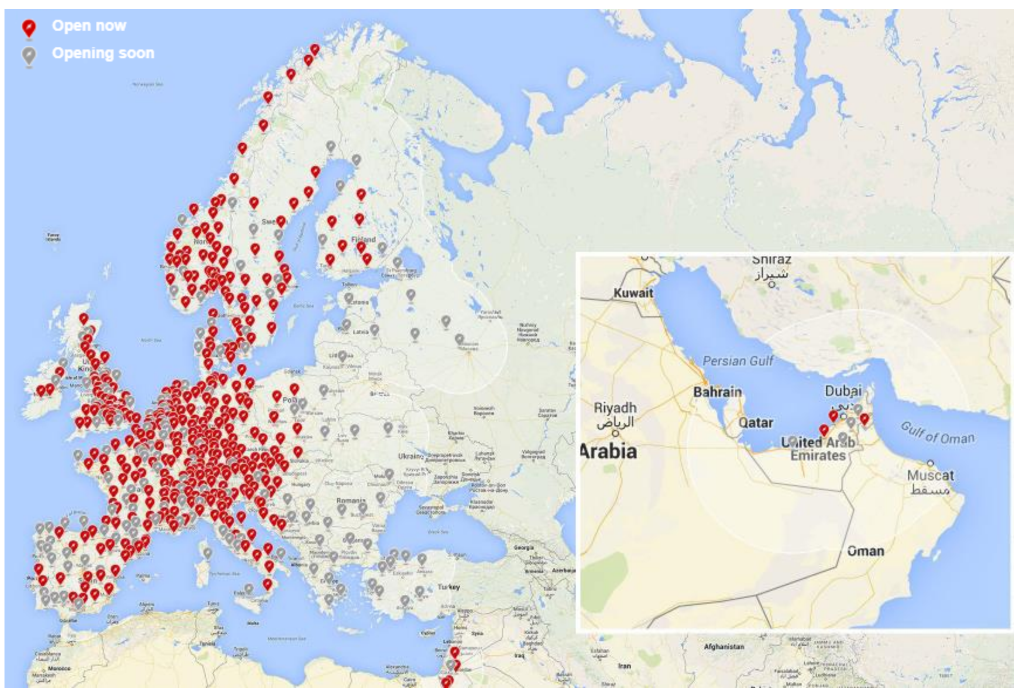
Tesla has already made significant investments in developing a charging network around the world through its Supercharger network. There are currently 1,229 Supercharger stations across the world with 9,623 plugs. The company has stated that it intends to increase the number of chargers to 18,000 around the world by the end of 2018. Despite Tesla's questionable (at best) history of meeting its targets, this is a positive development for the transition to EVs no matter the timeline. The company is looking to expand its Superchargers along main highways as well as destination chargers that will be placed at hotels, restaurants, shopping centers, and resorts to make charging more convenient.

Exhibit 79: Tesla's planned and in service Supercharger network – North America



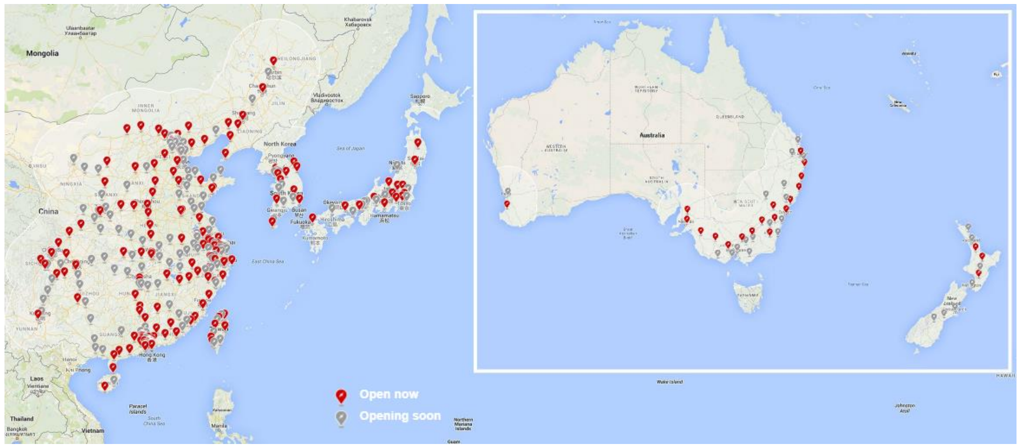
Source: Tesla

Exhibit 80: Tesla's planned and in service Supercharger network – Europe and Middle East



Source: Tesla

Exhibit 81: Tesla's planned and in service Supercharger network – Asia



Source: Tesla

Ionity

BMW, Daimler, Ford, and Volkswagen established this JV to build fast charging stations along major travel routes in Europe. The JV intends to bring ~400 charging stations (one Ionity charging station every 100-200km) by 2020, and will equip these stations with fast charging capability, up to 350kW. Ionity has already established locations in 19 European countries, and has partnered with Shell, Tank & Rast, OMV, and Circle K to help establish sites for ~200 of their upcoming stations. The company is targeting 100 new stations in 2018, and opened its first charging station in April 2018.

Volkswagen

Volkswagen funded Electrify America in 2016 (as required by law after dieselgate), and pledged to invest $2bn over the next 10 years in EV infrastructure and educational programs in the US. Of the $2bn investment, $800mm will be invested in California alone and the remaining $1.2bn will be invested in the remaining states. In the first investment cycle, Electrify America will establish electric vehicle chargers at over 650 community sites and 300 highway sites that will be no more than 120 miles apart and just 70 miles apart on average. Electrify America recently chose its suppliers for the first phase that will provide fast chargers that deliver 20 miles of range per minute of charge.

Exhibit 82: Electrify America's first investment phase plans

Source: Electrify America

Nissan and BMW

Nissan and BMW partnered with EVgo, a fast charging provider, to add 174 fast charging locations in 33 states in the US. Additionally, the two companies planned to add 50 more fast charging stations in 2017.

San Diego Gas & Electric

San Diego Gas & Electric (SDG&E) received approval to build 3,500 charging stations at multi-family communities and workplaces. Additionally, SG&E will build six stations at the Port of San Diego, San Diego International Airport, and other fleet hubs to support eTrucks.

Southern California Edison

Southern California Edison (SCE) has established the Charge Ready program, which is starting a pilot project that will establish 1,500 charging stations within its service territory. Ultimately, SCE will look to build 30,000 stations at an estimated cost of $355mm. The stations will be at workplaces, apartments, and condo complexes.

Pacific Gas & Electric

Pacific Gas and Electric Company (PG&E) instituted a new program called the EV Charge Network that will install 7,500 level 2 chargers at condos, apartments, and workplaces in Northern and Central California. The program will begin in 2018 and go through 2020, and will see PG&E spend $130mm.

Chinese charging infrastructure

In comparison to the US, China's charging infrastructure is much more built out, with over 440,000 outlets in the country (~214,000 of which are public). However, charging stations are condensed around larger cities, making intercity travel more difficult. Therefore, the State Grid Corporation of China (the government owned electric utility company) announced that it will install 120,000 outlets by 2020 that will cover the Beijing-Hebei-Shandong region as well as other major cities and regions to ease concerns of intercity travel. Additionally, ride-hailing company, Didi Chuxing, announced that it will be building a network of EV charging stations, though the company did not state the amount of stations or locations.

Appendix:

Regional assumptions and detailed forecasts

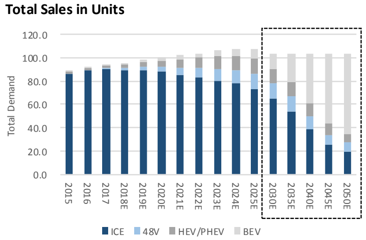
Exhibit 83: Global assumptions and forecast

Demand Assumptions	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
Total Demand	88.2	92.2	94.5	95.9	98.1	100.1	102.0	103.9	106.1	108.0	107.2	103.7	103.7	103.7	103.7	103.7
ICE	97.2%	96.7%	95.4%	93.6%	90.9%	87.8%	83.5%	80.0%	76.1%	72.3%	68.0%	62.3%	52.2%	37.8%	24.4%	19.0%
48V	0.4%	0.4%	0.9%	1.5%	2.8%	4.3%	5.9%	7.7%	9.4%	10.6%	12.7%	13.4%	12.4%	10.0%	8.4%	7.5%
HEV/PHEV	2.0%	2.4%	2.9%	3.5%	4.5%	5.4%	7.4%	8.6%	9.7%	11.0%	11.8%	11.3%	11.7%	10.8%	9.8%	7.4%
BEV	0.3%	0.5%	0.8%	1.4%	1.8%	2.4%	3.2%	3.6%	4.8%	6.1%	7.5%	13.0%	23.7%	41.5%	57.4%	66.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

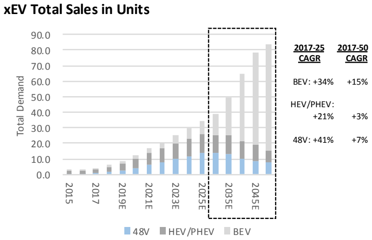
Unit Demand	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
ICE	85.8	89.2	90.1	89.8	89.2	87.9	85.2	83.1	80.7	78.0	72.9	64.6	54.1	39.1	25.3	19.7
48V	0.4	0.4	0.9	1.5	2.8	4.3	6.0	8.0	10.0	11.5	13.7	13.9	12.9	10.4	8.8	7.7
HEV/PHEV	1.8	2.2	2.7	3.4	4.4	5.4	7.6	9.0	10.3	11.9	12.7	11.7	12.1	11.1	10.2	7.7
BEV	0.3	0.4	0.8	1.3	1.8	2.4	3.2	3.8	5.1	6.6	8.0	13.5	24.6	43.0	59.4	68.6

VIO Detail	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
ICE	1,273.0	1,303.6	1,331.5	1,357.7	1,382.1	1,404.2	1,422.6	1,438.2	1,449.3	1,457.3	1,459.8	1,451.5	1,399.9	1,298.6	1,151.1	991.9
48V	0.8	1.1	2.0	3.3	5.9	9.9	15.5	22.8	31.6	41.5	53.1	108.7	144.1	162.7	167.8	166.3
HEV/PHEV	1.3	3.5	6.0	9.0	12.9	17.6	24.2	31.8	40.4	50.1	60.1	104.9	131.9	151.0	161.5	161.9
BEV	0.8	1.2	1.9	3.2	4.8	7.0	9.9	13.2	17.7	23.7	30.9	79.4	157.5	291.2	482.1	699.6
ICE VIO Penetration	99.8%	99.6%	99.3%	98.9%	98.3%	97.6%	96.6%	95.5%	94.2%	92.7%	91.0%	83.2%	76.4%	68.2%	58.7%	49.1%
48V VIO Penetration	0.1%	0.1%	0.1%	0.2%	0.4%	0.7%	1.1%	1.5%	2.1%	2.6%	3.3%	6.2%	7.9%	8.5%	8.5%	8.2%
HEV/PHEV VIO Penetration	0.1%	0.3%	0.4%	0.7%	0.9%	1.2%	1.6%	2.1%	2.6%	3.2%	3.7%	6.0%	7.2%	7.9%	8.2%	8.0%
BEV VIO Penetration	0.1%	0.1%	0.1%	0.2%	0.3%	0.5%	0.7%	0.9%	1.1%	1.5%	1.9%	4.5%	8.6%	15.3%	24.6%	34.6%

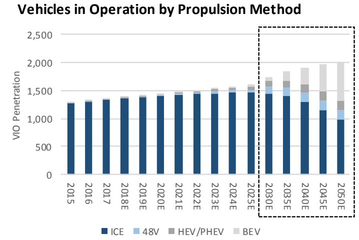
Total Sales in Units



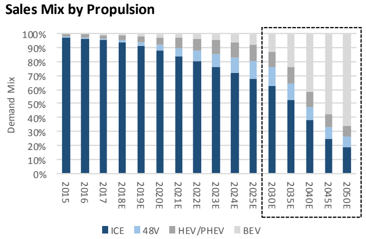
xEV Total Sales in Units



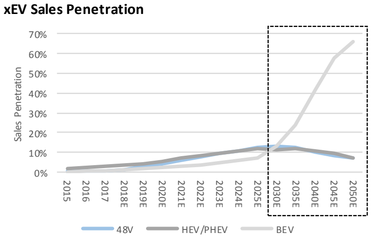
Vehicles in Operation by Propulsion Method



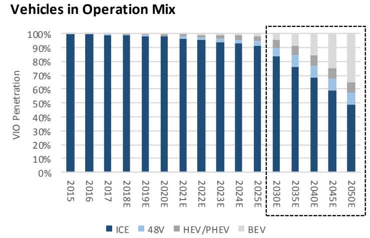
Sales Mix by Propulsion



xEV Sales Penetration



Vehicles in Operation Mix

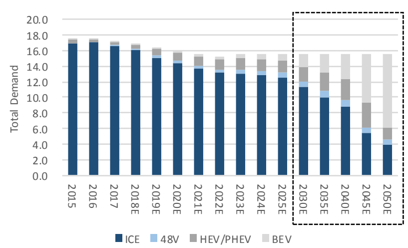


Source: US Energy Information Administration and RBC Capital Markets

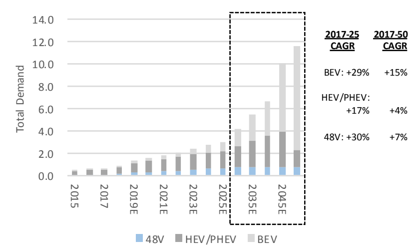
Exhibit 84: United States assumptions and forecast

Demand Assumptions	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
Total Demand	17.5	17.6	17.2	16.9	16.4	16.0	15.5	15.2	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5
ICE	97.1%	96.9%	96.3%	94.6%	92.0%	89.9%	88.2%	86.5%	84.6%	82.5%	80.8%	73.0%	65.0%	57.0%	35.0%	25.0%
48V	0.1%	0.2%	0.5%	0.9%	1.5%	2.0%	2.4%	2.9%	3.3%	3.7%	4.1%	5.0%	5.0%	5.0%	5.0%	5.0%
HEV/PHEV	2.4%	2.4%	2.7%	3.4%	5.3%	6.2%	7.2%	8.1%	9.1%	9.8%	10.1%	12.0%	15.0%	18.0%	20.0%	10.0%
BEV	0.4%	0.5%	0.6%	1.1%	1.3%	1.9%	2.1%	2.5%	3.0%	4.0%	5.0%	10.0%	15.0%	20.0%	40.0%	60.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Unit Demand	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
ICE	17.0	17.0	16.6	16.0	15.1	14.4	13.7	13.1	13.1	12.8	12.5	11.3	10.1	8.8	5.4	3.9
48V	0.0	0.0	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.6	0.8	0.8	0.8	0.8	0.8
HEV/PHEV	0.4	0.4	0.5	0.6	0.9	1.0	1.1	1.2	1.4	1.5	1.6	1.9	2.3	2.8	3.1	1.6
BEV	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.6	0.8	1.6	2.3	3.1	6.2	9.3
VIO Detail	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
ICE	259.2	265.5	268.8	271.4	272.9	273.7	273.7	273.2	272.6	271.8	270.7	262.6	250.4	235.1	212.0	182.2
48V	0.1	0.1	0.2	0.3	0.6	0.9	1.2	1.6	2.0	2.5	3.0	5.8	8.2	10.0	11.4	12.4
HEV/PHEV	0.6	1.0	1.4	1.9	2.7	3.5	4.5	5.5	6.6	7.8	9.0	15.3	22.0	29.3	36.7	39.1
BEV	0.2	0.3	0.4	0.5	0.7	1.0	1.3	1.6	2.0	2.5	3.2	8.6	17.0	28.0	47.0	78.7
ICE VIO Penetration	99.7%	99.5%	99.3%	99.0%	98.6%	98.1%	97.5%	96.9%	96.3%	95.5%	94.7%	89.9%	84.2%	77.8%	69.0%	58.3%
48V VIO Penetration	0.0%	0.0%	0.1%	0.1%	0.2%	0.3%	0.4%	0.6%	0.7%	0.9%	1.0%	2.0%	2.8%	3.3%	3.7%	4.0%
HEV/PHEV VIO Penetration	0.2%	0.4%	0.5%	0.7%	1.0%	1.3%	1.6%	1.9%	2.3%	2.7%	3.1%	5.2%	7.4%	9.7%	11.9%	12.5%
BEV VIO Penetration	0.1%	0.1%	0.1%	0.2%	0.3%	0.4%	0.5%	0.6%	0.7%	0.9%	1.1%	2.9%	5.7%	9.3%	15.3%	25.2%

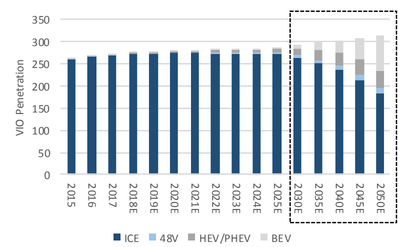
Total Sales in Units



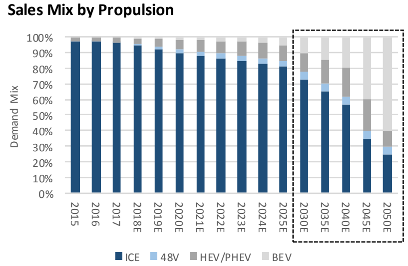
xEV Total Sales in Units



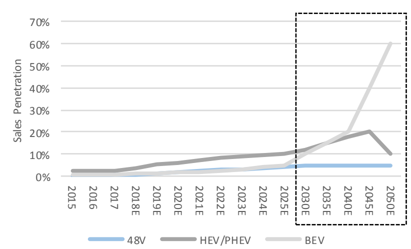
Vehicles in Operation by Propulsion Method



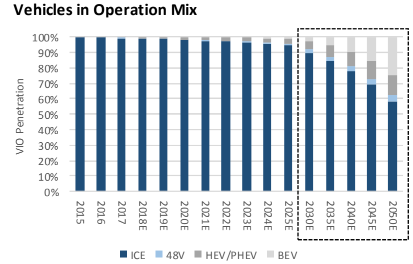
Sales Mix by Propulsion



xEV Sales Penetration



Vehicles in Operation Mix

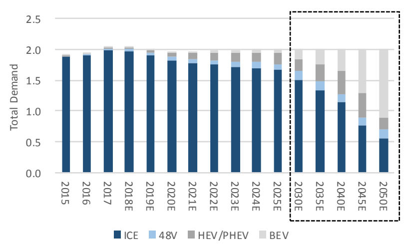


Source: US Energy Information Administration and RBC Capital Markets

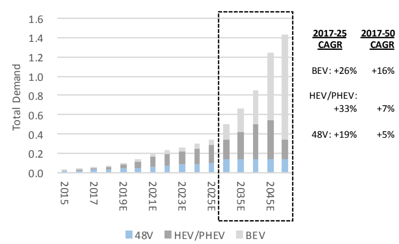
Exhibit 85: Canada assumptions and forecast

Demand Assumptions	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
Total Demand	1.9	1.9	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
ICE	99.0%	98.4%	97.4%	96.7%	94.9%	93.0%	90.5%	88.4%	86.6%	84.9%	82.9%	75.0%	67.0%	57.0%	38.0%	28.0%
48V	0.6%	1.0%	1.2%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%	4.5%	5.0%	7.0%	7.0%	7.0%	7.0%	7.0%
HEV/PHEV	0.1%	0.3%	0.9%	1.5%	2.5%	3.4%	5.3%	6.2%	7.2%	8.1%	9.1%	10.0%	14.0%	18.0%	20.0%	10.0%
BEV	0.3%	0.3%	0.5%	0.4%	0.6%	1.1%	1.3%	1.9%	2.1%	2.5%	3.0%	8.0%	12.0%	18.0%	35.0%	55.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Unit Demand	**2015**	**2016**	**2017**	**2018E**	**2019E**	**2020E**	**2021E**	**2022E**	**2023E**	**2024E**	**2025E**	**2030E**	**2035E**	**2040E**	**2045E**	**2050E**
ICE	1.9	1.9	2.0	2.0	1.9	1.8	1.8	1.7	1.7	1.7	1.7	1.5	1.3	1.1	0.8	0.6
48V	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
HEV/PHEV	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.4	0.2
BEV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.4	0.7	1.1
VIO Detail	**2015**	**2016**	**2017**	**2018E**	**2019E**	**2020E**	**2021E**	**2022E**	**2023E**	**2024E**	**2025E**	**2030E**	**2035E**	**2040E**	**2045E**	**2050E**
ICE	23.2	23.7	24.3	24.8	25.2	25.5	25.8	26.0	26.1	26.3	26.3	26.3	25.5	24.1	21.6	18.4
48V	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.9	1.4	1.6	1.9	2.0
HEV/PHEV	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.5	2.2	3.2	4.1	4.4
BEV	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.7	1.6	2.8	4.9	8.4
ICE VIO Penetration	99.9%	99.7%	99.5%	99.3%	99.0%	98.5%	97.9%	97.2%	96.4%	95.6%	94.6%	89.2%	83.1%	76.0%	66.6%	55.5%
48V VIO Penetration	0.1%	0.1%	0.2%	0.3%	0.5%	0.6%	0.8%	1.0%	1.2%	1.4%	1.7%	3.2%	4.4%	5.2%	5.7%	6.0%
HEV/PHEV VIO Penetration	0.0%	0.1%	0.1%	0.2%	0.4%	0.7%	1.0%	1.4%	1.8%	2.3%	2.8%	5.1%	7.3%	10.0%	12.7%	13.2%
BEV VIO Penetration	0.0%	0.1%	0.1%	0.1%	0.2%	0.2%	0.3%	0.4%	0.5%	0.7%	0.9%	2.5%	5.2%	8.8%	15.0%	25.3%

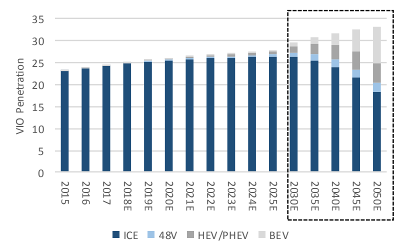
Total Sales in Units



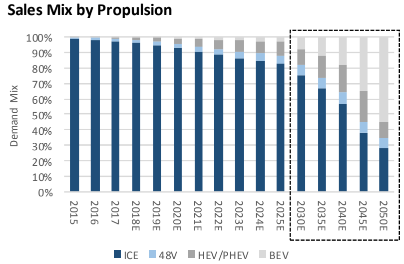
xEV Total Sales in Units



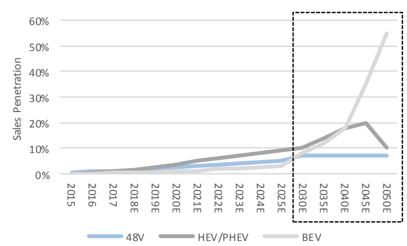
Vehicles in Operation by Propulsion Method



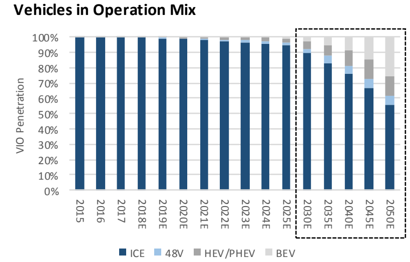
Sales Mix by Propulsion



xEV Sales Penetration



Vehicles in Operation Mix

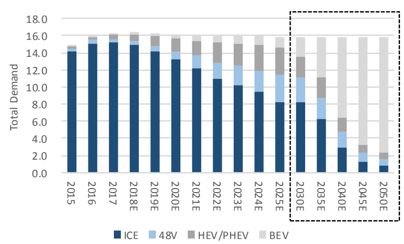


Source: US Energy Information Administration and RBC Capital Markets

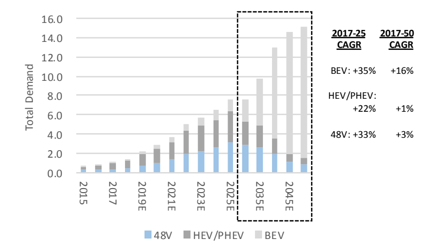
Exhibit 86: Western Europe assumptions and forecast

Demand Assumptions	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
Total Demand	14.9	15.9	16.3	16.4	16.3	16.1	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9
ICE	95.3%	95.3%	93.3%	91.3%	86.8%	82.0%	76.5%	68.5%	64.5%	59.0%	52.0%	52.0%	39.0%	18.0%	8.0%	5.0%
48V	2.2%	2.0%	2.0%	2.5%	4.5%	6.5%	9.0%	12.0%	14.0%	16.0%	20.0%	18.0%	16.0%	12.0%	7.0%	5.0%
HEV/PHEV	2.0%	2.3%	4.0%	5.0%	7.0%	9.0%	11.0%	15.0%	16.5%	18.5%	20.0%	15.0%	15.0%	10.0%	5.0%	5.0%
BEV	0.4%	0.4%	0.7%	1.2%	1.7%	2.5%	3.5%	4.5%	5.0%	6.5%	8.0%	15.0%	30.0%	60.0%	80.0%	85.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Unit Demand	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
ICE	14.2	15.1	15.2	15.0	14.1	13.2	12.2	10.9	10.3	9.4	8.2	8.3	6.2	2.9	1.3	0.8
48V	0.3	0.3	0.3	0.4	0.7	1.0	1.4	1.9	2.2	2.5	3.2	2.9	2.5	1.9	1.1	0.8
HEV/PHEV	0.3	0.4	0.7	0.8	1.1	1.4	1.8	2.4	2.6	2.9	3.2	2.4	2.4	1.6	0.8	0.8
BEV	0.1	0.1	0.1	0.2	0.3	0.4	0.6	0.7	0.8	1.0	1.3	2.4	4.8	9.5	12.7	13.5
VIO Detail	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
ICE	242.8	244.6	246.3	247.7	248.2	247.7	246.3	243.7	240.5	236.7	231.9	209.4	188.0	159.0	125.6	96.2
48V	0.3	0.6	0.9	1.3	1.9	2.9	4.2	5.8	7.8	9.9	12.5	24.1	31.0	33.6	31.9	27.9
HEV/PHEV	0.3	0.7	1.3	2.0	3.0	4.3	5.8	7.9	10.1	12.5	15.0	24.8	29.9	31.6	28.9	24.9
BEV	0.2	0.2	0.3	0.5	0.8	1.1	1.6	2.2	2.9	3.9	5.0	13.2	28.8	59.5	104.8	152.0
ICE VIO Penetration	99.7%	99.4%	99.0%	98.5%	97.7%	96.7%	95.5%	93.8%	92.1%	90.0%	87.7%	77.1%	67.7%	56.0%	43.1%	32.0%
48V VIO Penetration	0.1%	0.3%	0.4%	0.5%	0.8%	1.1%	1.6%	2.2%	3.0%	3.8%	4.7%	8.9%	11.2%	11.8%	11.0%	9.3%
HEV/PHEV VIO Penetration	0.1%	0.3%	0.5%	0.8%	1.2%	1.7%	2.3%	3.0%	3.9%	4.8%	5.7%	9.1%	10.8%	11.1%	9.9%	8.3%
BEV VIO Penetration	0.1%	0.1%	0.1%	0.2%	0.3%	0.4%	0.6%	0.9%	1.1%	1.5%	1.9%	4.9%	10.4%	21.0%	36.0%	50.5%

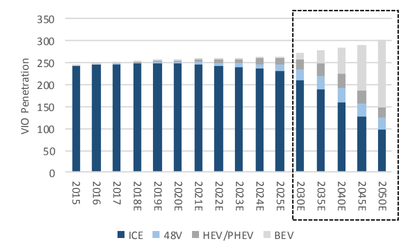
Total Sales in Units



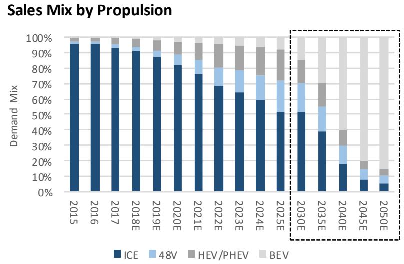
xEV Total Sales in Units



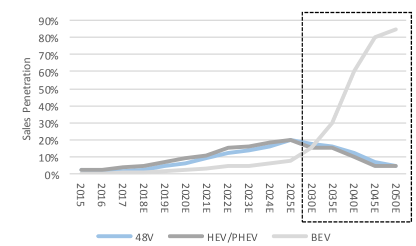
Vehicles in Operation by Propulsion Method



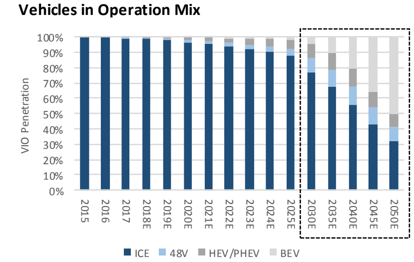
Sales Mix by Propulsion



xEV Sales Penetration



Vehicles in Operation Mix

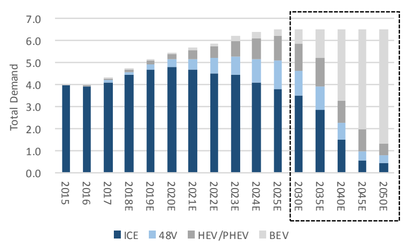


Source: US Energy Information Administration and RBC Capital Markets

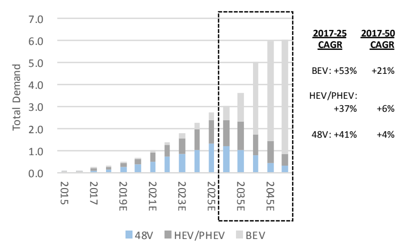
Exhibit 87: Central and Eastern Europe assumptions and forecast

Demand Assumptions	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
Total Demand	4.0	4.0	4.3	4.7	5.1	5.5	5.7	5.9	6.2	6.4	6.5	6.5	6.5	6.5	6.5	6.5
ICE	99.0%	98.8%	95.7%	94.8%	90.8%	87.3%	82.3%	76.5%	71.5%	64.5%	58.5%	53.5%	44.0%	23.0%	8.0%	7.0%
48V	0.4%	0.5%	2.0%	2.5%	4.5%	6.5%	9.0%	12.0%	14.0%	16.0%	20.0%	18.0%	16.0%	12.0%	7.0%	5.0%
HEV/PHEV	0.4%	0.5%	2.0%	2.3%	4.0%	5.0%	7.0%	9.0%	11.0%	15.0%	16.5%	18.5%	20.0%	15.0%	15.0%	8.0%
BEV	0.2%	0.3%	0.3%	0.4%	0.7%	1.2%	1.7%	2.5%	3.5%	4.5%	5.0%	10.0%	20.0%	50.0%	70.0%	80.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Unit Demand	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
ICE	4.0	3.9	4.1	4.5	4.7	4.8	4.7	4.5	4.4	4.1	3.8	3.5	2.9	1.5	0.5	0.5
48V	0.0	0.0	0.1	0.1	0.2	0.4	0.5	0.7	0.9	1.0	1.3	1.2	1.0	0.8	0.5	0.3
HEV/PHEV	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.5	0.7	1.0	1.1	1.2	1.3	1.0	1.0	0.5
BEV	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.3	0.3	0.7	1.3	3.3	4.6	5.2
VIO Detail	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
ICE	137.1	135.6	134.2	133.3	132.7	132.2	131.5	130.8	130.0	128.9	127.5	120.3	112.1	100.5	85.5	70.8
48V	0.2	0.2	0.3	0.4	0.6	0.9	1.4	2.1	2.8	3.8	4.9	10.1	9.1	8.1	6.9	5.9
HEV/PHEV	0.2	0.2	0.3	0.4	0.6	0.8	1.2	1.7	2.3	3.2	4.1	9.0	8.5	7.8	7.2	6.3
BEV	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.6	0.9	1.2	3.5	4.5	7.3	11.1	15.2
ICE VIO Penetration	99.7%	99.6%	99.5%	99.3%	99.0%	98.5%	97.8%	96.9%	95.8%	94.3%	92.6%	84.2%	83.5%	81.3%	77.2%	72.2%
48V VIO Penetration	0.1%	0.2%	0.2%	0.3%	0.5%	0.7%	1.1%	1.5%	2.1%	2.7%	3.6%	7.1%	6.8%	6.5%	6.3%	6.0%
HEV/PHEV VIO Penetration	0.1%	0.2%	0.2%	0.3%	0.4%	0.6%	0.9%	1.2%	1.7%	2.3%	3.0%	6.3%	6.3%	6.3%	6.5%	6.4%
BEV VIO Penetration	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.3%	0.5%	0.7%	0.9%	2.5%	3.3%	5.9%	10.0%	15.5%

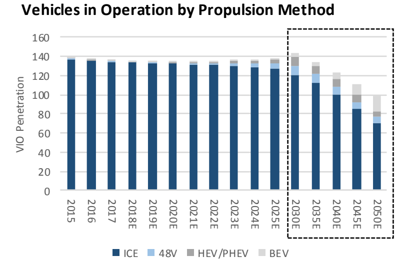
Total Sales in Units



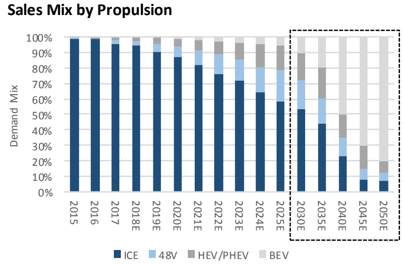
xEV Total Sales in Units



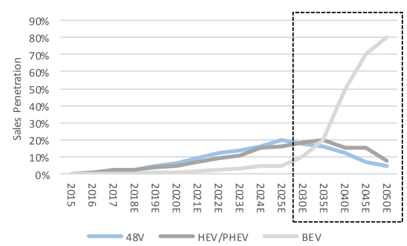
Vehicles in Operation by Propulsion Method



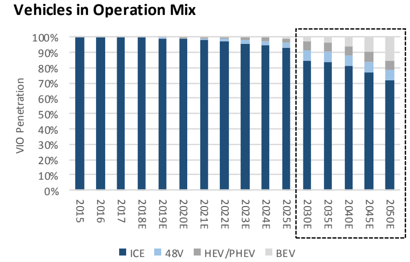
Sales Mix by Propulsion



xEV Sales Penetration



Vehicles in Operation Mix

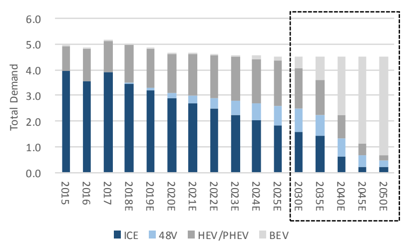


Source: US Energy Information Administration and RBC Capital Markets

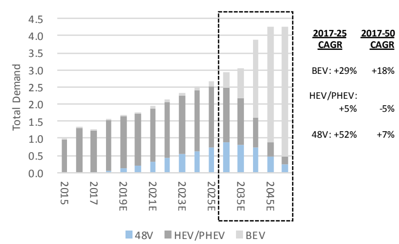
Exhibit 88: Japan assumptions and forecast

Demand Assumptions	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
Total Demand	4.9	4.8	5.1	5.0	4.9	4.7	4.7	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.5
ICE	80.5%	73.2%	76.1%	68.9%	65.8%	62.0%	58.3%	54.0%	49.0%	45.0%	41.0%	35.0%	32.0%	14.0%	5.0%	5.0%
48V	0.0%	0.0%	0.5%	1.0%	2.5%	4.5%	6.5%	9.0%	12.0%	14.0%	16.0%	20.0%	18.0%	16.0%	10.0%	5.0%
HEV/PHEV	19.2%	26.5%	23.1%	29.5%	31.0%	32.5%	34.0%	35.5%	37.0%	38.5%	40.0%	35.0%	30.0%	20.0%	10.0%	5.0%
BEV	0.2%	0.3%	0.3%	0.6%	0.7%	1.0%	1.2%	1.5%	2.0%	2.5%	3.0%	10.0%	20.0%	50.0%	75.0%	85.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Unit Demand	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
ICE	4.0	3.5	3.9	3.5	3.2	2.9	2.7	2.5	2.2	2.0	1.9	1.6	1.4	0.6	0.2	0.2
48V	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.6	0.6	0.7	0.9	0.8	0.7	0.5	0.2
HEV/PHEV	1.0	1.3	1.2	1.5	1.5	1.5	1.6	1.6	1.7	1.8	1.8	1.6	1.4	0.9	0.5	0.2
BEV	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.5	0.9	2.3	3.4	3.8
VIO Detail	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
ICE	77.3	75.8	74.8	73.4	71.8	70.0	68.2	66.3	64.2	62.1	59.9	49.0	40.6	32.6	24.1	17.4
48V	0.0	0.0	0.0	0.1	0.2	0.4	0.7	1.0	1.5	2.1	2.6	5.8	8.2	9.4	9.3	7.9
HEV/PHEV	0.1	1.3	2.4	3.8	5.0	6.2	7.4	8.5	9.7	10.8	11.9	16.5	18.4	18.1	15.6	12.2
BEV	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	1.9	4.9	11.8	23.5	36.8
ICE VIO Penetration	99.8%	98.2%	96.7%	94.9%	93.1%	91.2%	89.2%	87.0%	84.7%	82.3%	79.8%	66.9%	56.3%	45.4%	33.3%	23.4%
48V VIO Penetration	0.0%	0.0%	0.0%	0.1%	0.2%	0.5%	0.9%	1.4%	2.0%	2.7%	3.5%	8.0%	11.4%	13.0%	12.8%	10.7%
HEV/PHEV VIO Penetration	0.1%	1.7%	3.1%	4.9%	6.5%	8.1%	9.7%	11.2%	12.8%	14.3%	15.9%	22.5%	25.6%	25.2%	21.5%	16.4%
BEV VIO Penetration	0.1%	0.1%	0.1%	0.2%	0.2%	0.2%	0.3%	0.4%	0.5%	0.6%	0.8%	2.6%	6.8%	16.4%	32.4%	49.5%

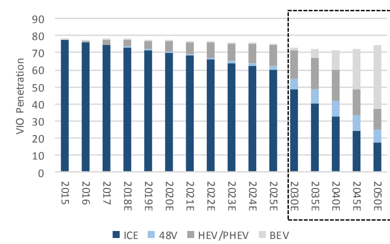
Total Sales in Units



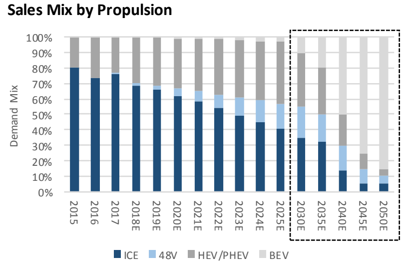
xEV Total Sales in Units



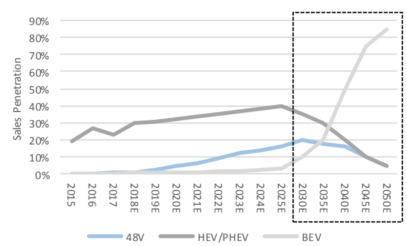
Vehicles in Operation by Propulsion Method



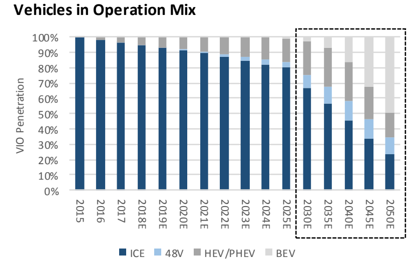
Sales Mix by Propulsion



xEV Sales Penetration



Vehicles in Operation Mix



Source: US Energy Information Administration and RBC Capital Markets

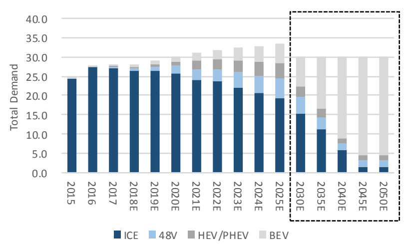
Exhibit 89: China assumptions and forecast

Demand Assumptions	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
Total Demand	24.5	27.6	28.1	28.1	29.2	30.2	31.0	31.7	32.4	33.0	33.5	30.0	30.0	30.0	30.0	30.0
ICE	99.4%	98.9%	96.8%	94.2%	90.5%	85.5%	78.0%	74.5%	68.0%	62.5%	57.6%	51.0%	37.5%	20.0%	5.0%	5.0%
48V	0.0%	0.0%	1.0%	2.0%	4.0%	6.5%	8.0%	10.0%	12.0%	13.0%	15.0%	14.0%	10.0%	5.0%	5.0%	5.0%
HEV/PHEV	0.2%	0.3%	0.6%	0.8%	1.5%	3.0%	7.5%	8.5%	10.0%	12.0%	12.5%	10.0%	7.5%	5.0%	5.0%	5.0%
BEV	0.3%	0.8%	1.7%	3.0%	4.0%	5.0%	6.5%	7.0%	10.0%	12.5%	15.0%	25.0%	45.0%	70.0%	85.0%	85.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

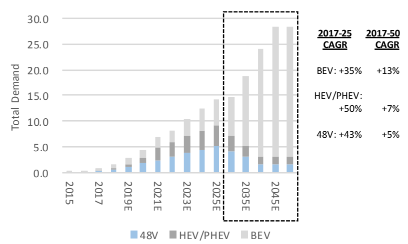
Unit Demand	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
ICE	24.4	27.3	27.2	26.5	26.4	25.8	24.1	23.6	22.0	20.6	19.3	15.3	11.3	6.0	1.5	1.5
48V	0.0	0.0	0.3	0.6	1.2	2.0	2.5	3.2	3.9	4.3	5.0	4.2	3.0	1.5	1.5	1.5
HEV/PHEV	0.1	0.1	0.2	0.2	0.4	0.9	2.3	2.7	3.2	4.0	4.2	3.0	2.3	1.5	1.5	1.5
BEV	0.1	0.2	0.5	0.8	1.2	1.5	2.0	2.2	3.2	4.1	5.0	7.5	13.5	21.0	25.5	25.5

VIO Detail	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
ICE	162.5	182.5	201.5	218.9	235.4	250.7	263.5	275.3	283.6	290.0	294.8	307.6	297.1	265.9	218.2	171.1
48V	0.0	0.0	0.3	0.8	2.0	3.8	6.1	9.0	12.5	16.1	20.4	38.3	46.8	46.3	42.2	39.2
HEV/PHEV	0.1	0.2	0.3	0.5	0.9	1.8	4.0	6.6	9.5	13.0	16.5	30.3	35.8	36.3	34.7	33.5
BEV	0.2	0.5	0.9	1.7	2.8	4.2	6.0	8.0	10.8	14.6	19.1	47.1	91.3	161.6	249.6	333.4
ICE VIO Penetration	99.8%	99.7%	99.3%	98.6%	97.6%	96.2%	94.2%	92.1%	89.6%	86.9%	84.1%	72.7%	63.1%	52.1%	40.1%	29.6%
48V VIO Penetration	0.0%	0.0%	0.1%	0.4%	0.8%	1.5%	2.2%	3.0%	3.9%	4.8%	5.8%	9.1%	9.9%	9.1%	7.8%	6.8%
HEV/PHEV VIO Penetration	0.1%	0.1%	0.2%	0.2%	0.4%	0.7%	1.4%	2.2%	3.0%	3.9%	4.7%	7.2%	7.6%	7.1%	6.4%	5.8%
BEV VIO Penetration	0.1%	0.2%	0.4%	0.8%	1.2%	1.6%	2.1%	2.7%	3.4%	4.4%	5.4%	11.1%	19.4%	31.7%	45.8%	57.8%

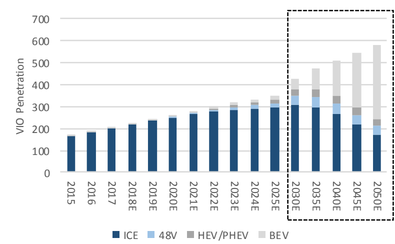
Total Sales in Units



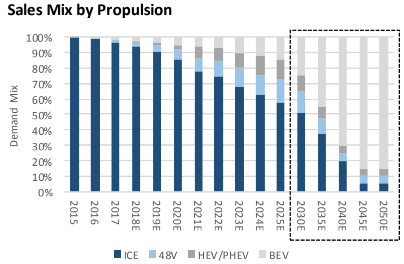
xEV Total Sales in Units



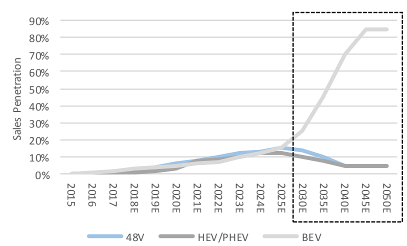
Vehicles in Operation by Propulsion Method



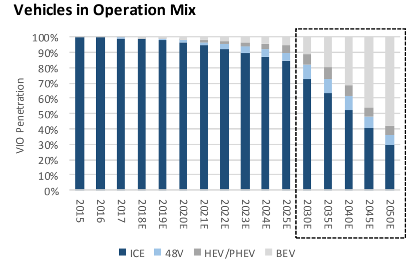
Sales Mix by Propulsion



xEV Sales Penetration



Vehicles in Operation Mix



Source: US Energy Information Administration and RBC Capital Markets

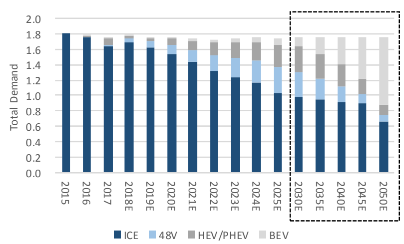
Exhibit 90: South Korea assumptions and forecast

Demand Assumptions	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
Total Demand	1.8	1.8	1.7	1.8	1.8	1.8	1.7	1.7	1.7	1.8	1.7	1.8	1.8	1.8	1.8	1.8
ICE	100.0%	98.6%	94.2%	94.8%	92.0%	87.5%	82.5%	76.5%	71.0%	66.5%	59.0%	56.0%	54.0%	52.0%	51.0%	38.0%
48V	0.0%	0.1%	0.5%	2.5%	4.5%	6.5%	9.0%	12.0%	14.0%	16.0%	20.0%	18.0%	16.0%	12.0%	7.0%	5.0%
HEV/PHEV	0.0%	1.0%	4.6%	2.0%	2.5%	4.5%	6.5%	9.0%	12.0%	14.0%	16.0%	20.0%	18.0%	16.0%	12.0%	7.0%
BEV	0.0%	0.3%	0.7%	0.8%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	5.0%	6.0%	12.0%	20.0%	30.0%	50.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

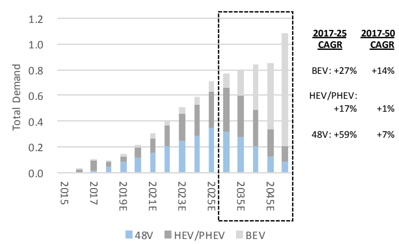
Unit Demand	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
ICE	1.8	1.8	1.6	1.7	1.6	1.5	1.4	1.3	1.2	1.2	1.0	1.0	0.9	0.9	0.9	0.7
48V	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.1	0.1
HEV/PHEV	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.3	0.3	0.2	0.1
BEV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.4	0.5	0.9

VIO Detail	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
ICE	21.0	21.7	22.3	22.8	23.3	23.7	23.9	24.1	24.1	24.1	23.9	22.9	22.0	21.2	20.4	19.2
48V	0.0	0.0	0.0	0.1	0.1	0.2	0.4	0.6	0.8	1.0	1.3	2.7	3.5	3.8	3.7	3.3
HEV/PHEV	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.5	0.7	0.9	1.1	2.4	3.5	4.1	4.3	4.0
BEV	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.8	1.4	2.6	4.4	7.2
ICE VIO Penetration	100.0%	99.9%	99.4%	99.1%	98.5%	97.7%	96.7%	95.3%	93.6%	91.8%	89.6%	79.8%	72.4%	66.7%	62.1%	56.8%
48V VIO Penetration	0.0%	0.0%	0.0%	0.2%	0.6%	1.0%	1.5%	2.3%	3.1%	3.9%	5.0%	9.2%	11.4%	12.1%	11.3%	9.8%
HEV/PHEV VIO Penetration	0.0%	0.1%	0.4%	0.6%	0.7%	1.0%	1.4%	1.9%	2.6%	3.3%	4.2%	8.4%	11.4%	12.9%	13.1%	12.0%
BEV VIO Penetration	0.0%	0.1%	0.1%	0.2%	0.2%	0.3%	0.4%	0.6%	0.7%	0.9%	1.2%	2.6%	4.7%	8.3%	13.5%	21.5%

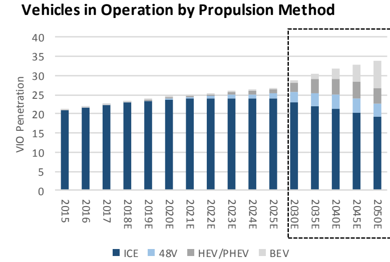
Total Sales in Units



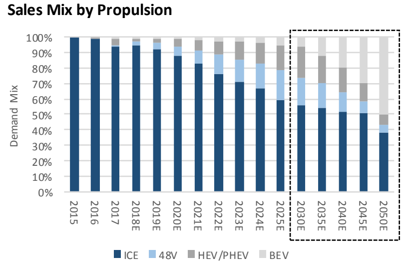
xEV Total Sales in Units



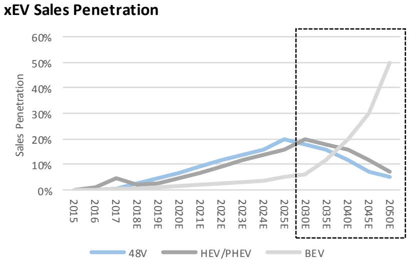
Vehicles in Operation by Propulsion Method



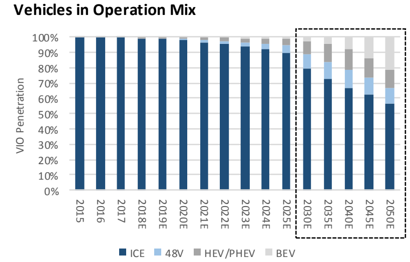
Sales Mix by Propulsion



xEV Sales Penetration



Vehicles in Operation Mix

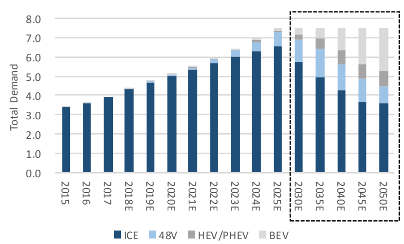


Source: US Energy Information Administration and RBC Capital Markets

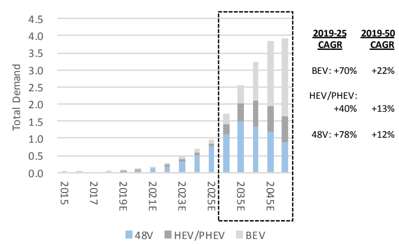
Exhibit 91: India assumptions and forecast

Demand Assumptions	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
Total Demand	3.4	3.6	4.0	4.3	4.7	5.1	5.5	6.0	6.5	7.0	7.5	7.5	7.5	7.5	7.5	7.5
ICE	100.0%	100.0%	100.0%	99.7%	99.1%	98.3%	96.9%	95.6%	93.0%	90.3%	87.0%	77.0%	66.0%	57.0%	49.0%	48.0%
48V	0.0%	0.0%	0.0%	0.0%	0.5%	1.0%	2.0%	3.0%	5.0%	7.0%	10.0%	15.0%	20.0%	18.0%	16.0%	12.0%
HEV/PHEV	0.0%	0.0%	0.0%	0.2%	0.3%	0.5%	0.6%	0.7%	1.0%	1.2%	1.5%	4.0%	7.0%	10.0%	10.0%	10.0%
BEV	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.5%	0.7%	1.0%	1.5%	1.5%	4.0%	7.0%	15.0%	25.0%	30.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Unit Demand	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
ICE	3.4	3.6	4.0	4.3	4.7	5.0	5.3	5.7	6.0	6.3	6.5	5.8	5.0	4.3	3.7	3.6
48V	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.5	0.8	1.1	1.5	1.4	1.2	0.9
HEV/PHEV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.3	0.5	0.8	0.8	0.8
BEV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.3	0.5	1.1	1.9	2.3
VIO Detail	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
ICE	28.9	31.0	33.4	36.1	39.0	42.1	45.3	48.7	52.3	56.0	59.7	75.6	83.5	85.7	84.1	81.3
48V	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.7	1.1	1.8	6.0	11.1	15.4	18.0	18.7
HEV/PHEV	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	1.3	3.0	5.5	7.8	9.6
BEV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	1.3	3.0	6.4	12.3	19.5
ICE VIO Penetration	100.0%	100.0%	100.0%	100.0%	99.8%	99.7%	99.3%	98.9%	98.2%	97.2%	96.0%	89.7%	82.9%	75.8%	68.8%	62.9%
48V VIO Penetration	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.4%	0.7%	1.2%	1.9%	2.9%	7.2%	11.0%	13.7%	14.7%	14.5%
HEV/PHEV VIO Penetration	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%	0.3%	0.4%	0.6%	1.5%	3.0%	4.8%	6.4%	7.5%
BEV VIO Penetration	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.3%	0.4%	0.6%	1.5%	3.0%	5.7%	10.1%	15.1%

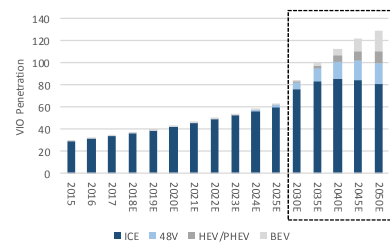
Total Sales in Units



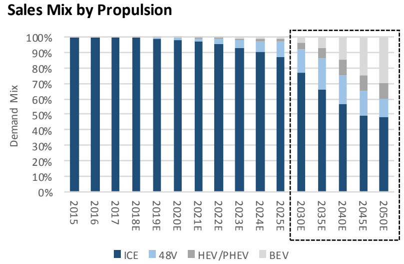
xEV Total Sales in Units



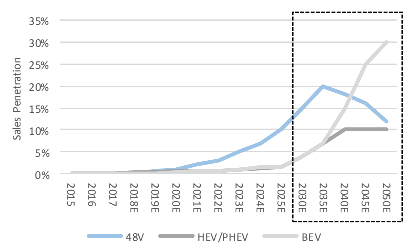
Vehicles in Operation by Propulsion Method



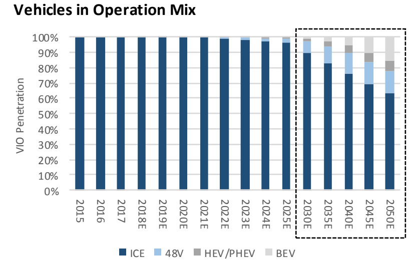
Sales Mix by Propulsion



xEV Sales Penetration



Vehicles in Operation Mix

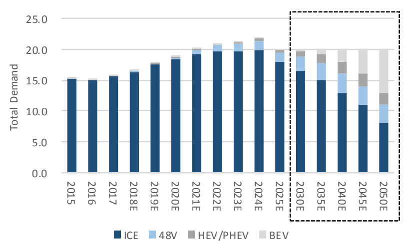


Source: US Energy Information Administration and RBC Capital Markets

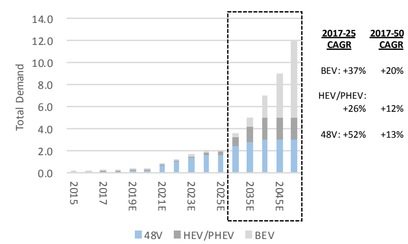
Exhibit 92: Rest of World assumptions and forecast

Demand Assumptions	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
Total Demand	15.3	15.1	15.7	16.5	17.8	18.8	20.1	20.9	21.3	21.9	20.0	20.0	20.0	20.0	20.0	20.0
ICE	99.7%	99.7%	99.3%	99.0%	98.5%	98.0%	95.8%	94.3%	92.3%	90.8%	89.5%	82.0%	75.0%	65.0%	55.0%	40.0%
48V	0.0%	0.0%	0.4%	0.5%	0.7%	1.0%	3.0%	4.5%	6.0%	7.0%	8.0%	12.0%	14.0%	15.0%	15.0%	15.0%
HEV/PHEV	0.2%	0.2%	0.3%	0.4%	0.6%	0.7%	0.8%	0.7%	1.0%	1.2%	1.5%	4.0%	7.0%	10.0%	10.0%	10.0%
BEV	0.1%	0.1%	0.1%	0.2%	0.2%	0.3%	0.4%	0.6%	0.7%	1.0%	1.0%	2.0%	4.0%	10.0%	20.0%	35.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Unit Demand	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
ICE	15.3	15.0	15.6	16.4	17.5	18.5	19.2	19.7	19.7	19.9	17.9	16.4	15.0	13.0	11.0	8.0
48V	0.0	0.0	0.1	0.1	0.1	0.2	0.6	0.9	1.3	1.5	1.6	2.4	2.8	3.0	3.0	3.0
HEV/PHEV	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.1	0.2	0.3	0.3	0.8	1.4	2.0	2.0	2.0
BEV	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.4	0.8	2.0	4.0	7.0
VIO Detail	2015	2016	2017	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2030E	2035E	2040E	2045E	2050E
ICE	321.1	323.2	325.9	329.2	333.5	338.7	344.4	350.3	355.9	361.6	365.0	377.8	380.7	374.6	359.7	335.2
48V	0.2	0.2	0.2	0.3	0.4	0.6	1.1	2.0	3.2	4.6	6.1	14.8	24.9	34.4	42.5	49.0
HEV/PHEV	0.1	0.1	0.2	0.2	0.3	0.4	0.6	0.7	0.9	1.1	1.4	3.8	8.6	15.4	22.3	27.8
BEV	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.5	0.7	0.9	2.2	4.9	11.2	24.5	48.3
ICE VIO Penetration	99.9%	99.9%	99.9%	99.8%	99.7%	99.6%	99.4%	99.1%	98.7%	98.2%	97.8%	94.7%	90.8%	86.0%	80.1%	72.8%
48V VIO Penetration	0.1%	0.0%	0.1%	0.1%	0.1%	0.2%	0.3%	0.6%	0.9%	1.3%	1.6%	3.7%	5.9%	7.9%	9.5%	10.6%
HEV/PHEV VIO Penetration	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%	0.2%	0.3%	0.4%	1.0%	2.0%	3.5%	5.0%	6.0%
BEV VIO Penetration	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%	0.6%	1.2%	2.6%	5.5%	10.5%

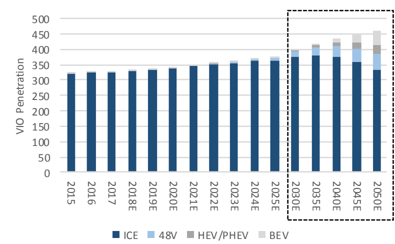
Total Sales in Units



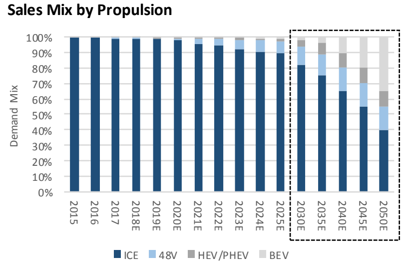
xEV Total Sales in Units



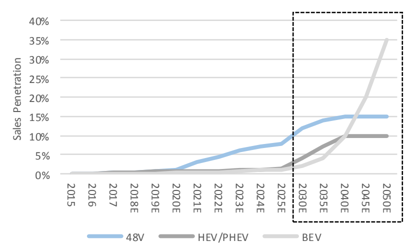
Vehicles in Operation by Propulsion Method



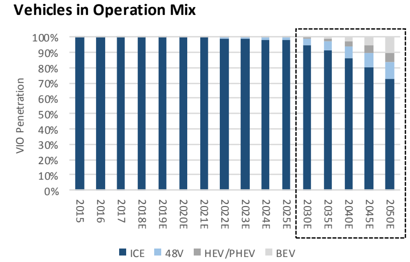
Sales Mix by Propulsion



xEV Sales Penetration



Vehicles in Operation Mix



Source: US Energy Information Administration and RBC Capital Markets

Regulations by region

United States

The US first enacted the Corporate Average Fuel Economy (CAFE) Standards in 1975 to curb vehicle energy consumption. The standards require automakers to meet certain fleet-wide average fuel economy metrics. The most recent iteration of the standards requires MY21 fleets to reach 40.3-41.0 mpg on average and the MY25 fleet to emit 163 grams/mile of CO_2, though these were rejected in April 2018 by the Trump administration. The EPA is working with the auto industry to re-establish more achievable CAFE standards.

The Federal government currently offers an incentive of $2,500-$7,500 for BEVs and PHEVs based on the size of the vehicle and its battery. The tax credit will be phased out once the automaker sells 200,000 qualified electric vehicles. Further, every state except for Alaska, Kansas, North Dakota, and South Dakota offers additional incentives and fee exemptions.

Additionally, the California Air Resource Board (CARB), an organization that reports to the California Governor that is charged with protecting the public from air pollution and fighting climate change, has set unique emission standards to California. The head of CARB has stated that the California Governor, Jerry Brown, has asked CARB to ban new ICE sales by 2040. California represented ~12% of total US new vehicle sales in 2017.

Canada

Canada has largely aligned its greenhouse gas (GHG) regulations with those of the US so as to facilitate trade across the border and to ease some of the burden on the North American automakers. From a national level, Canada does not offer countrywide tax incentives to purchase EVs, but British Columbia, Ontario, and Quebec offer varying amounts of rebates depending on the type of vehicle, battery size, etc. Ontario is particularly focused on driving EV adoption, offering incentives on electric and fuel cell vehicles, promoting the construction of charging stations inter-city, at workplaces, and at private homes through the Electric Vehicle Charging Incentive program. Further, some provinces, like British Columbia, allow plug in electric vehicles and fuel cell vehicles to access HOV lanes independent of the number of passengers in the car.

Western Europe

In 1992, seventeen member European countries outlined their pathway to controlling vehicle emissions through six stages. All new cars sold in the member states must be compliant with the increasingly strict Euro 6 regulation (details below). The major compliance issue with the Euro 6 regulation centers on diesel engines, and requires automakers to add additional content to their vehicles to comply. The ICCT estimates that the cost of compliance for diesel vehicles may be $471-$626 per car.

Exhibit 93: Euro 6 pollutant regulation detail

	Euro 5		Euro 6	
Pollutant	Gasoline	Diesel	Gasoline	Diesel
CO	1.0	0.5	1.0	0.5
HC	0.1		0.1	
HC + NOx		0.23		0.17
Nox	0.06	0.18	0.06	0.08
PM	0.005	0.005	0.005	0.005
PN (#/km)		6.0×10^{11}	6.0×10^{11}	6.0×10^{11}

Source: The International Council on Clean Transportation, and RBC Capital Markets

Additionally, many European countries have implemented their own regulations outside of the European emission standards. Below we list some of the major regulations by country:

Denmark: Electric vehicle purchasers are exempt from registration taxes in Denmark until at least 5,000 new electric vehicles are sold through the 2016-18 time period. After 2018, the government will begin to phase in the registration tax. Beginning in 2019, the registration tax rises to 40% of the standard amount and a 10,000 kroner deduction, then the tax rises to 65% of standard in 2020, 90% in 2021, and 100% in 2022.

France: France has instituted a bonus/malus tax scheme to help promote the adoption of low emission vehicles. In the case of a consumer purchasing a BEV (emitting <20 g/km of CO_2) and PHEVs (emitting 21-60 g/km of CO_2), they would receive a €6,300/€1,000 bonus, respectively. However, if they were to choose a high emission vehicle (>120 g/km of CO_2), the customer would have to pay a tax (or malus) depending on the vehicle and its CO_2 emissions. Additionally, if a customer were to scrap a diesel-powered vehicle in circulation prior to January 1, 2001, they would receive an additional €3,700 bonus. Further, some regions in France offer either a 50% or 100% exemption from registration taxes for alternative energy vehicles.

Additionally, to incentivize companies to transition their fleets to electric vehicles, the country has made BEVs exempt from the company car tax and hybrids (>110 g/km of CO_2) exempt for the first two years after registration.

Ultimately, France will ban the sale of gas and diesel powered vehicles in the country by 2040.

Germany: The country offers a €4,000/€3,000 rebate for BEVs/PHEVs, respectively. Additionally, Germany offers tax exemptions for BEVs/PHEVs for 10 years after purchase between 2011 and 2020 (reduced to five years after 2020): for BEVs, purchasers are fully exempt, and PHEVs are partially exempt depending on the level of CO_2 emissions. Some provinces also offer free parking, dedicated parking, and access to bus lanes for EVs.

Further, Germany considers the private use of a company car as taxable income, and is measured as 1% of the price of the vehicle, which disadvantages EVs as they are often more expensive than their ICE peers. To combat this, Germany allows EV users to offset the tax by €500/kWh (€10,000 max), which is reduced by €50/kWh each year.

Finally, the Bundesrat has suggested that Germany ban the sale of ICE vehicles by 2030, however, this has no authority on the German government. Chancellor Angela Merkel has stated that France and the UK have the right timeline, implying that Germany could pursue a ban on ICE by 2040.

Netherlands: Zero emission vehicles are fully exempt from registration taxes, while low emission vehicles (1-79 g/km of CO_2) fall in the lowest tax bracket, paying €175 plus €6/g of CO_2 emission. Further, zero emission vehicles are exempt from road taxes and a 50% exemption for vehicles with 1-50 g/km of CO_2 emissions. Additionally, certain cities in the Netherlands offer subsidies for EV purchases, the installation of at-home charging stations, and vehicle scrappage.

From a corporate perspective, the Netherlands allows companies to classify the purchase of electric vehicles as an investment under its environmental investment allowance (MIA). You can deduct 36% of the capital investment from taxable profit.

The Netherlands announced that they will be banning the sale of gas and diesel powered vehicles by 2030.

Norway: Norway has a substantial package of incentives for low and zero emission vehicles. For zero emission vehicles, there is no purchase or import tax, the vehicle purchase is exempt from the 25% VAT, and subject to lower annual road taxes. Other perks include exemption from tolls, ferries, free municipal parking, and access to bus lanes. Additionally, company cars have a 50% reduction in tax.

Norway is targeting to have 100% of sales in 2025 be zero emissions (electric or hydrogen) or low emission (PHEV). Interestingly, Norway is not utilizing a full ban on ICE vehicles, but rather utilizing a green tax system based on the polluter pays principle.

Sweden: The country has instituted a rebate for “super green cars,” which offers 40,000kr for purchasers of new zero emission vehicles, and 20,000kr for those who purchase a plug-in electric vehicle. Additionally, super green car purchasers are exempt from annual circulation tax (which is typically based on vehicle weight, fuel type, and CO_2 emissions). For company cars, Sweden offers a rebate that is calculated as 35% of the price difference between the super green car and a comparable ICE vehicle. While an employee using a company car can reduce the value of the car “benefit” by up to 40% if the car is an EV.

United Kingdom: The UK offers a subsidy for low emission vehicles that is based on CO_2 emissions, rather than the actual method of propulsion used within the vehicle. A vehicle is eligible for the subsidy of 25% of the vehicle’s cost (up to £5,000) if its CO_2 emissions are less than 75 g/km. Further tax incentives include exemption from the UK’s excise duty if CO_2 emissions are less than 100 g/km, and exemption from income taxes and national insurance contributions for a corporate car provided to employees for personal use. From a corporate perspective, a company can apply the entire cost of a low emission vehicle (<75 g/km of CO_2) in the first year against taxable income.

Additionally, the UK has pledged to spend £600mm to support the rise of ultra-low emission vehicles. The investment will be used to grow the country’s charging infrastructure, build out the government’s low emission vehicle fleet, continuation of the grant program, and more.

The UK has announced that it will ban the sale of ICE vehicles by 2040.

Central and Eastern Europe

A number of Central and Eastern European countries have enacted some form of incentive to help persuade consumers to shift to alternative energy vehicles, though these tend to be less thorough and aggressive. The majority of the enacted legislation exempts electric vehicles from select taxes (i.e. registration, annual circulation, and company tax). See the below exhibit for a summary of these incentives.

Exhibit 94: Central and Eastern European incentives

Country	Incentive
Bulgaria	EVs exempt from annual circulation tax
Czech Republic	Alternative fuel vehicles are exempt from road tax
Hungary	EVs are exempt from registration tax, annual circulation tax, and company tax
Latvia	EVs are exempt from registration tax, and pay the lowest amount of company car tax
Romania	EVs and hybrids are exempt from registration tax, and EV's are exempt from annual circulation tax
Slovakia	EVs are exempt from circulation tax, while hybrids have a 50% reduction in circulation tax

Source: ACEA, and RBC Capital Markets

Japan

Japan's tailpipe emission standards set similar regulations on light duty vehicles (gas and diesel powered) and automakers as the Euro 6 regulation.

Japan offers tax incentives on tonnage, acquisition, and ownership taxes based on how efficient the specific vehicle is and the type of vehicle (hybrids, PHEVs, BEVs, fuel cell, clean diesel, and gas cars all qualify). The tax break is determined by how much more efficient the vehicle is compared to the standard fuel efficiency of vehicles in 2015. Additionally, local municipalities will offer fee waiver, and access to otherwise restricted roadways.

China

China instituted its first fuel consumption standard framework in 2004. Phase I and II of the framework stated that each individual vehicle model must comply with fuel consumption regulations based on its weight prior to being sold to consumers, as opposed to similar programs in the US, CA, and EU, which apply regulations to fleet average metrics. Phase III and IV of the standards add a corporate-average fuel consumption (CAFC) aspect to the regulation (similar to the US, CA, and EU). Phase IV sets more aggressive consumption targets by 2020.

China has decided to implement a cap-and-trade policy that will begin in 2019, and apply to any OEM that manufactures or imports 30,000 vehicles annually. The policy will require OEM production of alternative energy vehicles to be 10% of their annual volume in 2019, and 12% in 2020. Those who do not meet the production targets will be forced to buy credits from other OEMs who have exceeded the target or face fines. Further, China has established a target for new energy vehicles to comprise ~20% of new vehicle sales by 2025. The country's vice minister of industry has stated that the government has begun researching a potential ban of ICE vehicles, though no date has been officially set yet. We believe that China will likely follow the lead of Germany, the UK, and others and set a 2040 expiration date for ICEs.

China has also instituted tax incentives and rebates in order to make NEVs more attractive to consumers. The government has been offering subsidies to buyers of NEVs of up to 110,000 yuan per unit. Recently, subsidies ended for vehicles with a driving range of under 150km, while vehicles with 300km of driving range will continue to receive the subsidies. Those with driving ranges of over 400km are entitled to greater subsidies. China has also exempted NEVs from purchase, circulation, and ownership taxes.

Locally, there are further subsidies that are available within a 50% limit of the amount granted by the central Chinese government. Additionally, several cities grant NEVs access to bus lanes, free parking/charging, and exempts them from peak hour restrictions to city centers. Further, some Chinese provinces have allowed NEV owners to skip the often long and costly process to obtain a license plate. For example, in Shanghai, a license plate can cost RMB 100k (~$15,800).

South Korea

South Korea's CARB NMOG sets similar regulations on light duty vehicles (gas and diesel powered) and automakers as the Euro 6 regulation. Additionally, South Korea's Plan for Fine Dust Management intends to reduce the amount of diesel vehicles in the country by 77% by 2022, and replace them with electric and fuel cell vehicles.

South Korea offers fairly significant incentives at the Federal and local level. The Federal subsidy for BEVs/PHEVs stands at KRW 14mm/5mm, with an additional KRW 3mm-12mm available at the local level. That's a total of ~$15,800-$24,200 in subsidies per vehicle. Further, South Korea has exempted electric cars from purchase tax surcharges, expressway tolls, parking fees, and lowered insurance premiums.

India

India's Bharat 3 sets similar regulations on light duty vehicles (gas and diesel powered) and automakers as the Euro 6 regulation. India has also established the policy for Faster Adoption and Manufacturing of Hybrid and Electric vehicles (FAME Scheme) which provides support to cities to develop necessary infrastructure, domestic EV manufacturing support, and consumer incentives for the adoption of electric vehicles.

While there are currently no Federal incentives offered for electric vehicles (though there are reports that these are being discussed), there are some local tax exemptions and subsidies offered. Several states fully or partially exempt EVs from VATs, while Delhi also offers a 15% subsidy on some electric cars and exempts those vehicles from road taxes and registration fees.

Companies mentioned

Adient Public Limited Company (NYSE: ADNT US; $56.13; Sector Perform)
Allison Transmission Holdings Inc (NYSE: ALSN.N; $41.96; Sector Perform)
American Axle & Manufacturing Holdings Inc. (NYSE: AXL; $15.49; Outperform)
Aptiv PLC (NYSE: APTV US; $96.06; Outperform)
Autoliv Inc. (NYSE: ALV; $141.67; Sector Perform)
BorgWarner Inc. (NYSE: BWA; $50.48; Outperform)
Cummins Inc (NYSE: CMI; $146.12; Sector Perform)
Dana Incorporated (NYSE: DAN; $23.99; Outperform)
Delphi Technologies PLC (NYSE: DLPH US; $50.19; Outperform)
Ford Motor Co. (NYSE: F; $11.21; Sector Perform)
General Motors Company (NYSE: GM; $37.16; Outperform)
GKN PLC (LSE: GKN LN; GBp473.90; Not Rated)
Honeywell International Inc. (NYSE: HON; $147.30; Sector Perform)
Lear Corp. (NYSE: LEA; $194.35; Outperform)
Linamar Corporation (TSX: LNR.TO; C$74.79; Sector Perform)
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Tenneco Inc. (NYSE: TEN; $46.24; Sector Perform)
Tesla Inc. (NASDAQ: TSLA; $305.02; Sector Perform)
Visteon Corporation (NASDAQ: VC US; $129.23; Sector Perform)
WABCO Holdings, Inc. (NYSE: WBC; $129.73; Outperform)

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