Deutsche Bank
Markets Research

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Industry
Electric & Autonomous Truck Technology

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North America
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Industrials
Machinery

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F.I.T.T. for investors

The Times, They Are A-Charging

Investor debate over the path for truck technology has intensified

DB has published a number of reports focused on four key 'Mega Themes' that have the potential to disrupt the transportation landscape: Electrification, Autonomous Vehicles, New Mobility Models, and Connected Cars. Up until this point, our analysis has focused on the light vehicle market; in this report, we extend our work to commercial vehicles, bringing together thoughts from DB's Machinery, Autos, Transportation, Metals & Mining, and Semiconductor analysts across the globe.

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Electrification: possible, even for line-haul trucking

The consensus view is that while there is a strong case for electrification of medium-duty trucks (we agree), there is little promise of widespread adoption for Class 8 line-haul, given several challenges – cost, weight, range, and infrastructure. Interestingly, we find that while an electric drivetrain adds $48k of cost vs. an ICE, the weight impact is negligible. However, fleet owners base their purchase decisions on payback periods, and we see scope for this to fall to <2 years by 2022, as battery costs continue to decline. That said, the payback period stands at ~3 years today, limiting near-term adoption given trucking companies' preference for an 18-24 month payback. Net/net, we forecast 10% and 15% penetration in terms of production for NAFTA Class 8 and Classes 5-7, respectively, by 2027, but much a slower ramp in Europe (2% by 2024). We believe our NAFTA adoption forecasts are above Street expectations.

Electrification: stock implications

The impact of electrification on truck OEMs is difficult to gauge, since electric trucks remain in the development stage, making market share shifts impossible to judge. We do know that Tesla will be a new entrant in a consolidated market, which could negatively effect all existing players (although Daimler seems to be most advanced in the development process). In conjunction with this report, we downgrade ALSN to Sell, largely due to near-term EPS headwinds (tough comps for O&G parts, NA On-Hwy), but long-term electrification risk is also a factor. Sell-rated CMI would also likely to face headwinds given lower A/M parts content in EVs vs. ICEs.

Autonomous: adoption supported by payback, but held up by other factors

It is much easier to argue for increased adoption of driverless trucks, as level 5 automation costs an incremental ~$23k today (but this could fall to $5k over time) vs. the $40-45k annual driver salary. That said, there are exogenous factors that could delay adoption: regulation (i.e. questions over safety) and union pushback; we view these issues as temporary. The DB Autos team believes driverless passenger cars could gain traction as early as 2020, arguably clearing the path for driverless trucks. We expect platooning to be a crucial intermediary step in this process.

Autonomous: stock implications

Globally, we agree that the manufacturers of critical automation components/ software are likely to benefit the most from this trend. We highlight several names: WABCO, Continental, Delphi, Intel/Mobileye, and NVIDIA. We also expect trucking companies to get on board with driverless vehicles, driven by the promise of lower labor costs and a solution to the ongoing driver shortage.

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Executive Summary

Deutsche Bank has published a number of reports focused on four key 'Mega Themes' that have the potential to disrupt the transportation landscape: Electrification, Autonomous Vehicles, New Mobility Models, and Connected Cars. Up until now, most of our reports have focused on potential changes to the light vehicle market, including the competitive landscape for OEMs and suppliers. In this report, we extend our work to commercial vehicles, as we expect debate over potential disruption to gain prominence as Tesla (covered by Rod Lache, Hold, price: $355.43) unveils its Class 8 truck, expected in late September.

At a high level, our conclusions are as follows:

Electrification: Possible, Even For Line Haul

- **A relatively short payback period could drive faster than expected penetration of electric Class 8 trucks**, but there are still problems that must be solved before widespread adoption can take place. That said, electric trucks may be more performance competitors than many investors perceive. We calculate a ~3-year payback period today, admittedly outside of trucking companies' preferred 18-24 month zone, but based on our Auto team's expectation for battery costs to fall to $100/kWh by 2022 (vs. $170/kWh today), the payback could drop to <2 years by this time.

  In the near-term, adoption is likely to be constrained by this slightly extended payback, concerns over driving range and thus, charging infrastructure. That said, investors may be surprised at the speed at which infrastructure can be built out (Tesla has constructed 830 SuperCharger locations in 31 countries to date, expected to double in 2017). However, the short driving range (~200 miles) is likely to constrain the market to specific use cases, until battery technology improves/costs decline. We forecast 10% adoption by 2027 within the NAFTA Class 8 market.

- **The shorter, closed-loop nature of typical medium-duty truck routes should yield faster adoption of electric trucks vs. heavy-duty**. Range is not a major concern for medium-duty trucks, given that they tend to drive much shorter routes (well below 200 miles/day), haul less tonnage, and often follow closed-loop networks, allowing for nighttime charging. As such, we agree with consensus on this topic – medium-duty adoption of electric vehicles is likely to be much faster than with heavy-duty trucks. We project 15% adoption by 2027 within the NAFTA Class 5-7 market.

- **OEMs that offer the best payback period/total cost of ownership are likely to win share**. Tesla will be a new entrant in the market, which presents risk to existing OEMs in itself (Daimler, Volvo, Navistar, PACCAR) – we believe the company that provides the best combination of average selling price with battery range/cost will win, and Tesla will have many advantages in this regard. Nonetheless, today it seems that all OEMs are developing electric trucks with range in the ~200 mile zone, which shifts the focus to the ASP. At this point, Daimler, MAN/Scania and Tesla appear to be preparing to launch electric truck offerings, so they could potentially have a head start vs. Navistar and PACCAR.

- **Legacy components suppliers could face significant headwinds**. This centers around components that will be phased out in a fully electric world, such as the transmission (Allison Transmission) and engine (Cummins). Note that in conjunction with this report, we have downgraded Allison Transmission (covered by Nicole DeBlase) to Sell (price as of 8/31: $34.54), as we match longer-term electrification concerns with shorter-term earnings headwinds.

Autonomous: Adoption Supported by Payback

- **Overall, it is much easier to argue for increasing adoption of autonomous technology within the truck market**, particularly heavy-duty trucks, given an easy payback hurdle – level 5 automation systems cost an incremental ~$23k today (although this could decline to $5k in the future), while a the average truck driver earns ~$40-45k annually. However, we believe that regulatory concerns (safety in particular) and union pushback could delay adoption. That said, our global autos team believes that driverless passenger vehicles could become widespread around 2020, and driverless trucks should follow closely behind – perhaps by 2025.
- **In the meantime, we expect fleet owners to deploy more automation technology, in the level 2-3 zone**. This is supported by clear benefits to safety statistics and fuel efficiency; we believe fleet owners will move to platooning (already being testing globally) as it is the next step towards driverless trucks, which will help to address the ongoing driver shortage.
- **Key beneficiaries of the ongoing movement towards autonomous trucks are key components suppliers,** including WABCO, Continental, Delphi, Intel/Mobileye, and NVIDA, among others. We do not expect OEMs to be impacted significantly.

Electric Trucks: Possible, Even For Line-Haul

The consensus view among the investment community is that while there is a strong case for electrification of medium-duty commercial vehicles (we agree), there is little promise of widespread adoption for Class 8 line-haul trucks. We understand the line of thinking given a number of obvious challenges – cost, weight, range and infrastructure, for instance – however, fleet owners base their decisions on payback periods, and we see scope for this to fall to <2 years by 2022, as battery costs continue to decline (this could also be impacted by new government incentives/subsidies).

That said, we calculate a ~3 year payback period today, which probably limits near-term adoption, given that trucking companies tend to seek an 18-24 month payback on new investments. Moreover, driving range will have a considerable impact on the adoption curve; so far, electric trucks announced by MAN/Scania and Daimler (Buy, price: EUR 61.59) will come to market with just 200 miles of range, addressing just ~20% of the NAFTA Class 8 truck market today, barring significant infrastructure investment. A recent Reuters article suggested that Tesla could launch an electric truck with up to 300 miles of range, which could expand the addressable market considerably.

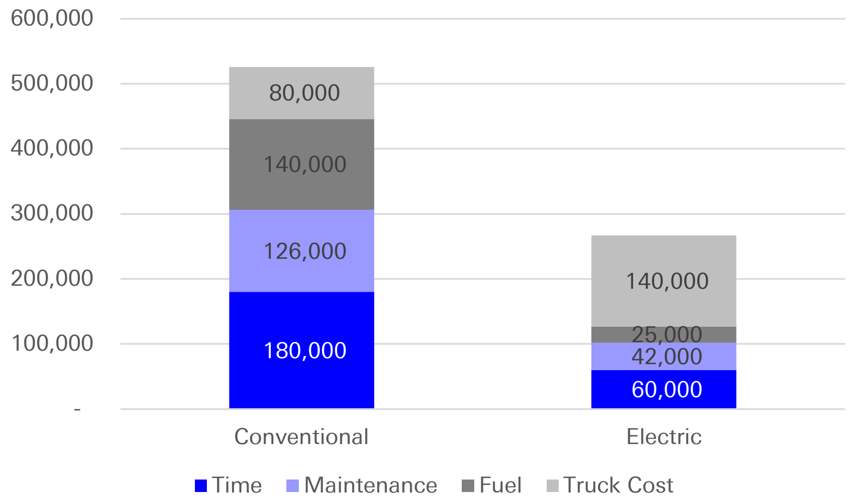
Consensus is skeptical on electrification of Class 8 line-haul trucks, due to four key concerns

Over the past several months, we have observed an influx of investor interest in the potential for electrification of commercial vehicles, particularly Class 8 line-haul trucks. We believe two major developments have precipitated these discussions: 1) faster than expected traction of electrification within the passenger vehicle market; and 2) Tesla's forthcoming heavy-duty truck announcement, which is currently planned for late September.

While most investors agree that electric medium-duty vehicles will soon be viable, the consensus view is that this is a long way off for Class 8 line-haul trucks. It is somewhat easy to argue for increasing adoption of electric powertrains in vehicles that run along shorter, closed-loop networks, given that battery capacity and charging infrastructure are key concerns. We do not dispute this – we also agree that within the commercial vehicle market, medium-duty trucks have the fewest barriers to adoption.

We recently attended ACT's annual seminar, which included a presentation from Motiv, a Bay Area-domiciled company that converts various types of medium-duty vehicles from internal combustion engines (ICE) to electric drivetrains. The company estimates that the total cost of ownership of a medium-duty truck can be reduced by $260k (49%) through electrification. We believe this proves the point that medium-duty trucks are likely to be early adopters of electric powertrain technology.

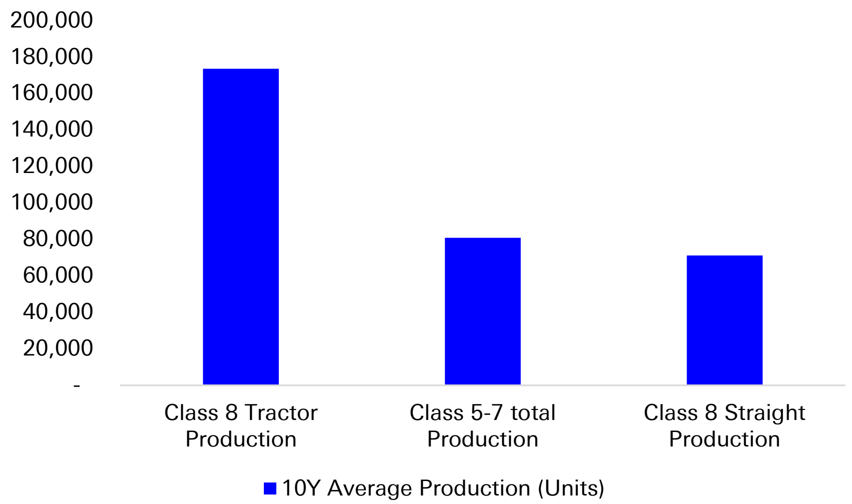
Figure 1: As per Motiv (a medium-duty EV conversion company), the total cost of ownership is $260k lower (over 8-year useful life) than an ICE-powered version



Source: Deutsche Bank, Company Information

However, the Class 8 line-haul market is far larger than Class 8 vocational or medium-duty in unit volume, and we believe this explains Tesla's choice to start there.

Figure 2: Class 8 tractors have averaged higher unit production than Class 5-7 truck and Class 8 straight combined, in the last 10 years (on average)



Source: Deutsche Bank, ACT research
Note: Class 5-7 is trucks only

Four major reasons for skepticism around Class 8 line-haul electrification. It is not entirely surprising that investors have doubts about the potential for widespread electrification of Class 8 line-haul trucks; we highlight four major consensus opinions underpinning this view.

1) Cost

There is not yet much visibility into how electric trucks will be priced; only Chinese player BYD has a product on the market today (see Figure 74 for a full run-down of currently available commercial vehicles), and it is currently priced at $300,000, over 2x the cost of a combustion-engine powered Class 8 truck. This is of particular importance given that fleet owners make decisions based on the total cost of ownership calculation, much different than consumers, who make more emotional decisions (style, eco-conscious, etc).

2) Weight

The energy density of Tesla's battery packs is currently just 155 Wh/kg, far lower than 12,900 Wh/kg for gasoline and 13,300 Wh/kg for diesel. Therefore, the implication is that electric trucks would have to carry a prohibitive amount of battery weight in order to travel a long distance, which reduces haulage capacity, given the current 80,000 lb. weight limit in the US.

3) Range

Expanding upon the weight concern above, reduced energy density of batteries also implies a trade-off between battery weight and driving range. This is also a problem since the average Class 8 truck covers 100,000 miles per year, equating to ~300 miles/day (based on a 6-day work week). This is considerably higher than the 10,000-12,000 annual miles driven by the typical passenger vehicle.

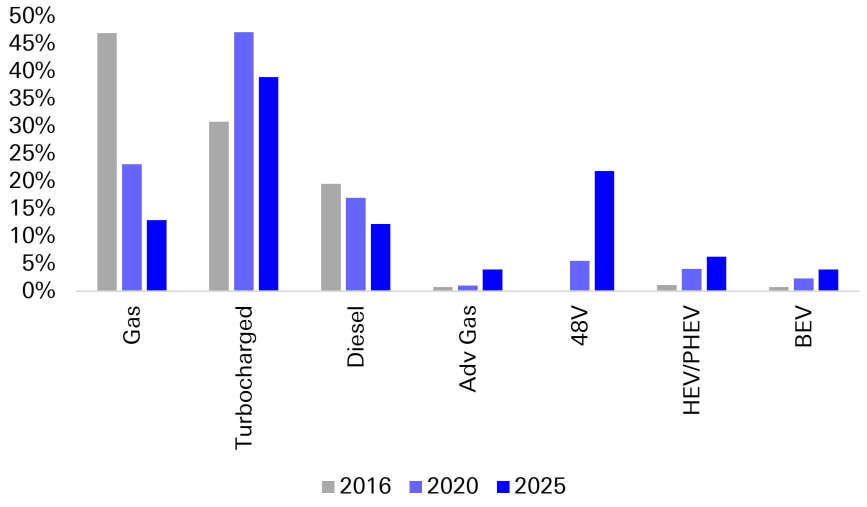
4) Infrastructure/recharging

As of today, there is no battery charging infrastructure that specifically accommodates heavy-duty trucks, and given the question of battery weight/range, this could certainly limit adoption of fully electric trucks. In addition, recharge times may be relatively high given the size of the batteries required to power a Class 8 truck.

We propose a few factors that could drive faster than expected electrification of Class 8 line-haul trucks

Deutsche Bank's global Autos team does believe that we are approaching an inflection point on the adoption curve for electric light vehicles, as the powertrain approaches cost parity with internal combustion engines; our Autos team estimates that this is likely to occur sometime close to 2030.

Figure 3: The DB Autos team forecasts increasing EV penetration of light vehicle sales in major markets



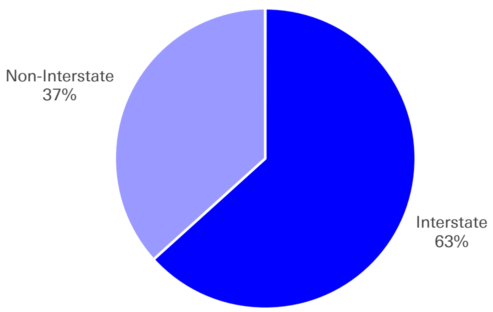
Source: Deutsche Bank, IHS, Industry Contacts
Note: Major markets includes NA, Europe & China

But as noted in the previous section, the consensus view is that cost and performance parity for electric Class 8 line-haul trucks will take even longer than for passenger vehicles. We've revisited this line of thinking, prompted by comments from Tesla suggesting that its forthcoming heavy-duty truck will be both financially and operationally compelling for fleet owners.

Interestingly, we have come up with at least four key differences between electric light and commercial vehicles that could actually argue favorably for electrification of trucks:

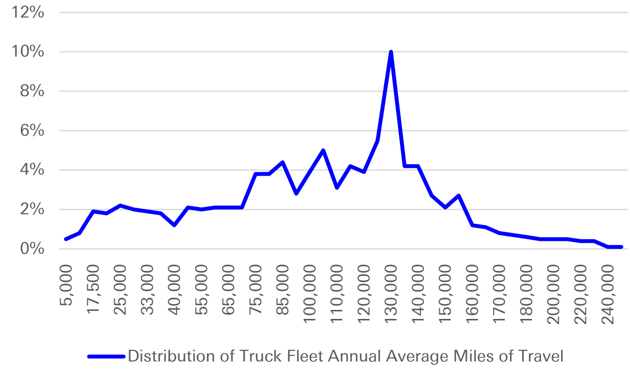
- **More expensive conventional powertrains**: When we sum the cost of a typical truck powertrain (including the engine, transmission, differentials, fuel systems, exhausts, emission systems), we come to a range of $35-40k, significantly more expensive than $3.5-5k for a typical light vehicle.
- **Greater annual mileage**: Payback periods of electric vehicles are greatly influenced by miles driven, given that the cost in mi/kWh is far lower for batteries than for fossil fuels. As such, the greater annual mileage of a truck (100k mi/year) vs. a light vehicle (10-12k) significantly improves the economics.
- **Routes provide opportunity for recharging**: Roughly two-thirds of miles driven by Class 8 line-haul trucks occur on highways, and drivers typically spend 2-3 hours per day at loading docks, which could provide a recharging opportunity.
- **Not all Class 8 trucks drive >200 miles per day**: Although the average Class 8 line-haul truck drives ~100k miles per year, equating to ~320 miles per day, there is a (somewhat) normal distribution around this mean. As we show in Figure 5, ~20% of the Class 8 population drives the equivalent of <200 miles per day, and we believe this group of trucks has the greatest near-term potential for electric powertrain adoption given the projected range of new trucks (i.e. Tesla's forthcoming launch).

Figure 4: Roughly two-thirds of annual miles driven by Class 8 line-haul trucks occur on highways



Source: Deutsche Bank, Department of Transportation

Figure 5: The 'typical' Class 8 line-haul truck drives ~100k miles/day, but 20% of the population drives <200 miles/day



Source: Deutsche Bank, US Census Bureau (2002 study – has been discontinued)

We calculate a ~3-year payback for an electric truck vs. a conventional truck, but this could fall to <2 years based on our Auto team's battery cost forecasts

As noted at the beginning of this section, fleet owners broadly base their truck purchase decisions on cost/benefit analysis, focused on the total cost of ownership and/or payback periods. Below, we have worked through an estimate of the payback associated with transitioning from a conventional combustion engine-powered Class 8 truck to one that embeds an electric drivetrain. But we must first add a disclaimer to this analysis: it is based on what we have gleaned about electric truck economics from industry sources, given that there remains plenty of uncertainty over a number of variables, most notably the ASP of forthcoming electric truck offerings.

We come to a 3-year payback period after comparing the higher expected acquisition cost of an electric truck with its lower annual operating costs. DB Autos Analyst Rod Lache expects Tesla's forthcoming heavy-duty truck to be priced at $200,000 (based on management commentary that it will come at a 'slight premium' to the Model X SUV, which is priced at $150,000) for 210 miles of driving range, and so we use this for the purposes of our analysis. This represents a $75,000 premium over a comparable conventional Class 8 truck; however, we estimate that annual operating costs could be reduced by $26,000, which is predicated on $6,500 maintenance cost savings, coupled with $19,500 fuel cost savings (based on 65,000 miles driven annually at a $0.17 cost of driving an electric truck per mile, well below $0.47 for a diesel truck).

A recent Reuters article suggested that Tesla could also launch a model with a 300-mile range, and so we have assumed a $240,000 total acquisition cost and applied the same per-mile fuel/maintenance cost savings (but to 100,000 miles driven annually); this also yielded a ~3-year payback period.

In our view, a ~3-year payback period looks a bit stretched relative to fleet owners' 18-24 month preference – but this ignores any potential benefits from government subsidies/incentives and input cost reduction (particularly battery costs). To this point, DB's Autos team expects battery costs to decline substantially in the coming years, to ~$100/kWh by 2022 (vs. $170/kWh today). Assuming that these savings flow directly to the purchase price, this would reduce the payback period to slightly less than 2 years, in fleet owners' desired range.

Figure 6: We calculate a 3-year payback period (vs. a conventional diesel truck) for an electric truck with a 200-mile range…

200 Mile Range	Electric	ICE
Acquisition Cost	200,000	125,000
Annual Fuel Cost	11,050	30,550
Miles Driven Per Year	65,000	65,000
Cost Per Mile	0.17	0.47
Annual Maintenance Cost	3,250	9,750
Miles Driven Per Year	65,000	65,000
Cost Per Mile	0.05	0.15
Increase in Acquisition Cost		75,000
Decline in Annual Cost		26,000
Payback Period (Years)		**2.9**

Source: Deutsche Bank

Figure 7: …and we calculate a similar payback period for an electric truck with a 300-mile range

300 Mile Range	Electric	ICE
Acquisition Cost	240,000	125,000
Annual Fuel Cost	17,000	47,000
Miles Driven Per Year	100,000	100,000
Cost Per Mile	0.17	0.47
Annual Maintenance Cost	5,000	15,000
Miles Driven Per Year	100,000	100,000
Cost Per Mile	0.05	0.15
Increase in Acquisition Cost		115,000
Decline in Annual Cost		40,000
Payback Period (Years)		**2.9**

Source: Deutsche Bank

Government subsidies could materially reduce our estimated payback period. We will avoid providing great detail around current government subsidies for electric light vehicles, but we have summarized these neatly in Figure 8 below. It is too early to know if the US federal/state governments will come to the conclusion that they should also subsidize electric trucks (there are no government incentives in existence today), but it should be noted that if this changed, it would have a material impact on our payback analysis.

Figure 8: Incentives for electric passenger car purchases have helped drive Tesla's rise in popularity, and also have supported growth of the electric car market from almost non-existent to relevancy on a global scale in just a few years

State	Amount
Federal	$7,500 income tax credit
Arizona	Reduced Vehicle License Tax, Carpool lane access and reduced rates for electric vehicle charging
California	$2,500 rebate (based on income eligibility)
Delaware	$1,000 rebate
Colorado	$5,000 tax credit
Hawaii	Carpool lane access and reduced rates for electric vehicle charging
Louisiana	$6,900 - $9,500 income tax credit, depending on battery choice
Maryland	Funding exhausted for Plug-In Vehicle Excise Tax Credit
	$700 rebate on wall connectors and installation
Massachusetts	$1,000 rebate (funds limited)
Nevada	Carpool lane access and reduced rates for electric vehicle charging
New Jersey	Sales tax exempt
New York	$500 rebate
Oregon	$750 rebate on wall connectors and installation (more for commercial use)
Pennsylvania	$1,750 rebate (first 250 applicants only)
Rhode Island	$2,500 rebate
Washington DC	Excise tax exempt

Source: Deutsche Bank, Tesla
Note: The data captured above applies to the Tesla Model S, as it qualifies for all incentives available at state and federal level. Actual incentive detail (e.g. $ amounts) may vary based on car make/model/year

While the key components of an electric truck with a range of ~200 miles do add a net ~$40k in costs (vs. an ICE-powered version), we were surprised to find that total weight seems comparable. In Figure 9 and Figure 10 below, we analyze the major puts and takes from both a cost and weight perspective, when comparing an electric truck with an ICE-powered truck. Note that everything below should be classified as DB estimates, with the help of various publications/disclosures/company commentary. Moreover, this should only be used as a rough guide – we do not yet know the exact configuration of an electric truck (and won't until Tesla's announcement). For example, we have not included potential weight and cost reductions from axles (as in an electric truck, motors could be applied directly to the wheels), which could subtract another $5,000 and 1,500 lbs. But that said, the point is that we were surprised that the weight of an electric and ICE-powered truck seem pretty comparable, based on what we know today.

The analysis does change a bit for an electric truck with a range of ~300 miles, adding $31k of cost and 2,400 lbs. of additional weight.

Figure 9: The components of an electric truck with ~210 miles of driving range cost ~$40k more than those on a conventional ICE-powered truck

Cost ($)	Deletions	Additions	Net Increase/Decrease	Notes
Battery Pack	-	72,250	72,250	We assume a 425 kWh battery, ~5x the size of that on the Tesla Model S
Electrical Architecture	-	2,800	2,800	We assume a cost 2x that of a light vehicle (~$1,400)
Power Electronics	-	4,000	4,000	Similarly, we also assume a cost 2x that of a light vehicle ($2,000)
Electric Motors	-	2,400	2,400	Tesla has indicated that its Class 8 truck will use a series of E-motors from the Model 3; we assume 4 per truck
Engine	(30,000)	-	(30,000)	Cost of typical new 15L combustion engine
Transmission	(7,000)	4,000	(3,000)	Most trucks are being ordered with AMTs today; Evs only need a simple gearbox
Aftertreatment System	(2,500)	-	(2,500)	Estimated cost of full aftertreatment system
Differentials	(5,500)	-	(5,500)	Estimated cost of two differentials
Fuel System	(400)	-	(400)	Estimated cost of fuel system
Total	**(45,400)**	**85,450**	**40,050**	

Source: Deutsche Bank, Company Information

Figure 10: The components of an electric truck are roughly even with those on a conventional ICE-powered truck in terms of weight, but this only allows for ~210 miles of driving range.

Weight (lbs)	Deletions	Additions	Net Increase/Decrease	Notes
Battery Pack	-	6,000	6,000	Consistent with the added capacity, we also assume that the weight is 5x that of the battery pack on the Tesla Model S
Electrical Architecture	-	-	-	Insignificant incremental weight
Power Electronics	-	-	-	Insignificant incremental weight
Electric Motors	-	280	280	Based on 4 E-motors from the Model 3
Cummins Engine	(2,964)	-	(2,964)	Weight of typical 15L combustion engine
Automated Manual Transmission	(978)	489	(489)	We assume weight of EV transmission is 25% that of AMT
Aftertreatment System	(250)	-	(250)	Estimated weight of full aftertreatment system
Differentials	(800)	-	(800)	Estimated weight of two differentials
Fuel System	(2,100)	-	(2,100)	Estimated weight of fuel system
Total	**(7,092)**	**6,769**	**(323)**	

Source: Deutsche Bank, Company Information

We provide greater detail around the major inputs of our analysis below:

- **Battery pack**: Clearly, this is the heaviest and most costly component found on an electric truck. For illustrative purposes, we have assumed that an electric Class 8 truck carries a 425 kWh battery, which is approximately 5x the size of the first Tesla Model S battery pack. We similarly assume that this battery is 5x as heavy as what is found on the Tesla Model S, implying 6,000 lbs. Based on Tesla's current cost/kWh, we have estimated that this battery would cost $72k, and applying 85% utilization, this implies ~210 miles of driving range (Tesla's ability to utilize Model S packs, from their automated high volume assembly, could represent a sizeable initial cost advantage). This could potentially reduce adoption given the typical 320 miles driven per day; more on this later. Importantly, Tesla management expects its battery costs to drop to $100/kWh (vs. $170/kWh today) by the end of the decade, which would reduce the cost of the battery pack embedded in our analysis to $42k.
- **Electrical architecture**: The 12V electrical architecture (including wire harnesses, junction boxes, terminals, connectors) on a typical light vehicle costs ~$500, while high voltage (400V) architecture for larger electric

passenger cars (i.e. Chevy Bolt, Tesla Model S, Nissan Leaf) has been estimated at ~$1,400. Based on discussions with industry sources, we assume that the electrical architecture of a heavy-duty truck could cost 2x that of a larger electric passenger vehicle, implying $2,800. Note that we assume these components add negligible weight to the truck.

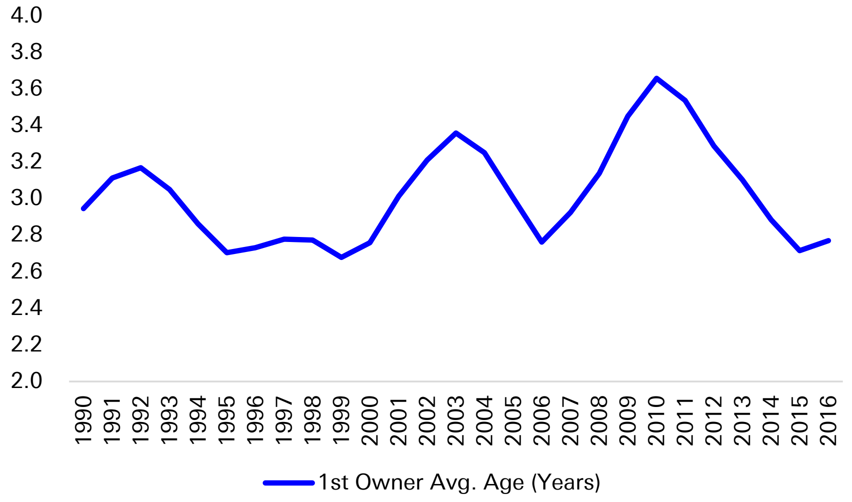
- **Power electronics**: This category of components (including inverters, converters) represents another sizeable cost for an electric vehicle, adding ~$2,000 to the cost of an automobile. We again scale this up by 2x to come up with a heavy-duty truck estimate, to ~$4,000. Similar to the electrical architecture, we do not assume the power electronics add substantial weight to the vehicle.
- **Electric motors**: Tesla has indicated that its Class 8 truck will utilize a number of relatively low-cost E-Motors from its high volume Model 3 – another potential cost advantage. We assume four E-Motors are incorporated on each truck, costing ~$2,400 in total. Combined, these motors weigh 280 lbs. and are able to generate 1,030 hp of torque.
- **Transmission**: While an electric truck does not require advanced transmission technology (70%+ of new trucks are ordered with an automated manual transmission), it does need a basic gearbox to reduce RPM from the motors to the axles. On this basis, we assume that the gearbox only costs ~$4,000, a bit less than the typical AMT, which costs ~$5,000. It should also weigh far less than an AMT; we assume it weighs ~489 lbs., 50% of the weight of Eaton's Ultrashift transmission.

Note that we have removed three major components that are required for a conventional diesel truck, but not an electric truck: the engine, aftertreatment system, differentials, axles and fuel system. The estimated costs and weights of these items can be found in the analysis tables.

Switching to an electric powertrain could extend the useful life vs. conventional trucks

The average age of a NAFTA Class 8 truck is 6 years; although the useful life is 10 years (or 1m miles), maintenance costs tend to step up materially after the third year, and so most large national fleets only hold their trucks for 2-4 years before trading in. Conversely, owner-operators have a greater tendency to hold trucks until the (typical) 10-year scrappage point.

Figure 11: The average age of a truck among first owners has ranged from 2-4 years for some time now



Source: Deutsche Bank, ACT Research

However, we see the potential for electric truck adoption to extend the average age of Class 8 trucks. For a conventional truck, the engine tends to consume the most parts and require the most maintenance, particularly in years 6-10 of its useful life. With no engine (replaced by a relatively simple electric motor with 1m mile bearings), the focus shifts to the battery. Again using Tesla as a proxy, the company's batteries retain 95% of their original capacity after 1,200 charges (i.e. four years, assuming one full charge/discharge each day, six days per week). Tesla's NCA Lab batteries are projected to retain 80% of their capacity after six years of heavy duty use.

Electric trucks should also cost less to maintain

Lacking traditional oil changes, fuel filters, spark plug replacements and emissions checks, electric drivetrains undoubtedly require far less intensive maintenance. The combined effect of decreased component costs and increased vehicle uptime should benefit fleet owners. Furthermore, although a braking system is clearly required on both ICE and electric-powered vehicles, the regenerative braking systems employed by electric vehicles significantly reduces wear and tear on the brakes.

We see the potential for fleet owners to reduce repair & maintenance spending by up to $10k per year by switching to an electric drivetrain. In Figure 12 and Figure 13 below, we lay out the major operating costs of a heavy-duty truck, and we see that ~10% was allocated to repair & maintenance (R&M) as of 2016 (or $15.6k). A recent publication from PwC suggested that tires represent ~$5k of this annual R&M spending, which would clearly not be eliminated by electrification. However, assuming that the bulk of other maintenance spend could be cut, this provides up to $10k of additional annual savings potential, reducing our theoretical payback period to 1.9 years. This also does not account for the fact that fewer repairs means more uptime (aka revenue generation opportunity), which should allow the truck to drive more miles.

Figure 12: Fuel costs and repair & maintenance together accounted for ~35% of operating costs as of 2015…

Share of Total Operating Cost	2008	2009	2010	2011	2012	2013	2014	2015
Fuel Costs	38%	28%	31%	35%	39%	39%	34%	25%
Lease Payments	13%	18%	12%	11%	11%	10%	13%	14%
Repair & Maintenance	6%	8%	8%	9%	8%	9%	9%	10%
Driver	35%	37%	39%	36%	33%	34%	35%	40%
Other	8%	9%	9%	10%	9%	9%	9%	11%

Source: Deutsche Bank, ATRI (American Transportation Research Institute)

Figure 13: Or about $55,900/year for a truck logging 100,000 miles

HD Tractor Operating Cost per year *	2008	2009	2010	2011	2012	2013	2014	2015
Fuel Costs	$63,300	$40,500	$48,600	$59,000	$64,100	$64,500	$58,300	$40,300
Truck/Trailer Lease or Purchase Payments	$21,300	$25,700	$18,400	$18,900	$17,400	$16,300	$21,500	$23,000
Repair & Maintenance	$10,300	$12,300	$12,400	$15,200	$13,800	$14,800	$15,800	$15,600
Driver	$57,900	$53,100	$60,800	$61,100	$53,300	$56,900	$59,100	$63,000
Other	$12,500	$13,600	$14,600	$16,400	$14,800	$15,000	$15,700	$17,400
TOTAL	**$165,300**	**$145,200**	**$154,800**	**$170,600**	**$163,400**	**$167,500**	**$170,400**	**$159,300**

Source: Deutsche Bank, ATRI
Note: Assumes 100,000 miles traveled per vehicle, per year

But there are still a number of issues that could constrain adoption in the near-term

Admittedly, the result of our payback analysis surprised us – we had expected a much more negative result. However, there are still a number of barriers/uncertainties that are likely to constrain demand for electric heavy-duty trucks in the near-term; so we do not expect to see a material uptick in adoption until 2020, at the earliest. We have come up with five major issues that need to be considered when forecasting the adoption curve:

1) Range/battery technology

Yes, Tesla's forthcoming truck, which is expected to have ~210 miles of driving range, can address ~20% of the current market without dealing with the recharge question (given that this proportion of the market drives 200 miles/day or less, on average), but the average NAFTA Class 8 line-haul truck travels >300 miles/day, and until this range can be extended – perhaps via improved battery technology – it is likely to be a barrier for many fleets. That said, a recent Reuters article speculated that Tesla could launch a Class 8 electric truck with 300 miles of range.

At last year's IAA Commercial Truck trade show, all major European showcased electric trucks; Daimler, for example, has been testing electric LCVs with the Fuso Canter E-Cell since 2010. In the table below, we highlight the heavy truck models that have been revealed by European OEMs thus far, and the range problem highlighted above becomes clear – Daimler's 'Urban Truck' only has a range of 200km, and carries 1.7 tons of extra weight for the battery. That said, Daimler did acknowledge that it expects to see material improvement with respect to range and battery costs over the next decade, with the battery cost expected to decline to EUR200/kWh.

Figure 14: Announced (but not yet available) European OEM electric trucks

Manufacturer	Model	Battery size (kWh)	Range (km)
MAN	e-Truck	NA	200
Mercedes Benz	Urban eTruck	212	200
Mercedes Benz	Fuso Canter E-Cell	70	100

Source: Deutsche Bank, Company Information

2) Residual values

Because national trucking companies tend to trade their trucks in after 2-4 years, residual values are a critical component of their total cost of ownership calculation. We expect many fleet owners to avoid purchasing electric trucks given uncertainty about the trajectory of residual values. That said, this issue could be mitigated based on our prior argument, which suggests that electrification might extend the average age of a truck.

3) Fleet buying behavior

Trucking companies are a conservative bunch – it typically takes a very long time for new technologies to gain widespread acceptance in this market. As such, we would expect the adoption curve to be slow at first, as with nearly all technologies that have gained traction within the trucking space in the past.

4) Charging infrastructure

While we understand that Tesla plans to solve the problem of fast, reliable Supercharging stations, and possibly also very fast battery swap, there are no such facilities available today, and it will a few years to build these out, at a minimum.

Note that today's Tesla SuperChargers deliver 120 kW of power per vehicle, meaning that an hour of charging would yield 70 miles of additional range for an electric truck. That said, the company's next generation SuperChargers are expected to yield 350 kW of power per vehicle, implying 200 miles of range per hour of charging time.

5) Competitive dynamics

Tesla will likely be first to market with a commercially viable electric truck, but it remains unclear how the large global truck OEMs will respond – this market is in its infancy, and fleet owners will not have the number of choices they are used to when purchasing a heavy-duty truck (most national fleet owners prefer to buy from multiple OEMs).

In fact, Cummins just recently announced a new Class 7 electric powertrain, which will be available in 2019 (for urban buses) and 2020 (extended range), implying the potential for other OEMs to come to market with an electric offering in time.

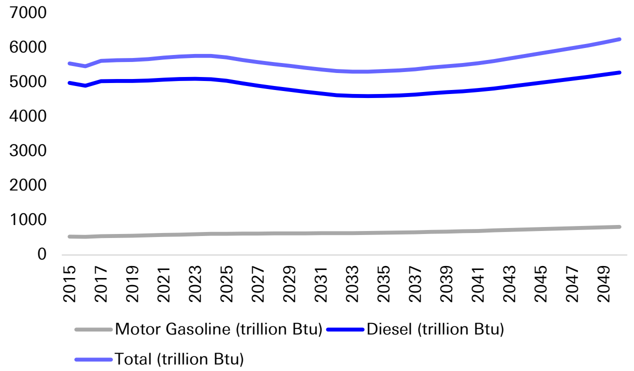
DB electric truck adoption forecasts

EIA forecasts seem far too pessimistic

We think the EIA's EV adoption forecasts are too low. As seen below, the EIA believes that by 2050, alternative fuels will represent ~2.4% of total energy consumed by commercial vehicles (specifically freight trucks) vs. <1% today. Within the mix, electricity is forecasted to grow from just ~0.02% of total alternative fuel consumed to ~10% over the same period. This implies a 24% CAGR in electric energy usage within the commercial truck space through 2050.

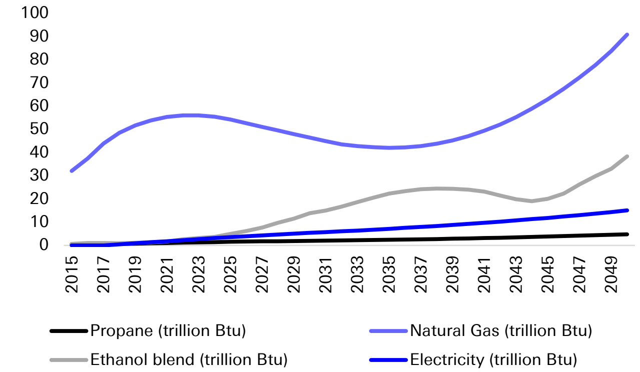
Although this is a robust annual growth rate, if this projection proves correct, by 2050, electricity will still only represent 0.25% of total energy consumed by commercial vehicles. We think this is far too conservative, but wanted to include it in order to illustrate a more bearish case for adoption.

Figure 15: Diesel is expected to remain the dominant fuel source of US freight trucks for the foreseeable future



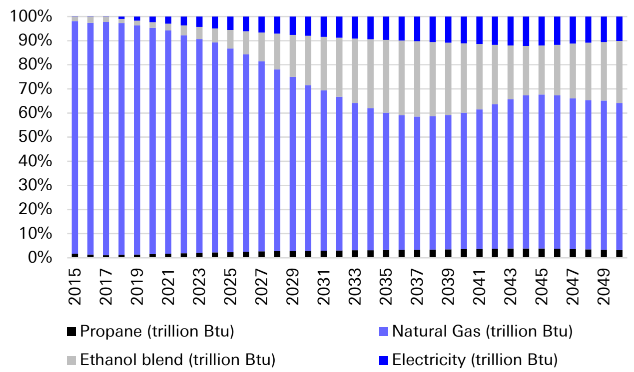
Source: Deutsche Bank, EIA
Note: Does not include commercial buses

Figure 16: Growth in alternative fuels is expected to be robust, but off a very low base



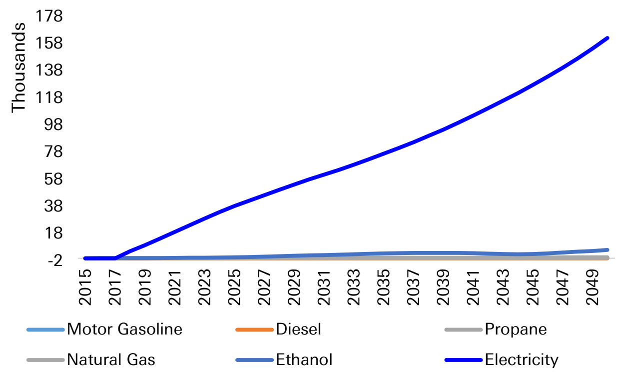
Source: Deutsche Bank, EIA
Note: Does not include commercial buses

Figure 17: Electricity is expected to grow to ~10% of alternative fuel sources in comm'l vehicles by 2050…



Source: Deutsche Bank, EIA
Note: Does not include commercial buses

Figure 18: …Exhibiting the most rapid growth among fuel sources over that period



Source: Deutsche Bank, EIA
Note: Chart is indexed to start (in 2015) as a percent; Does not include commercial buses

We project 10% and 15% EV adoption for NAFTA Class 8 and Class 5-7, respectively, by 2027

For the NAFTA Class 8 market, we project electric truck adoption of 10% (of annual production) by 2027. While the aforementioned concerns keep us cautious on the potential for rapid, widespread acceptance of heavy-duty electric trucks, and the payback period is currently extended vs. trucking company preferences, we expect this to come down to a more palatable level as battery costs continue to fall.

The ramp in adoption starts off slow in our forecast, with Tesla dominating the market in 2018-19 (given that the company has a commercial product reveal planned for September 2017), but we assume that by 2020-21, existing truck OEMs will begin to launch competing electric offerings, thus driving an acceleration in adoption. Of course, if government subsidies/incentives are initiated and/or battery technology improves significantly faster than we currently expect, this could yield upside to our current forecasts.

Figure 19: Our NAFTA heavy-duty electric truck penetration forecasts culminates with ~10% penetration of annual production by 2027

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
North America Class 8 Production (units	297,097	323,282	228,347	245,492	265,845	294,890	297,814	250,485	287,206	292,950	298,809	304,786	310,881	317,099
% Chg Y/Y	*N/A*	*9%*	*-29%*	8%	8%	11%	1%	-16%	15%	2%	2%	2%	2%	2%
BEV* production (units)	-	-	-	-	798	2,064	5,212	8,767	12,924	17,577	20,917	24,383	27,979	31,710
% Chg Y/Y	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*159%*	*152%*	*68%*	*47%*	*36%*	*19%*	*17%*	*15%*	*13%*
% Penetration	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.3%**	**0.7%**	**1.8%**	**3.5%**	**4.5%**	**6.0%**	**7.0%**	**8.0%**	**9.0%**	**10.0%**

Source: Deutsche Bank, ACT Research
Notes:
**We are projecting BEVs, or all-electric vehicles, and are not forecasting variations of hybrids. Many hybrids may be 'mild' and only use battery power for auxiliary purposes, which does not necessitate a fully electrified powertrain, or replace the majority of ICE-related components, which we are trying to capture in this analysis.*
**Class 8 production forecasts for 2017-2022 utilize ACT Research forecasts (as of ACT's August 2017 forecasts)*
**BEV penetration in 2014-2016 is an estimation and may not be completely reflective of all BEVs produced in that year*

Shifting to NAFTA medium-duty, we see the potential for faster adoption, and project 15% of production by 2027. Unlike heavy-duty, there are already commercially available medium-duty electric vehicles, and since the routes of medium-duty trucks tend to be shorter and closed-loop in nature, there is a much stronger argument for adoption. As such, we forecast adoption stepping up much more rapidly, to 15% by 2027.

Figure 20: Our NAFTA medium-duty forecasts build to current light vehicle penetration of ~15% by 2027

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
North America Class 5-7 Production (uni	297,097	237,432	232,864	250,069	251,188	258,008	270,768	265,470	274,894	280,392	286,000	291,720	297,555	303,506
% Chg Y/Y	*N/A*	*-20%*	*-2%*	7%	0%	3%	5%	-2%	4%	2%	2%	2%	2%	2%
BEV* production (units)	125	150	250	500	1,256	2,580	5,415	10,619	16,494	22,431	31,460	36,465	41,658	45,526
% Chg Y/Y	*N/A*	*20%*	*67%*	*100%*	*151%*	*105%*	*110%*	*96%*	*55%*	*36%*	*40%*	*16%*	*14%*	*9%*
% Penetration	**0.0%**	**0.1%**	**0.1%**	**0.2%**	**0.5%**	**1.0%**	**2.0%**	**4.0%**	**6.0%**	**8.0%**	**11.0%**	**12.5%**	**14.0%**	**15.0%**

Source: Deutsche Bank, ACT Research
Notes:
**We are projecting BEVs, or all-electric vehicles, and are not forecasting variations of hybrids. Many hybrids may be 'mild' and only use battery power for auxiliary purposes, which does not necessitate a fully electrified powertrain, or replace the majority of ICE-related components, which we are trying to capture in this analysis.*
**Class 5-7 production forecasts for 2017-2022 utilize ACT Research forecasts (as of ACT's August 2017 forecasts)*
**BEV penetration in 2014-2016 is an estimation and may not be completely reflective of all BEVs produced in that year*

Longer payback period in Europe yields flatter adoption curve; our team expects 2% EV penetration for HD trucks by 2024

Tim Rokossa, our European Autos analyst, performed a similar payback period calculation for the EU heavy-duty truck market, and while it was broadly consistent for a truck with a 200-mile range (~3 years), it extends to ~4 years for a truck with a 300-mile range. This can be attributed to higher electricity prices vs. the US, along with fewer annual miles driven (81,000 average vs. 100,000 in the US).

Figure 21: In Europe, payback period of a 200-mile range electric truck is also ~3 years

200 Mile Range	**Electric**	**ICE**
Acquisition Cost	200,000	120,000
Annual Fuel Cost	11,400	30,000
Miles Driven Per Year	60,000	60,000
Cost Per Mile	0.19	0.50
Annual Maintenance Cost	3,000	9,000
Miles Driven Per Year	60,000	60,000
Cost Per Mile	0.05	0.15
Increase in Acquisition Cost		80,000
Decline in Annual Cost		24,600
Payback Period (Years)		**3.3**

Source: Deutsche Bank, Company Information

Figure 22: However, for a 300-mile range truck, the payback extends to ~4 years

300 Mile Range	**Electric**	**ICE**
Acquisition Cost	240,000	120,000
Annual Fuel Cost	15,200	40,000
Miles Driven Per Year	80,000	80,000
Cost Per Mile	0.19	0.50
Annual Maintenance Cost	4,000	12,000
Miles Driven Per Year	80,000	80,000
Cost Per Mile	0.05	0.15
Increase in Acquisition Cost		120,000
Decline in Annual Cost		32,800
Payback Period (Years)		**3.7**

Source: Deutsche Bank, Company Information

This longer payback period results in a shallower electric truck adoption curve, culminating in just 2% of EU heavy-duty production in 2024. Given the longer payback period (particularly for longer-range trucks) and complications around charging infrastructure construction (i.e. different national standards), our European team forecasts slower adoption vs. the US, to just 2% of European heavy-duty truck production by 2024.

Figure 23: Our EU Autos team expects much slower adoption, culminating to just 2% of HD truck production by 2024

	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
European Heavy-duty Truck Production (un	314,815	353,415	382,899	390,935	398,285	410,243	424,321	438,726	452,743	465,356	477,915
% Chg Y/Y	*N/A*	*12%*	*8%*	2%	8%	11%	1%	-16%	15%	2%	2%
BEV* production (units)	-	-	-	-	-	21	849	1,755	3,169	4,654	9,558
% Chg Y/Y	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*4037%*	*107%*	*81%*	*47%*	*105%*
% Penetration	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.2%**	**0.4%**	**0.7%**	**1.0%**	**2.0%**

Source: Deutsche Bank, LMC
Notes:
**We are projecting BEVs, or all-electric vehicles, and are not forecasting variations of hybrids. Many hybrids may be 'mild' and only use battery power for auxiliary purposes, which does not necessitate a fully electrified powertrain, or replace the majority of ICE-related components, which we are trying to capture in this analysis*
** HD production forecasts for 2017-2024 utilize LMC forecasts*

Assessing the company-level implications

US Machinery – Nicole DeBlase

From an OEM perspective (i.e. Navistar and PACCAR), the impact of electrification will evolve as product comes to market. We do see some risk from Tesla coming in as a new entrant in the near-term, but we do not expect OEMs to just sit around and absorb market share losses (especially since most have already publicly discussed R&D investment in electric trucks). We see less of an impact for PACCAR than Navistar given PACCAR's outsized exposure to Class 8 trucks; Navistar has a strong foothold in the NAFTA medium-duty truck market, and we see a much clearer argument for electrification here, particularly over the next several years. In our view, the Navistar/VW alliance could bring a more sophisticated perspective to the process, and joint engineers are likely focusing attention on electrification.

With respect to suppliers, Allison is a clear loser from a shift towards electrification, while Cummins' future is a bit more unclear (albeit we are more negative on this). Allison is a market leader in fully automatic transmissions, and as per our discussion above, electric vehicles have no need for this product – they require only a very basic gearbox. Given that Allison's strongest market positions lie in NAFTA medium-duty and Class 8 straight trucks, both of which are ripe for electrification (particularly the former), we believe the company is more at risk than component suppliers that focus on Class 8 line-haul trucks.

Cummins has been a bit cryptic when it comes to its electrification plans; it is clear this is an R&D focus, and management has stated that it will be a major market participant. Just last week, the company unveiled a prototype electric truck; the company plans to offer an electric powertrain in 2019 (for urban buses only) and 2020 (extended range) – but this is focused solely on regional haul and urban/shuttle buses; the company does not expect long-haul trucking to electrify for another 10 years. Regardless, the company is hosting an analyst meeting on November 16th, and we expect this to be a major topic of discussion.

Net/net, we believe electrification would negatively impact the company, given that a considerable portion of its sales (35%+) are driven by components/aftermarket purchases, and electric vehicles simply require far fewer components spend/shop visits. Therefore, Cummins content over the total life of the vehicle should theoretically be much lower than with internal combustion engines. In the near-term, though, this would only impact the medium-duty truck business – heavy-duty trucks remain a significant part of Cummins' portfolio.

US Autos – Rod Lache

While Tesla has not yet revealed many details, we believe that the company's Electric Trucks will be much more competitive than widely perceived. More specifically, we believe that Tesla may shatter widely held perceptions about cost, weight, and range. If priced at the levels that we anticipate (i.e. $200k for a 200 mile range truck and $240k for a 300 miles), Tesla's truck may be able to achieve an initial payback of <3-years, even without external government incentives. And if our battery cost estimates prove correct, paybacks should decline to <2 years by the early 2020's.

Tesla should be able to leverage significant competitive technology and cost advantages via their high volume, highly automated manufacturing capacity (i.e. Tesla's truck will use several stock electric motors from Model 3, and we expect them to use several stock battery packs). This alone should position them to take a significant share of this burgeoning market. Tesla's leadership in AI/Autonomous Driving expertise (they are amongst the world leaders in deploying autonomous driving capability) could represent another significant advantage in the eyes of fleet operators.

And we see other advantages from Tesla's approach to this market. Unlike its competitors, Tesla has been 100% committed to Electrification from Day 1. This has led them to expend 100% of their efforts toward succeeding in this market (i.e. they have nothing to lose in legacy markets), and eliminating obstacles/ reservations. This has included widespread deployment of rapid charging infrastructure, which has all but eliminated range limitations for light vehicles (i.e. ability to use vehicles on longer trips, range anxiety). We believe that Tesla will follow a similar strategy for Electric Trucks. 350 kw Supercharging, which is already available today, can add 200 miles of range for a Class 8 truck in about an hour (0.58 miles per kWh). We believe it's also noteworthy that Tesla has been testing rapid battery swap, which can add hundreds of miles in a matter of minutes. Tesla has also proven that widespread infrastructure deployment is not an insurmountable task, as they've already deployed U.S. coast to coast infrastructure for light vehicles, faster and at lower cost than was widely expected. The market impact has been profound, as Tesla's Model 3 will likely sell >10x the volume of its closest, and most aggressively priced competitor (GM's Bolt EV).

Disruption to this market may come sooner, and it may be larger than is widely perceived. Commercial trucks and buses are a core component of Tesla's "Master Plan". They see this as a key objective, as Tesla believes that changes to this mode of transportation can have a significant impact on global CO2 generation In other words, all signs point to Tesla having high volume expectations (based on discussions with Tesla, we believe that internal market share aspirations are in the 20% range). We expect this to come soon, with SOP in late 2018, based on the company's plans to utilize slightly less vertical integration (Tesla does not see any reason to make their own Cabs or Gliders), and common sourcing with Tesla's light vehicles (uniquely possible for EV's). We believe the market will be receptive.

What does this mean for Tesla:

The commercial vehicle market presents a large opportunity for Tesla. Based on our initial estimates of what Tesla's truck offering could look like, we believe that the paybacks will be compelling to large fleet operators in particular, allowing Tesla to capture meaningful market share. The business also presents a compelling ROI opportunity for Tesla as we expect that capital costs will be lower than many might expect given high parts commonality with existing light vehicle platforms, and less vertical integration. In a very conservative case in which we only assess a modest penetration of the Class 8 market, we believe that Tesla could achieve ~$7bn in revenue by 2024 and ~$1bn in EBIT. Based on a 20x multiple of net income (30% tax rate) discounted back 15% per year, we believe that the Tesla Semi could conservatively be worth $35 per share.

Our base case assumes that EVs will eventually see significant adoption amongst the cohort of class 8 vehicles that driver fewer than 200miles per day.

We start with the addressable market as US class 8 retail sales… 20% of Class 8 vehicles drive <200 miles per day). And we assume that in the US, Tesla is able to achieve 20% share of the <200 mile cohort by 2024, ~9k units (which seems conservative as the ports of Los Angeles and Long Beach alone operate 14,000 "Yard Trucks", designed to haul trailers around commercial freight yards). We also assume that Tesla captures 3% share of the >200 mile cohort, ~6k units in the U.S. Overall, this equates to ~6.4% U.S. Class 8 market share for Tesla by 2024.

Outside the U.S., we assume that 30% of Class 8 Trucks drive <200 miles per day, and 70% drive >200 miles. In these markets, we assume that Tesla is able to achieve just 2.5% share of the <200 mile cohort by 2024, ~14.5k units. And we assume that Tesla captures just 0.2% share of the >200 mile cohort, or ~3k units. Overall, this corresponds with 0.9% market share outside of the U.S.

In total, these assumptions correspond with global volume of ~32k units for Tesla in 2024; mostly the short range model (i.e. 200 mile range). We assume that the 200 mile "short range" truck should sell for $200k and the 300 mile "long range" truck should sell for $240k. Our financial model assumes that Tesla is able to achieve a 20% gross margin in this business and have minimal operating expenses (5% of revenue).

Our base case does not contemplate any penetration of the medium duty truck market, which has roughly 220k unit sales in the US and >600k units internationally. Arguably, this should be an easier market to penetrate as more applications drive shorter distances in closed loops; however, Tesla is starting their product effort by proving the more difficult application (class 8) is achievable, and we do not yet know when a medium duty offering might be released.

What if Tesla achieves 20% of the Commercial Truck market? If Tesla were to ignore the International market and were to achieve a market share of 20% of the overall US class 8 market, they could see unit sales of ~46k units, with revenue of ~$11bn and EBIT of ~$1.6bn. In this scenario, the truck business would be worth at least $56 to Tesla shares compared to our base case scenario which equates to $35.

Figure 24: We examine the implications if TSLA were to achieve 20% of the US Class 8 market

Tesla Truck Model & TAM	2018	2019	2020	2021	2022	2023	2024
Total U.S. Class 8 Retail Sales	206,000	228,200	230,000	204,800	220,000	224,400	228,888
Source: ACT, Deutsche Bank							
Total Global ex-US Class 8 Sales	1,528,432	1,581,862	1,689,599	1,706,400	1,799,322	1,872,679	1,928,359
Source: LMC							
US Market Split							
<200 Miles per Day (~20%)	41,200	45,640	46,000	40,960	44,000	44,880	45,778
>200 Miles per Day (~80%)	164,800	182,560	184,000	163,840	176,000	179,520	183,110
Global ex-US Market Split							
<200 Miles per Day (~30%)	458,530	474,559	506,880	511,920	539,797	561,804	578,508
>200 Miles per Day (~70%)	1,069,902	1,107,303	1,182,719	1,194,480	1,259,525	1,310,875	1,349,851
Tesla Share of Market							
US Market Segment Share							
<200 Miles per Day	2.00%	3.00%	4.00%	7.00%	10.00%	15.00%	20.00%
>200 Miles per Day	0.00%	0.50%	1.00%	1.50%	2.00%	2.50%	3.00%
Global ex-US Market Segment Share							
<200 Miles per Day	0.00%	0.00%	0.20%	0.70%	1.20%	1.70%	2.50%
>200 Miles per Day	0.00%	0.00%	0.00%	0.05%	0.10%	0.15%	0.20%
Tesla Volume by Region							
US Volume	824	2,282	3,680	5,325	7,920	11,220	14,649
International Volume	-	-	1,014	4,180	7,738	11,517	17,163
Tesla Volume by Product Range							
Short Range Semi	824	1,369	2,854	6,450	10,878	16,283	23,619
Longe Range Semi	-	913	1,840	3,055	4,780	6,454	8,193
TOTAL Semi	**824**	**2,282**	**4,694**	**9,505**	**15,658**	**22,737**	**31,812**
Tesla Semi ASPs ($'000)							
Short Range Semi	$ 200	$ 200	$ 200	$ 200	$ 200	$ 200	$ 200
Longe Range Semi	$ 240	$ 240	$ 240	$ 240	$ 240	$ 240	$ 240
Tesla Truck Revenue ($MM)	**$ 164.8**	**$ 492.9**	**$ 1,012.4**	**$ 2,023.2**	**$ 3,322.8**	**$ 4,805.6**	**$ 6,690.1**
Truck Gross Profit	$ 16.5	$ 73.9	$ 202.5	$ 404.6	$ 664.6	$ 961.1	$ 1,338.0
Gross Margin	*10%*	*15%*	*20%*	*20%*	*20%*	*20%*	*20%*
Opex (5% of rev)	$ 8.2	$ 24.6	$ 50.6	$ 101.2	$ 166.1	$ 240.3	$ 334.5
Truck EBIT	$ 8.2	$ 49.3	$ 151.9	$ 303.5	$ 498.4	$ 720.8	$ 1,003.5
Net Income Impact (30% tax rate)	$ 5.8	$ 34.5	$ 106.3	$ 212.4	$ 348.9	$ 504.6	$ 702.5
							20x Multiple
20x 2024 Net Income Discount 15%/yr	$ 6,073.9						$ 14,049.3
Diluted Shares	172.2						
Per Share Value	**$ 35**						

Source: Deutsche Bank, Company Information, ACT, LMC

European Autos – Tim Rokossa

Daimler would likely benefit from a transition towards electrification. We generally see larger OEMs with a focus on leading edge technology as the beneficiaries from a shift to both electrification and autonomous (more on this later). In our view, the substantial investment needs on one hand and tremendous cost savings potential on the other hand, favor the market leaders. We see Daimler as well-positioned at the forefront of all these trends.

The company is leading in commercial vehicle electrification. The Urban E-Truck, which can carry up to 26 tons, has a range of about 200km and is expected to be launched in 2020. The battery size is also expected to be around 212kw/h. While the former is not yet on the market, Daimler's Fuso brand already launched the Canter E-Cell several years ago and the new version is providing a range of about 100km with a battery size of 70 kw/h. While demonstrating Daimler's ability to develop the technology, at the same time, this also demonstrates the shortcomings of battery technology for heavy trucks. The use of electric trucks seems to be much more feasible for short-haul than long-haul applications.

Conversely, VW's MAN and Scania brands have not discussed investments in electric trucks as publicly, so are not viewed to be as considerable beneficiaries should we see a shift (especially since both companies are significantly exposed to heavy-duty trucks – 98% of sales for MAN and 78% for Scania).

Autonomous: Adoption Supported By Payback

It is much easier to argue for increased adoption of driverless trucks, given that level 5 automation costs an incremental ~$23k today (with scope for reduction to $5k over time) vs. the $40-45k average annual driver salary. In this case, once the technology is ready, the only factors that could delay widespread deployment are regulatory in nature (questions over safety) and union pushback. But we view these as temporary; moreover, the DB Autos team believes driverless passenger vehicles could gain traction (possibly outside the US) as early as 2020 from a technical perspective, which would arguably clear the path for driverless trucks.

In the meantime, we expect lower levels of autonomous technology to gain traction among fleet owners, driven by improved safety and fuel efficiency. Platooning is already being tested globally, and could be an important next step on the path to driverless trucks – especially since a reduction in drivers helps trucking companies given the ongoing driver shortage.

At the company level, key beneficiaries of this trend are likely to be critical component suppliers (i.e. WABCO, Continental, Delphi, Intel/Mobileye, NVIDIA).

What is autonomous trucking technology?

Autonomous technology encompasses much more than just driverless vehicles – there are five levels of 'autonomous' technology, most of which still require a human at the helm. Given the various complexities associated with driving a long-haul truck (i.e. slower reaction time and cargo weight variations) that do not exist with passenger vehicles, we believe that in the near-term, companies are more likely to focus on technologies involving a human driver in a 'copilot' role (similar to the airline industry), although we do see scope for a movement towards Level 4/5 automation over the long-term (dependent upon regulatory change).

Level 1 technology, including driver assistance systems (such as lane assist), has already been implemented in many trucks today. However, we expect fully automated vehicles (driverless) to be adopted in the future, perhaps in the 2025 time frame (assuming this begins to happen in passenger vehicles around 2020). As we graduate from one level of automation to another, both system complexity and costs increase. However, these costs are mitigated by savings from fuel, insurance, and/or labor, which we discuss in greater detail below.

Figure 25: Summary of autonomous vehicle technology levels

In the US, The National Highway Traffic Administration (NHTSA, part of the US Department of Transportation) has adopted the SAE International definitions for each level of automation, based on 'who does what, when':

Level 0 (Driver Only) – No automation; the human driver is responsible for all driving tasks.

Level 1 (Assisted) – The automated system on the vehicle can assist the human driver within defined use cases (such as basic 'cruise control') of the driving task.

Level 2 (Partial Automation) – The vehicle's automated system conducts multiple parts of the driving task (controlling both speed and steering within a lane). The human continues to monitor the driving environment and performs the remaining driving tasks.

Level 3 (Conditional Automation) – The automated system conducts multiple parts of the driving task and monitors the driving environment within defined use cases. The human driver must always be ready to resume control, as requested by the automated system.

Level 4 (High Automation) – The automated system conducts the driving task and monitors the driving environment within defined use cases (such as on a highway). The human need not take back control when operating in these defined use cases, and can mentally disengage, but does assume control outside of the defined use cases.

Level 5 (Full Automation) – The automated system performs all driving tasks that a human driver could perform, in all use cases.

Source: NHTSA, Deutsche Bank

Major components of autonomous systems

To achieve advanced levels of automated driving, it is widely believed that vehicles will require three components: 1) Sensors (i.e. cameras, radars, LiDAR, sonars); 2) Advanced artificial intelligence that is capable of operating in highly complex and dynamic multi-agent environments; and; 3) Detailed digital 3D map data for accurate localization, path planning, and redundancy (confirming data from sensors).

Figure 26: Major components of autonomous systems

Sensors	Maps	AI
• Environmental awareness • 360° view • Redundancy	• Accurate localization • Redundancy • Path Planning	• Multi-agent interaction • Probabilistic prediction • Path planning • Self-learning

Source: Deutsche Bank, Mobileye, Industry Experts

Artificial Intelligence

Artificial intelligence (AI) systems in driverless vehicles stimulate human perceptual and decision-making processes using sensors, maps and control systems (such as steering and brakes). The industry continues to work tirelessly to develop artificial intelligence for autonomous driving. And within the passenger vehicle space, it has advanced to the point that computers are attaining high degrees of accuracy identifying features that can be seen visually through a camera (i.e. vehicles, pedestrians, cyclists, lane markings, traffic signs, traffic signals, and other landmarks). State-of-the-art systems are even advancing to a level in which a computer is able to project the correct drivable path even when common visual cues (i.e. lane markings, curbs) are partially obscured, such as on snow-covered roads. Within the next three years, it is expected that on-board automation will achieve 'super-human' capability, as data is interpreted from multiple sensors, at 360 degrees, at speeds that exceed human abilities, with no distraction and no change in performance due to fatigue.

Today's AI work is also advancing in the field of 'Driving Policy'. While this subject is typically described as developing the 'rules of the road' that vehicles follow, the subject matter is much more complex. Robo-vehicles need to be integrated into real world conditions with drivers and pedestrians that do not necessarily follow consistent rules and laws, and where cues that determine proper courses of action may have billions of permutations (e.g. construction zones, turns at intersections, dense urban areas with numerous unpredictable agents, roads that have poor or undetectable lane markings, merging into traffic). The computer systems also need to understand how the driver should behave based on millions of indirect cues. For example, when two vehicles reach a 4-way intersection at the same time and both want to turn left, which one goes first? There are literally hundreds of subtle signs that humans interpret to determine the outcome. When a human driver sees a ball roll into the middle of the road, a human driver will likely prepare for the possibility of a child entering the roadway. Computers need to achieve very high levels of cognition in order to function well in these, and other, scenarios.

Maps

Humans are clearly able to drive based on vision alone; however, AI is not yet capable of achieving this with sufficiently high confidence – the computers need help. Detailed 3D maps will be key, as they will provide three important functions: 1) Accurate localization (for the on-board computer to know exactly where the vehicle is), 2) Path planning, and; 3) Redundancy for vehicle sensors (can compare what the sensors see vs. what was expected). Overall, it's not that the car can't drive on unknown roads, it's about making the system more robust. To this point, maps allow for prediction and forecasting, foresight into scenes that are obstructed, and can be used to reduce false positives and negatives (maps can embed info such as location of a guardrail that sets off the radar, or the location of an exit ramp that has previously confused the vision systems). The map also provides vehicles with key baseline data points on the environment, with details on lane width, road curvature, locations of cross walks and traffic lights. This data works in conjunction with onboard AI to interpret the real-world situation. The importance of mapping data was in some ways underscored by the $4bn spent by Daimler, Volkswagen, and BMW to acquire Nokia's HERE business in 2015.

Sensors

Sensor and software technology enable vehicles to process their surroundings, both from a geographical and situational perspective (i.e. pedestrian traffic, construction work, etc.). Generally, the higher the level of autonomous driving, the more sophisticated the sensors (along with a higher quantity).

Cameras – the Best 'General' Sensors, and Cheap
Benefits – Only recently has machine vision advanced to the point that computer algorithms are viewed as highly reliable for interpreting the visual world (i.e. object recognition, distance measurement, trajectory estimation, identifying road boundaries, etc.). With these advances, a consensus has grown around vision serving as the best "general sensor" to serve as the basis for a variety of safety functions (i.e. Autonomous Emergency Braking, Pedestrian Recognition, Traffic Sign Detection, Lane Departure Warning, Adaptive Cruise Control, Lane Keeping Assist, Intelligent High Beam Control, etc). Vision continues to advance, and it is expected to serve at the core of future autonomous driving systems.

Challenges – While cameras are able to identify a wide range of inputs (e.g. color, texture, shape, rate of optical expansion, 3D structure from motion), the key deficiency of machine vision is that it suffers from the same factors that impair human vision, such as inclement weather, direct sunlight, and extreme darkness. Automakers often include other sensor modalities (typically radar) to offset these deficiencies and provide redundancy, as well as increased accuracy.

Radar – Measuring Motion
Benefits – Radar calculates distance by comparing emitted and reflected microwave signals. As a secondary sensor, radar appears to be a particularly affordable option ($100 per vehicle); it is also unaffected by poor visibility, which would appear to be very complimentary to vision.

Challenges – Today's radar does not have sufficient resolution to identify objects (e.g. differentiating between a pedestrian and a light pole) at high range. It also has difficulty with non-metallic, stationary, or laterally approaching objects. That said, a new generation of radar, with high angular resolution (also known as imaging radar) looks promising. This may address many of its current deficiencies, and combined with vision, may eliminate the need for LiDAR.

LiDAR – 3D Mapping
Benefits – LiDAR is one of the most critical technologies for driverless vehicles as provides better quality data than radar and is unaffected by darkness or direct sunlight (unlike optical cameras). LiDAR is a sensor that is used to create a high-resolution digital image across a very narrow band (the width of a laser beam). It provides 360-degree vision and depth information by continually projecting laser light beams and measuring the time and distance each light pulse travels.

Challenges – Production bottlenecks and a high price point have slowed adoption and caused select OEMs (such as Tesla) to use a combination of other technologies. The cost of LiDAR systems in light vehicles today can range from ~$8k for the smallest offering by Velodyne, up to ~$80k for a high-end model. However, costs are expected to fall dramatically with a focus on solid-state LiDAR devices, alternative LiDAR sensors (such as Oryx's Nano-Antennas) and mass production. The cost of these systems is expected to decline to a few hundred dollars per unit by 2020 for solid-state LiDAR.

Vehicle to Vehicle, Vehicle to Infrastructure

Benefits – V2V involves the installation of DSRC (dedicated short range communications) radio transponders, which send basic vehicle telemetry information including location, direction of travel, speed, turning/yaw, and application of brakes. This data will be sent to surrounding vehicles that are within 1,000 feet of one another. Once deployed, this technology will be used to prevent crashes in many instances that may not necessarily be prevented by onboard vehicle sensors. For example, it can warn drivers not to turn left in front of opposing vehicle traffic or not to enter an intersection due to a high probability of a collision. Unlike onboard sensor-based ADAS technology, V2V should work for situations where the threat is not visible (because opposing traffic is blocked by buildings, blind curves, etc.). NHTSA estimates that two features alone – Intersection Movement Assist and Left Turn Assist—could prevent up to 592,000 crashes and save 1,083 lives per year. It is also believed that this technology will be fused with onboard Autonomous Emergency Braking Dynamic Braking Support systems, and together, these will serve as important building blocks for autonomous driving.

For commercial trucks, an additional benefit from deployment of V2V will be the enablement of vehicle 'platooning'. This mode of driving involves commercial vehicles following each other in very close proximity (nose to tail), to achieve fuel efficiency improvement of ~8% for the total fleet based on the reduction of aerodynamic drag experienced by vehicles traveling in the 'draft' of the lead vehicle. Platooning may also accelerate deployment of increased automation in trucks, since the autonomous 'platoon' could be led by a semi-autonomous vehicle with a human driver. All following vehicles could benefit from lower cost of operation through the elimination of a human driver, as well as improvement in fuel efficiency.

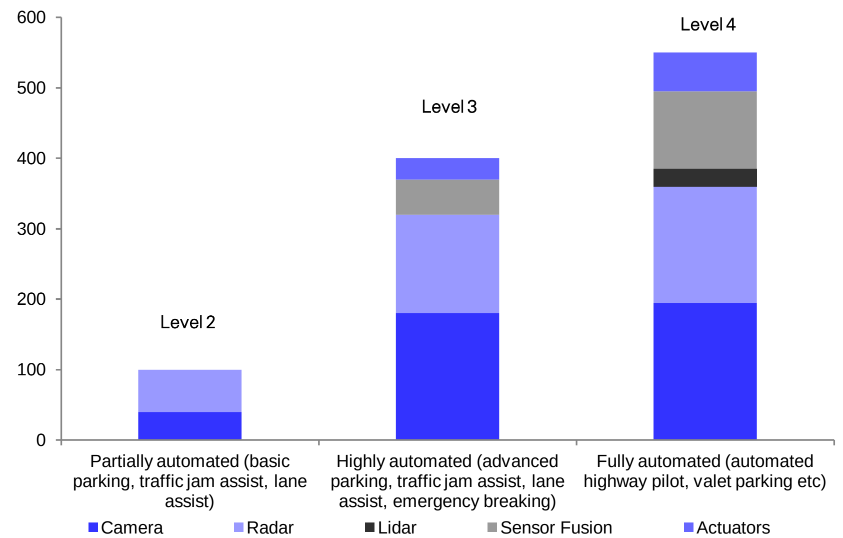
Challenges – We see the greatest challenges for V2V in the light vehicle market, since very few vehicles will be able to 'talk' to one another during the initial years of implementation. Consequently, there may be minimal perceived benefit to the consumer (system will cost $220, including $130 for DSRC transmitters, $10 for the antenna, $20 for onboard GPS, and $50-60 for wiring, changes to the vehicle HMI, and control units). Commercial trucks, on the other hand, may see immediate benefits, as noted above.

Level 2 ADAS may not move the needle as much in CVs, but level 3+ should

ADAS features further increase semiconductor content given that it requires more sensors, as computing and processing is required to support radar, video recording/processing, sensor fusion, etc. For example, in light vehicles, Level 2 ADAS (partially automated basic parking, traffic jam assist, and lane assist) adds ~$100 to the $350 average semi content per car, purely from radar and camera features. Moving beyond ADAS towards autonomy in light vehicles, sensor fusion, LiDAR and actuators will become more important, with greater uptake of Level 3 (advanced parking, traffic jam, lane assist, emergency braking) and Level 4 (full automation) features, potentially adding ~$600+ semi content ($400 from Level 3 automation alone).

We see similar a similar incremental spend in the heavy-duty truck case for level 2, as first implementations by OEMs for basic ADAS also seem to mostly focus on front-facing cameras and radar. This means the spend does not likely differ substantially from an LV, in our view, as the size/weight of the vehicle plays a smaller role for trucks. However, once we move to level 3 and full automation, we would expect a cocoon of radar, vision and LiDAR to be deployed around the entire truck. This will be required for features like 'platooning', and should add low to mid-4-digit dollar component costs to CVs, in our view, depending on the size of the vehicle. To this point, longer trucks will need more sensors, and additional trailers likely need their own set of cameras, radar, and likely even LiDAR. Therefore, we see similar percentage semi content increases (or more) from level 3 onwards for trucks, but believe level 2 may only be a small content driver in the context of the much higher CV semis build of materials.

Figure 27: ADAS semi content in light vehicles per level of automation ($)



Source: Deutsche Bank, Company data ADAS – Advanced Driver Assistance Systems

We expect adoption of driverless vehicles to first occur in off-road applications and point-to-point routes

Off-road applications are primed for self-driving technology as they typically encompass private land and consist of well-marked routes. Fully automated vehicles have already been adopted in a few select markets, such as ports and mining, while other markets, such as agriculture, have focused on lower level automation. We go through select examples of technology currently being used in these off-highway markets below.

Figure 28: Penetration phases by vocation

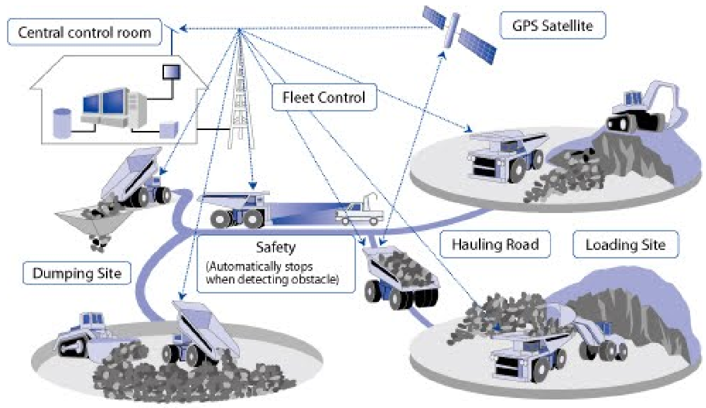
Application Vocation	Short Term (1-4 years)	Medium Term (5-8 years)	Long Term (9-11 years)	Future (2035)
Construction	Low	Low	Low	Low
On-highway	Low	Low	Low	Medium-High
Regional	Low	Low	Low	Medium
Bus & Coach	Low	Low	Low	Medium
Refuse	Low	Low	Medium	High
Factories	Low	Medium	Medium	Medium-High
Port / Harbor	Medium	Medium	Medium	Medium-High
Agriculture	Medium	Medium	Medium	Medium-High
Mining	Medium	Medium	Medium	High

Source: Frost & Sullivan, Deutsche Bank

Autonomous trucks are already being utilized in some off-road applications such as mining. Rio Tinto has been a leader on this front, operating 73 mining trucks (manufactured by Komatsu) around the clock at its Australian iron ore mine. The company intends to fully automate its operations in Australia over time, also encompassing robotic rock drilling rigs and driverless locomotives. Rio Tinto claims that its investment in automated trucks has reduced operating costs by 15%, by replacing human workers with robots.

BHP Billiton has also deployed driverless trucks (manufactured by Caterpillar) and drills in its Australian mines. Commodity extraction operations are well-positioned to adopt automated technologies as they typically already have a centralized control center that coordinates and tracks all equipment. Outside of Australia, Suncor recently became the first Canadian oil sands operator to test autonomous trucks in its Alberta operations.

Figure 29: Automated mining operation

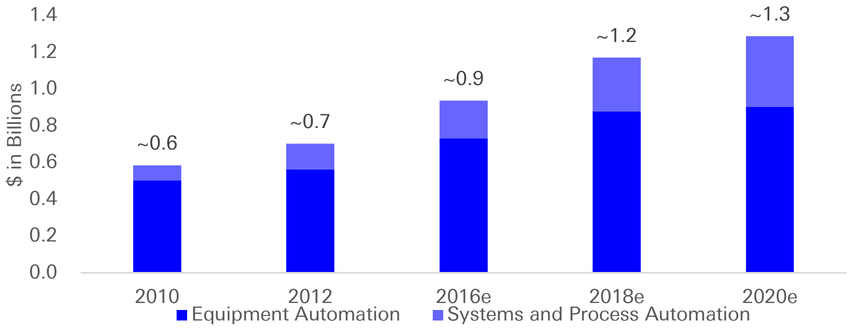


Source: Komatsu, Deutsche Bank

In addition, ports have seen increased penetration of automation technology. Adoption of automated guided vehicles (AGVs) in ports has been driven by growth in global trade, compounded by the need to handle greater container capacity (of larger ships). To this point, higher container volume has strained port and terminal operators, which need to handle these higher volumes as efficiently as possible. Cargotec laid out the case for automation technology adoption in July 2017, stating:

"And the terminal performance in automated terminals is clearly improving. And I think the credibility around the systems from a technology point of view is increasing. From a financial point of view, I only see positive drivers. The business case is overwhelmingly good for the sort of terminal operators. We are looking at then about 40% of here fixed. ***Operating costs are labor related and you're able to take more than half of the labor out. Your payback time for these investments is really a question of only a few years, so it's very attractive in that sense.*** *Obviously, this is an industry that has long traditions, not very high clock speed. The profitability of terminal operators has traditionally been very good. So the sort of -- the real kind of pressure to actually change this is not as large as it is in some other industries, where the efficiency requirements have been probably pushing for those changes quicker. But I think with the consolidation of the shipping lines and sort of more pricing pressure coming to us, the terminal operators, I would assume that, that would even accelerate further the need for efficiency."*

Figure 30: Global maritime equipment automation is expected to grow 6-10% annually through 2020



Source: Cargotec, Drewry, PEMA, and Company information. As of September 2014 (latest available). Converted at 1.17 USD/EUR

Automated vehicles are also being increasingly adopted in the warehousing and distribution space. Similar to the adoption of automation in ports, retailers are looking at automating warehouses to control costs (labor + real estate) and increase efficiency. In the past, automated vehicles relied on "guides" consisting of magnetic tape, wire and other fixed paths, but new sensor technology has allowed for more flexible vehicles that are not tied to a specific path. Instead, many of the automated vehicles operating today use an electronic map of the warehouse. Increasing industry adoption can be partially attributed to Amazon, which purchased Kiva Systems (which supplies automated warehouse vehicles) for $775m in 2012. As a result, a number of Kiva-like start-ups have emerged, including 6 River Systems (started by ex-Kiva executives), Fetch, and Locus Robotics.

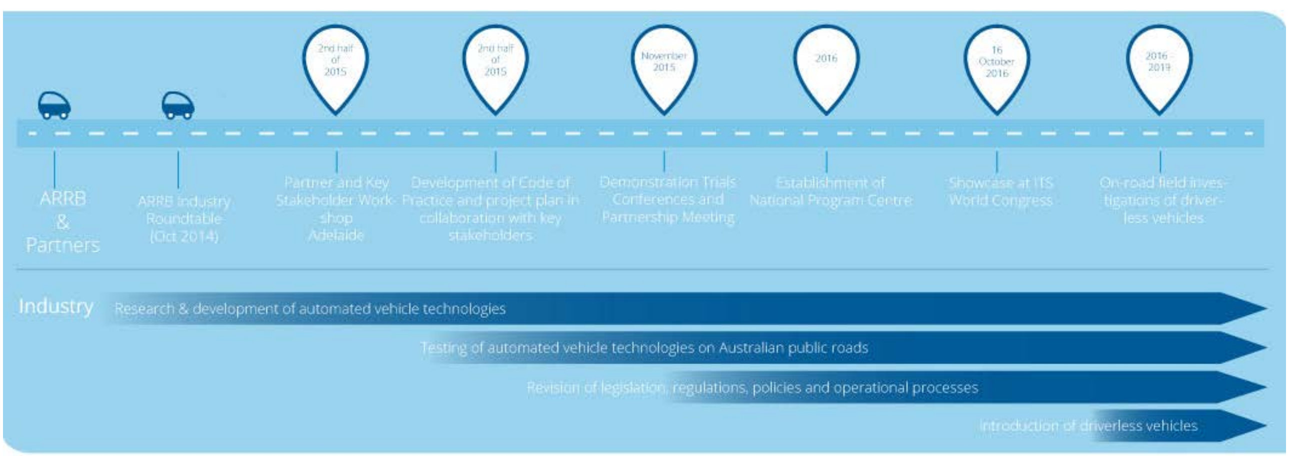
Agriculture is another application that seems ripe for the deployment of autonomous technology. Tractors and combines are already able to steer themselves using on-board computers/GPS. This guidance technology is used to harvest ~50% of all crops harvested in the US, vs. adoption rates of ~25% for soil mapping and variable-rate input applications (as per the USDA). The adoption of auto-steering reduces farmer fatigue and errors by determining precise field locations. Driverless Ag equipment is not currently available, but is under development by Ag equipment OEMs. In 2016, CNHI unveiled its Case IH Autonomous Concept Vehicle, which did not even have a cab. The tractor travels along predetermined routes programmed by the operator, who is able to remotely track its movements. Additionally, the tractor is able to sense obstacles in its path, and thereby avoid collisions.

Shifting to on-highway applications, we expect point-to-point vehicles to be the earliest adopters of autonomous vehicles. In our view, point-to-point and close-looped systems will be the earliest adopters of on-highway autonomous technology, since they require less robust mapping technology.

We expect public transit vehicles, such as buses and shuttles, to see the earliest adoption of driverless (level 5) technology. We believe this will prove less complex than line-haul trucking, because the routes are generally shorter in distance, well-traveled, and do not change often. This reduces the complexity of associated mapping technology, as the vehicles are not required to navigate unknown terrain. There are already a number of cities that are testing this technology:

- The European Regional Development Fund helped support testing of driverless buses in Finland in 2016. After a successful test phase, Finland announced in July 2017 that it will debut regular autonomous bus service on public roads this coming fall. The buses used in the test operate at around 15 mph (25 km/h) and are 'taught' a route by having operators drive them using steering and acceleration controls, which are then fine-tuned via software. The buses are equipped with laser sensors and GPS to keep them on-route during operation, and will only deviate from the set route if taught alternative routes as well.
- In July 2017, three driverless (and electric) shuttles began testing outside of Paris. During the first three months of official use, the shuttles will operate with a 'welcome officer' on-board. After this period, the shuttles will circulate without any staff. The push toward driverless transportation in Paris comes as the city starts to look towards hosting the summer Olympics in 2024.
- Australia has launched driverless bus trials in a number of locations. In August 2016, Western Australia launched the first driverless electric bus trial in Perth; a shuttle carried 11 passengers at an average speed of 25km per hour. The South Australian Government is providing $10m in funding to help support mobility technologies through its Future Mobility Lab Fund. One of these projects is a partnership with Adelaide Airport which, in March 2017, kicked off a trial of driverless shuttles used to transport passengers between the airport's terminal and parking lot.

Figure 31: Australia Driverless Vehicle Initiative – Timeline for development and testing of highly and fully automated vehicles



Source: Australia Driverless Vehicle Initiative, Deutsche Bank

- In the US, the University of Michigan and NAVYA partnered in December 2016 to test electric autonomous shuttles on a private track designed for testing automated and driverless vehicles. The University announced in June 2017 that it will launch driverless shuttles in fall 2017 to move students across a two-mile route on campus.

Similar to public transportation, refuse vehicles also operate on set routes that are able to be pre-programed. Volvo has partnered with Renova, a Swedish waste management company, to test autonomous refuse vehicles. The truck is equipped with onboard sensors, along with a GPS and LiDAR-based system for mapping and positioning, to monitor the vehicle's surroundings and avoid obstacles. During refuse collection, the truck will drive from bin to bin while the human operator walks ahead to focus on collection. The test pilot is expected to run through 2017, which will be followed by an evaluation period.

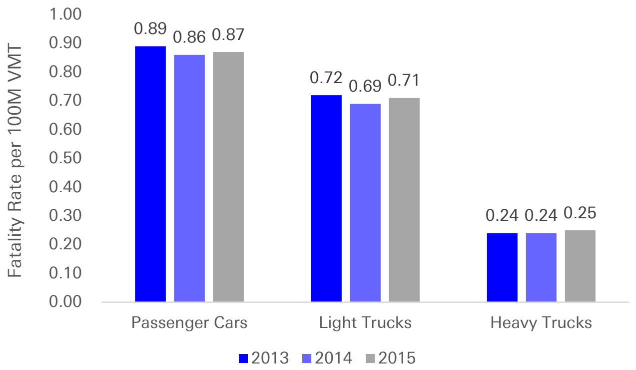
Payback analysis very supportive of driverless Class 8 trucks, but must first clear regulatory hurdles

Summary of autonomous truck technology – what are the key systems?

We expect penetration of advanced driver assistance systems (ADAS) to increase over the next several years, driven by a greater focus on safety, which could result in more stringent regulations. At the most simplistic level, ADAS can improve the driver's view of the roadway and alert him/her of impending danger, while more advanced versions can take control of braking or steering if needed.

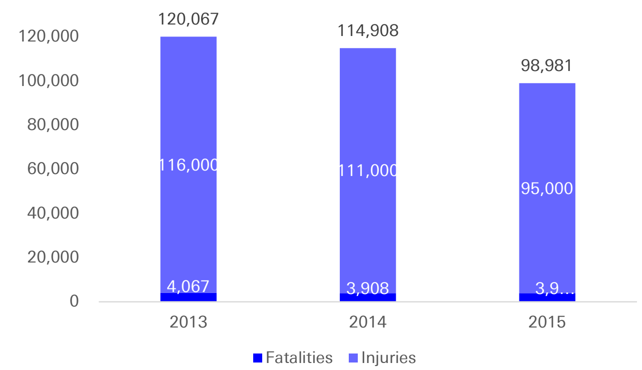
The number of crashes, injuries, and deaths involving commercial trucks has increased over the past several years; >4,000 people were killed in crashes involving large trucks in 2015, a 4.1% Y/Y increase, and the highest level seen since 2008 (per the National Center for Statistics and Analysis). Select systems, such as collision avoidance and emergency braking, are especially useful in mitigating/avoiding rear-end crashes, which account for nearly 50% of all two-vehicle accidents (as per the NTSB). Other ADAS, including lane departure warning systems, can also prevent a wide range of crashes.

Figure 32: Occupant fatality rate per 100m people by vehicle type



Source: Department of Transportation and NHTSA

Figure 33: Fatalities and injuries in crashes involving large trucks



Source: Department of Transportation and NHTSA

- **Crash Avoidance Systems**: Heavy vehicle crash avoidance systems such as Meritor WABCO's OnGuard and Bendix's Wingman Advanced provide braking assistance, which prevents/reduces the severity of collisions. These systems use radar to detect the presence of moving or stationary vehicles ahead, and alert the driver of possible rear-end collisions. If the driver fails to respond to the warning, the systems can also apply the brakes automatically to avoid or mitigate a collision. To this point, WABCO (Hold, price: $141.76) reports that its OnGuard mitigation technology has reduced the number of rear-end accidents by up to 87%. In 2013, the EU enacted legislation mandating adoption of this technology for all new trucks weighing >12 tons, and the rule will be expanded to all commercial vehicles beginning in November 2018. A similar mandate does not exist in the US, but does appear on the NTSB's 'Most Wanted List of Transportation Safety Improvements for 2017-18', and has been adopted proactively by a number of fleets.

Figure 34: Collision avoidance system overview

Source: Deutsche Bank, NTSB

- **Lane Departure Warning Systems**: At the lowest automation level, this technology uses an on-board camera to provide visual and/or audio clues to alert the driver if he/she is veering into an adjacent lane (lane departure warning). More advanced versions provide more active assistance (lane keep assist), re-centering the vehicle if it veers too far from the lane markers, or proactively keeping the vehicle centered within the lane (lane centering assist). System manufacturers include WABCO, Bendix (Knorr-Bremse), and Delphi.

We believe safety will be a major driver of ADAS adoption; we draw parallels to passenger cars. ADAS adoption within the automotive market is already strongly supported by regulatory requirements. For example, autonomous breaking is crucial to score a 5-star NCAP crash test rating.

For passenger cars, at a high level, growth in Active Safety is being promoted through changes to New Car Assessment Programs (NCAPs), through which regulators test vehicles for safety performance, and then publish the results through 'Star Ratings'. Regulators are well aware that consumers and automakers alike prioritize safety – 97% of US vehicles achieve 4 or 5 stars, while 90% of European vehicles are classified as such. Consequently, regulators have found that they can push advanced safety system adoption higher by adjusting Star Rating requirements. Globally, we estimate that Automatic Emergency Braking (AEB) was ~9% penetrated across the Auto Industry in 2015; based on our assumptions for global adoption, we project that penetration will increase to >40% by 2020 and to just under 70% by 2025.

Figure 35: DB's Global Forward Collision Avoidance & Mitigation (FCAM) technology penetration assumptions

	2015	2016	2017e	2018e	2019e	2020e	2025e
European Production*	20,950	21,540	22,245	22,451	22,512	22,956	24,256
Penetration %	26%	37%	49%	58%	69%	79%	100%
North American Production*	17,495	17,837	17,352	17,515	17,677	18,241	19,201
Penetration %	7%	10%	18%	29%	42%	54%	100%
Japan Sales**	5,200	5,252	5,305	5,358	5,411	5,465	5,744
Penetration %	16%	18%	26%	38%	50%	62%	100%
ROW Production*	45,145	48,491	50,028	50,827	52,963	55,190	65,753
Penetration %	2%	3%	4%	9%	16%	21%	46%
Global Automotive Production*	88,791	93,120	94,930	96,151	98,563	101,852	114,954
Global forward crash avoidance and mitigation systems	9.50%	13.10%	18.30%	25.70%	34.60%	42.20%	69.10%
FCAM Volume	**8,407**	**12,154**	**17,404**	**24,712**	**34,137**	**42,964**	**79,447**

Source: Deutsche Bank, IHS, Industry Experts
**IHS estimate in 000's*
***DB estimate in 000's*

Over time, automated driving functions are also expected to gain acceptance within the global trucking market, as these technologies improve efficiency (i.e. more predictable transport times) and reduce costs (i.e. labor, fuel, and maintenance). There is a range of systems that could be adopted, including computer-assisted tasks, like back-up assist, to more advanced driverless (level 5) technology.

- **Traffic Jam Assist:** Traffic Jam Assist is classified as a Level 1 or Level 2 technology, since drivers are expected to monitor the vehicle's surroundings. This technology takes control of accelerating and braking functions in stop-and-go traffic, making it especially useful for delivery trucks in urban city centers. Typically, Traffic Jam Assist is designed to operate at speeds well below 30 mph; the system automatically turns off once the vehicle exceeds the pre-set speed limit. These systems are currently being tested by Scania (owned by Volkswagen) and Daimler.
- **Automated Trailer Backing/Trailer Backup Assist:** This Level 2 technology assists the driver in backing up a trailer, which can be especially helpful for less experienced drivers that must reverse their vehicles in space-constrained environments. The feature has been featured within 2016 models of both GM and Ford trucks.
- **Highway Pilot:** Daimler debuted its Highway Pilot system in Germany in 2014 as part of a demonstration of its Future Truck 2025 initiative, and again in 2015 during a showcase outside of Las Vegas. The system uses various cameras and radar sensors to detect surrounding traffic. The Level 2 version of this technology, where the driver is still responsible for monitoring traffic and road conditions, is expected to be available in 2018-20. The advanced version of this technology will be classified as Level 3, as the driver is no longer responsible for constant monitoring, and is expected to be available between 2020-23 (as per the American Trucking Association).
- **Driver Assistive/Highly Automated Truck Platooning:** Allows a lead truck to control one or more subsequent trucks by managing speed and braking through continuous digital communication. The combination of a lower drag and a consistent speed allows for fuel efficiencies for both the lead and rear trucks. In general, platooning encompasses several levels of automation; the ATA expects Level 2 truck platooning (system steering) to become commercially available in 2020-22, with more advanced systems launched progressively afterwards. A number of systems that help facilitate platooning are available today. For example, Peloton Technology, a US based start-up, has partnered with a number of OEMs to test this technology. Daimler also has a system called the Highway Pilot Connect system, which enables platooning.

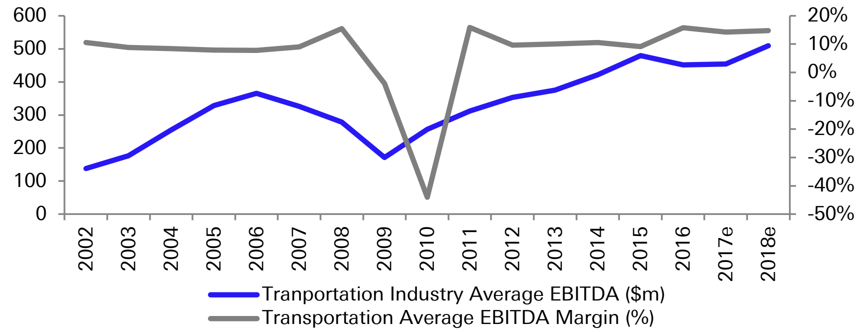
We see the potential for driverless truck adoption to begin around 2025, supported by an attractive payback – but there are union/safety hurdles to clear

Overall, we expect long-haul trucking to begin adopting higher levels (4/5) of autonomous driving technology around 2025. Trucking routes often include long stretches of predictable highway driving, making it easier to map vs. dense urban areas; thus, we expect driverless trucking to be technologically feasible in the next few years. However, actual adoption may lag feasibility given union pushback and legislative hurdles.

We believe that the industry's trajectory towards advanced levels of automation may happen more quickly than is widely anticipated. Automakers including General Motors, Daimler, BMW, Audi, Nissan, Volvo, and Tesla have begun to introduce semi-autonomous driving capabilities (also known as Level 2 Automation) in their flagship vehicles. This level of automation combines Adaptive Cruise Control and Lane Keeping Assistance, which relieve drivers of tedious work such as driving in traffic or across long distances on the highway. Automakers will continue to push the envelope on automation. Companies such as General Motors, VW/Audi, Daimler, Nissan, Volvo, Tesla, and others are currently testing vehicles that are capable of completely automated driving. A further step in this direction, to Level 3 (autonomous driving under certain conditions, but with a driver that can regain full control) will begin commercial deployment in late 2017 (Audi's new A8). Commercial deployment of Level 4/5 vehicles (Full Automation under all conditions, including vehicles that are unoccupied) is likely no more than 3-years away.

Putting union and regulatory factors aside, trucker adoption will depend upon cost/benefit analysis. Commercial fleet owners already operate with razor-thin margins, and are generally slow to adopt new technology, especially without a compelling payback case. In general, fleet owners target an 18-24 month payback period, as they tend to trade trucks in before they accumulate 500k miles, which typically occurs between 3-5 years of age (but many large national fleets trade in closer to 300k miles, at the three-year mark).

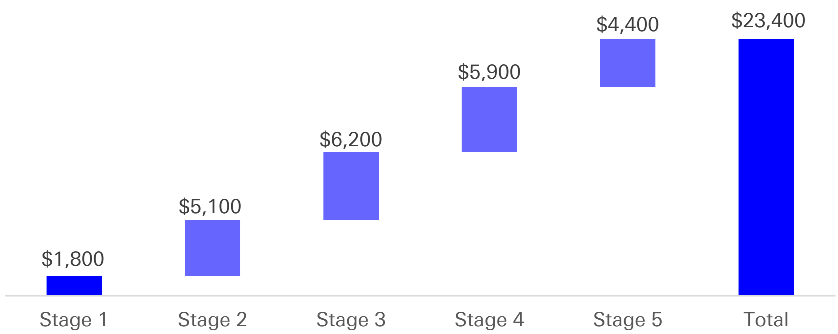
Figure 36: Commercial fleet purchases will largely be driven by the payback period given razor-thin industry EBITDA margins



Source: Company Filings, Factset, Deutsche Bank

While the incremental cost of a driverless truck (vs. current technology) is not yet known, we can estimate this based on the cost of individual components. Of course, this differs substantially based on the level of automation; as per Roland Berger (see Figure 37), the estimated incremental cost ranges from $1.8k at the lowest level to $23.4k for a driverless vehicle. Software is expected to account for around 85% of the incremental costs, while hardware (i.e. cameras, radar systems, etc.) accounts for the other 15%.

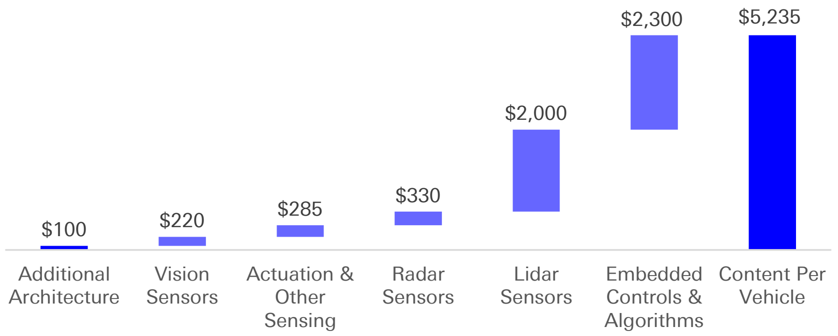
Figure 37: Total incremental cost of a level 5 driverless truck is ~$23k



Source: Roland Berger, Expert Interviews, Deutsche Bank

However, as per DB Auto analyst Rod Lache, over the medium-term, the cost of driverless truck technology is expected to decline dramatically, with some industry sources pointing to just ~$5k incremental costs for a truck with level 5 automation technology. Clearly, this would make the payback hurdle much easier to clear.

Figure 38: Delphi autonomous driving component estimates



Source: Company Information

We highlight four major sources of cost savings associated with the deployment of automated truck technology:

- **Driver wages and benefits:** Driver wages have steadily increased since 2012 as a result of driver shortages and lower productivity associated with new legislation such as Hours of Service. As per the ATA, the average marginal cost (per mile) of a driver is $0.63, accounting for ~40% of the total marginal cost/mile of transportation, as it stands today. Thus, there is clearly a strong argument for the adoption of fully autonomous trucks, should fleets be permitted (by government regulatory bodies) to eliminate the driver. However, this is a significant hurdle to clear given expected pushback from unions and safety concerns.
- **Fuel**: Platooning is one of the most promising near-term applications for commercial vehicles, and results in fuel savings from lower vehicle drag (similar to a bike or car race). According to the research by the National Renewable Energy Laboratory, platooning can result in up to ~5% fuel savings for the lead truck and ~10% savings for trailing trucks (can vary depending a number of factors including speed). While fuel costs are generally passed on to customers, if one fleet adopts platooning to lower fuel costs, others will likely need to follow in order to remain competitive.
- **Repair and Maintenance (R&M):** Several factors impact R&M costs, such as the age of the truck, the vehicle configuration, and the technology installed.
- **Insurance Premiums:** Truck insurance premiums are generally based on mileage exposure and vehicle replacement costs.

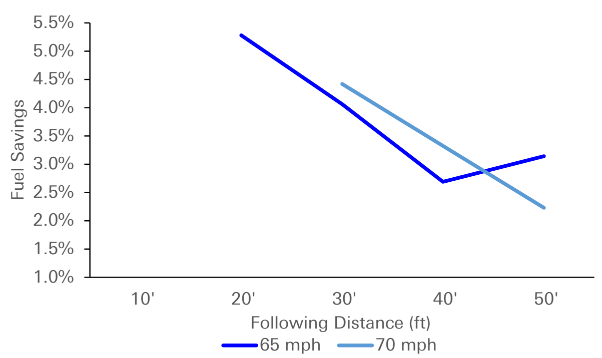
Figure 39: Breakdown of average marginal cost per mile (publicly traded truck load carriers)

	2012	2013	2014	2015	2016	1H17
Marginal Cost Per Mile						
Salaries, Wages & Benefits	$0.48	$0.49	$0.52	$0.58	$0.60	$0.62
Fuel	0.32	0.28	0.26	0.18	0.15	0.16
Ops & Maint.	0.13	0.15	0.16	0.17	0.18	0.18
Taxes & Liscenses	0.03	0.03	0.03	0.03	0.03	0.03
Insurance & Claims	0.05	0.06	0.06	0.06	0.07	0.07
Communications	0.01	0.01	0.01	0.01	0.01	0.01
Deprec. & Amortization	0.12	0.13	0.13	0.15	0.16	0.16
Rent & Purchased Transportation	0.89	0.93	0.99	0.99	0.96	1.00
Other Operating Expenses	0.02	0.02	0.02	0.02	0.04	0.04
Total	$2.05	$2.09	$2.19	$2.21	$2.18	$2.27
% of Total						
Salaries, Wages & Benefits	23%	23%	24%	26%	27%	27%
Fuel	15%	14%	12%	8%	7%	7%
Ops & Maint.	7%	7%	7%	8%	8%	8%
Taxes & Liscenses	1%	1%	1%	1%	1%	1%
Insurance & Claims	3%	3%	3%	3%	3%	3%
Communications	0%	0%	0%	1%	0%	0%
Deprec. & Amortization	6%	6%	6%	7%	7%	7%
Rent & Purchased Transportation	44%	44%	45%	45%	44%	44%
Other Operating Expenses	1%	1%	1%	1%	2%	2%
Total	100%	100%	100%	100%	100%	100%

Source: Deutsche Bank, ACT, and Company Information

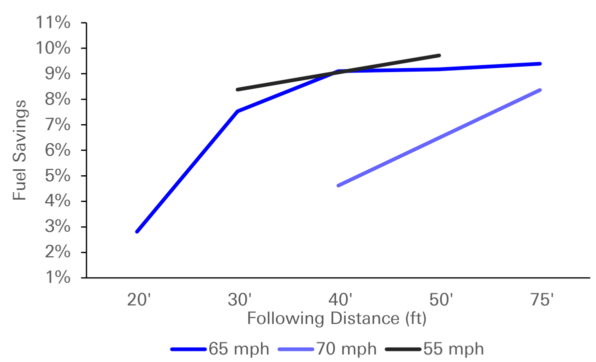
Platooning yields significant fuel cost savings. Based on a study by the National Renewable Energy Laboratory (NREL), US trucks drove 169.8bn total miles in 2014, of which 65.6% would have been eligible for platooning. While associated fuel savings can vary, researchers have found that the sweet spot generally occurs at 55 mph (90 km/h) with a 30-foot (9-meter) following distance. Using this speed and distance, the NREL study found that the lead truck was able to generate ~4% fuel savings per route, while the trailing trucks were able to reduce their fuel costs by ~8%, for total fuel savings of slightly more than 6% across the fleet. The figures below illustrate potential fuel savings for both lead and trailing trucks in a platoon across a number of different speed and distance combinations.

Figure 40: Class 8 truck platooning fuel savings (lead truck)



Source: NREL, Deutsche Bank

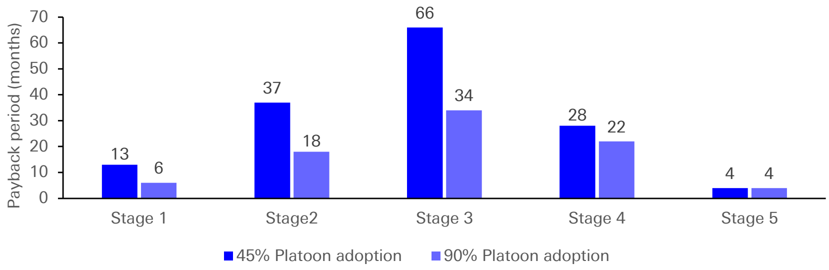
Figure 41: Class 8 truck platooning fuel savings (trailing trucks)



Source: NREL, Deutsche Bank

The adoption of platooning can also increase the payback for level 1-3 automation technologies. As illustrated In Figure 42, for level 3 technology, the payback period falls to 2.8 years (vs. 5.5 years ex-platooning), assuming that >90% of miles are traveled in a platoon. Over the longer term, level 4-5 technology adoption is expected to be less impacted by the platooning decision.

Figure 42: Impact of platooning on autonomous truck technology payback periods



Source: Roland Berger, Deutsche Bank

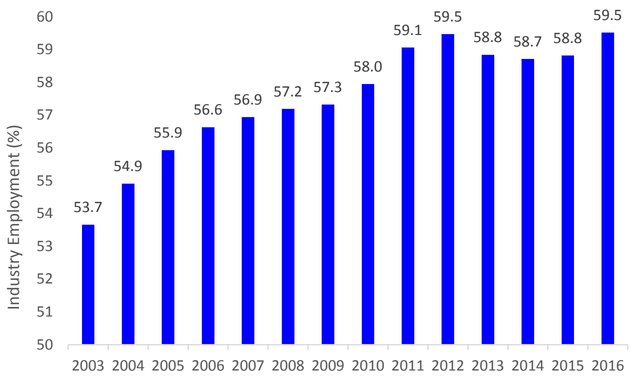
A number of truck platooning tests have already taken place, across the US and Europe. The European Truck Platooning Challenge occurred in 2016, which demonstrated platooning on public roads via a group of truck OEMs, including DAF Trucks, Daimler Trucks, Iveco, MAN Truck & Bus, Scania and Volvo Group. As part of this demonstration, the vehicles traveled from several European cities to the Netherlands.

In the US, Utah and Florida authorized testing of commercial vehicle platooning in 2015 and 2016, respectively, Additionally, Arkansas, Georgia, North Carolina, South Carolina, Tennessee and Texas approved platooning trials or exempted platoons from follow-too-closely regulations in 2017. As such, we have seen a number of successful test runs featuring platooning technologies, such as:

- Supported by a state bill, Florida is expected to start a pilot test in September 2017 that will study the use of driver-assisted truck platooning technology. The goal of the test is to compile data (over 2-3 weeks) that will support legislation for platooning on the turnpike that runs from Miami to Orlando by late 2018.
- In March 2017, Volvo Trucks and Partners for Advanced Transportation Technology (PATH) at the University of California Berkeley completed a successful demonstration of platooning in Los Angeles. Volvo VNL trucks utilized sensors, V2V communication and Cooperative Adaptive Cruise Control Technology (CACC), a more advanced version of Adaptive Cruise Control, to demonstrate the potential of the technology in live traffic.

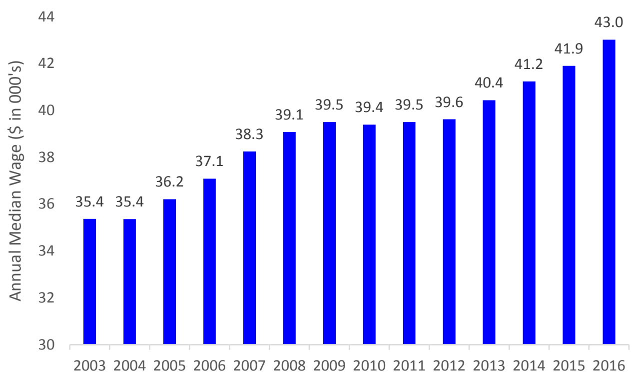
There is no question that eliminating the driver would move the payback period dramatically in favor of autonomous truck technology, but pushback from unions and safety concerns are likely to delay level 5 adoption. Driver wages have steadily increased since 2012 as a result of unfavorable supply/demand dynamics (driver shortage) and lower productivity associated with legislation such as the Hours of Service rules. The average marginal cost per mile of a driver is $0.63, accounting for almost 40% of trucking's total marginal cost per mile (per ATA). Thus, we would expect to see rapid adoption of autonomous technology if fleets are allowed to completely eliminate the driver. However, we view this as unlikely in the medium-term given expected pushback from unions and highway safety concerns.

Figure 43: Heavy truck driver employment



Source: BLS, Deutsche Bank

Figure 44: Heavy truck driver median annual wage



Source: BLS, Deutsche Bank

Recent union lobbying has successfully stopped federal legislation supporting driverless commercial vehicles. While a number of states have enacted legislation allowing for on-road testing of driverless vehicles, many industry participants have noted the need for a federal rule given that vehicles need to operate consistently across state lines (particularly in line-haul trucking). In June 2017, the first federal driverless truck bill was drafted (by both parties) in Congress, in an effort to speed up deployment of autonomous vehicles. While this is certainly a positive development, this bill puts a 10,000-pound weight limit on driverless vehicles following successful lobbying efforts by the Teamsters union. Our auto team's industry contacts have suggested that driverless automobiles should be on the road by 2020, leading us to believe that fully autonomous trucks could come in the 2025 time frame.

Current systems are not yet robust enough to operate at a level 5 driverless level, especially in dense urban areas with unpredictable pedestrian obstacles. Robo-vehicles need to be integrated into real world conditions with drivers and pedestrians that do not necessarily follow consistent rules and laws, and where the cues that determine proper courses of action may have billions of permutations (e.g. construction zones, turns at intersections, dense urban areas with numerous unpredictable agents, roads that have poor or undetectable lane markings, merging into traffic). The computer systems also need to understand how the driver should behave based on millions of indirect cues. For example, when two vehicles reach a 4 way intersection at the same time and both want to turn left, which one goes first? What are the conditions that allow a truck to merge into another vehicle lane? There are literally hundreds of subtle signs that humans interpret to determine the outcome. When a human driver sees a ball roll into the middle of the road, a human driver will likely prepare for the possibility of a child entering the roadway. Computers need to achieve very high levels of cognition in order to function well in these, and other scenarios.

Assessing the company-level implications

There are a number of companies already providing autonomous truck technologies, spanning truck OEMs, suppliers, and software providers.

Truck Suppliers

Commercial truck OEMs, unlike automakers, are more likely to outsource components (as per historical behavior). Thus, we characterize component suppliers as the biggest beneficiaries in the movement towards autonomous trucks.

WABCO (covered by DB analyst Nicole DeBlase) is already a key player in ADAS, and has been investing in new products and partnerships to grow its product offerings in higher levels of automation. As such, we see WABCO **as the best way to play the autonomous theme in the Machinery space**. Prior to the advent of autonomous, the company was already a long-term content gain story, as WABCO's content per vehicle in the US (currently $1,500), Brazil ($1,000), and China ($500) catches up with that of Europe ($3,200). This story should be amplified by the broader industry trend of automation.

Currently, WABCO provides a multitude of different products that enable autonomous technology, including:

- Driver Assistance Systems: Lane departure warning systems, collision mitigation, blind spot detection, predictive cruise control, tire pressure sensors.
- Brake & Stability Control: Automatic braking systems, stability control (reduces rollover risk).
- Antilock Brakes (ABS): WABCO was the pioneer of this technology, and now provides both ABS and air disc brakes (which offer superior performance vs. drum brakes).
- Driveline Control: Automatic manual transmission technology (gaining significant share in the US), which enhances safety and improves fuel efficiency.
- Vehicle Electronic Systems: Controls and supervises electrical loads throughout the vehicle.
- Aerodynamics: Side skirts and tails that attach to trailers, enhancing fuel efficiency by improving the air flow over the vehicle.

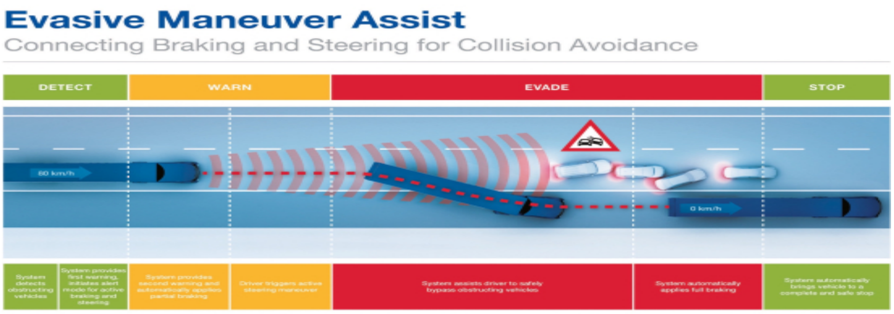
This product portfolio is set to expand, with WABCO's CEO and Chairman Jacques Esculier highlighting additional products in the pipeline related to autonomous driving during the recent 2Q17 earnings call, stating:

"There is the technologies that we have developed not long ago that will continue to penetrate our markets, and that will be a major vector for our performance, like it has been, obviously, for the last years, and I'm talking about advanced driver systems, systems-related products, like autonomous emergency braking system, which probably will become mandated progressively across all regions. I'm talking about lane departure, warning systems and so on. And then I'm talking about this world, as you said, of air disc brakes, which is a technology that we have continuously refined…And then there is the rich portfolio of new technologies that have not yet been developed and finalized, and that's all on the path of autonomous driving, digitalization, big data around

our FMS infrastructure. All that stuff is obviously under development and should, when it hits the market, provide a very nice opportunity for our performance as well." – WBC (7-20-17)

These products will add to other newly announced products geared towards autonomous driving. This includes the Evasive Maneuver Assist (EMA) solution which was designed in partnership with AF; the technology fuses WABCO's breaking, stability, and vehicle dynamics control systems with ZF's active steering technology to help the driver safely steer around an obstructing vehicle and to bring truck and trailer to a complete stop.

Figure 45: Evasive Maneuver Assist – connecting braking and steering for collision avoidance



Source: Company Information

WABCO has also recently demonstrated its OnCity system, which uses LiDAR technology to detect potential collisions when the vehicle is turning. The system will first alert the driver of a potential obstacle, and is able to independently apply the brakes to prevent an accident if needed.

Figure 46: OnCity system uses LiDAR technology to detect obstacles when turning

Source: Company Information

More recently, in August 2017, WABCO announced the acquisition of RH Sheppard, which expands its product offering into steering capabilities, noting:

"This acquisition represents another key milestone as WABCO advances toward enabling self-driving commercial vehicles…We have a clear line of sight on the fundamental technologies - such as active steering, active braking, electronic stability control and other advanced driver assistance systems - which will enable significant intermediary steps on our industry's path to realize fully autonomous driving."

This transaction follows a number of acquisitions, partnerships, and joint ventures announced in 2016 to aid in the development of autonomous products, including:

- Agreement with Mobileye to develop solutions for commercial vehicles that will combine Mobileye's vision system and mapping technology with the control and actuation technologies from WABCO's electronic braking, stability and emergency braking systems in combination with capability for active steering control. The WABCO-Mobileye solution is expected to focus on advanced safety capabilities and technology.
- Working with Peloton to provide solutions for truck platooning by utilizing WABCO’s braking technology.
- Acquisition of Laydon Composites, a manufacturer of aerodynamic devices for heavy-duty trucks and trailers, which can also be used to complement fuel savings associated with platooning.

Continental (covered by DB analyst Tim Rokossa) is well positioned to benefit from growth of ADAS products on multiple fronts, not just for passenger cars but also trucks. The company not only acts as a Tier 1 system supplier, but also expanded its own algorithm know-how via the acquisition of Elektrobit. On the hardware side, Continental (Buy, price: EUR 191.45) supplies vision systems with mono as well as stereo and surround view cameras, short and long range radar, flash LiDAR (3D flash LiDAR from 2019 onwards) and sensors. With the e-horizon system, the company also aims to participate in mapping/connectivity. Continental supplies almost all OEMs globally with ADAS components as displayed below (Gen 1 is running out this year):

During 2016, Continental generated €1.3m revenues from ADAS products and by 2020, technologies related to autonomous driving (incl. V2x, road databases, etc) should account for >€3bn.

What is often overseen is that Continental provides only group the Chassis & Safety components (Radar, Camera, other Sensors). Additionally, revenues with autonomous driving are also consolidated in Interior. In total, Continental aims to generate ~€3bn of revenues by 2019 – a target we believe they will easily overachieve. For 2017-19, ADAS alone explains almost 1/5th of our expected group top-line growth.

Figure 47: Our estimates for ADAS and rest of automotive

	2013	2014	2015	2016	2017e	2018e	2019e
Chassis & Safety sales			8,450	8,978	9,738	10,517	11,359
ADAS sales	134	330	850	1,275	1,785	2,410	2,964
Adj. EBIT C&S			814	892	935	1,060	1,150
margin in %			10%	10%	10%	10%	10%
EBIT ADAS			33	102	161	265	341
margin in %			4%	8%	9%	11%	12%
% of sales growth				81%	67%	80%	66%
% of EBIT growth				93%	135%	84%	84%
Group sales		34,506	39,232	40,550	44,127	46,758	49,498
% ADAS			2%	3%	4%	5%	6%
% of sales growth				32%	14%	24%	20%
Group adj. EBIT			4,444	4,731	4,925	5,641	6,174
% ADAS			1%	2%	3%	5%	6%
% of EBIT growth				24%	30%	15%	14%

Source: Deutsche Bank and Company Filings

ADAS revenues only account for a comparable small revenue share of the larger suppliers in our universe. However, generally these revenues provide the highest organic growth figures driving the sub units share of group revenues. We estimate that Continental, Bosch and Valeo were the leading suppliers in terms of ADAS revenues in 2015 globally. Continental generated close to €900 of ADAS revenues in 2015 shortly followed by Valeo (DBe – the company has a wider definition of ADAS for example including ultrasonic parking sensors. We see around €1bn including this for 2015 and €1.2bn in 2016). All suppliers engaged in this trend saw significant revenue growth over the course of the last three years. Moreover, all ADAS players expect rapid revenue growth from this technology. Profitability, on the other hand, remains somewhat unclear, but as Continental indicated, it should catch up with the group level soon.

Continental believes that ultimately, every vehicle will require a system of 1 SRR, 1 LRR, 4 flash LiDAR, one camera and a surround view system.

Truck OEMs:

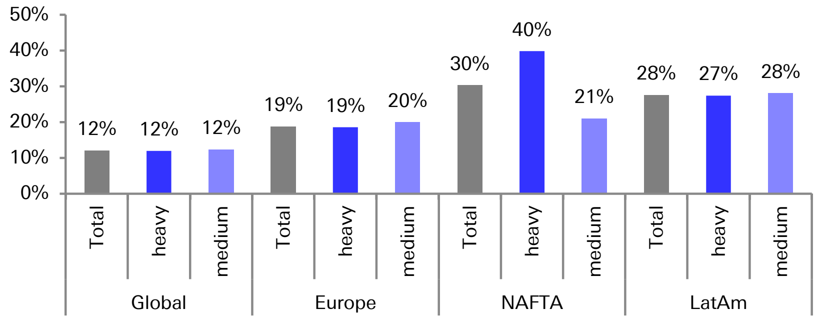
Of the truck OEMs, we view Tesla and Daimler as best positioned to benefit from the transition to autonomous trucking in the near-term, given significant R&D investments. For Daimler, we believe the company will be able to leverage the investment it are already making in autos to trucks. This is a key differentiator between Europe and US truck OEMS, as European manufacturers are more likely to build on their internally developed passenger vehicle technology, while US players are more likely to outsource. Thus, while we see Daimler as well-positioned, we see less direct impact for US truck OEMs (Paccar and Navistar).

Tesla (covered by DB analyst Rod Lache) has noted that it is working to develop its own fully electric heavy-duty truck that will also likely include some autonomous/platooning capabilities.

Daimler (covered by DB analyst Tim Rokossa): We generally see larger OEMs with a focus on leading edge technology as the beneficiaries from the trends discussed in this report. In our view, the substantial investment needs on the one hand and tremendous costs savings potential on the other hand favor the market leaders. We see Daimler as well positioned at the forefront of all these trends.

The company is the largest Western OEM with €33bn revenues and 415k units sold in 2016. The company has dominating market position in all developed regions.

Figure 48: Daimler has a dominating market position in all developed regions (as of 2016)

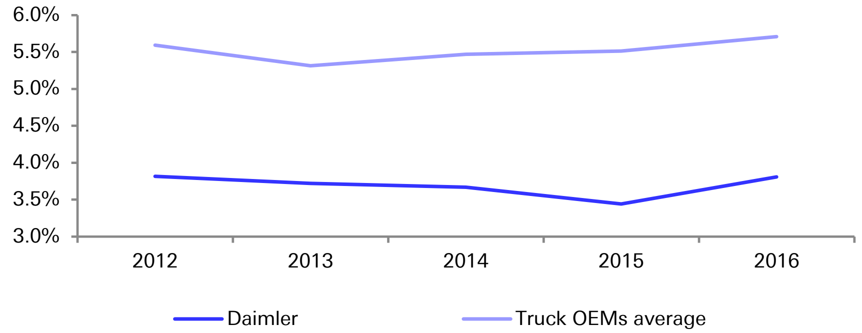


Source: Deutsche Bank and Company Filings

Interestingly, they are not a top spender when it comes to R&D. In absolute terms their R&D budget stands at about €1.3bn as much as the combined VW group but less than for example Volvo. Interestingly, in relative terms with only 3.8% this is 190bps below the average of trucks of 5.7% of sales. Over the last years the company continuously invested between 3.4% and 3.8% of its revenues. We take this is a sign that economies of scale do make a major difference in the space and that Daimler does perhaps indeed benefit from R&D efforts on electrification and autonomous driving in its pass car business.

Consequently, the company already presented much of the discussed autonomous driving vision with its Future Truck 2025 in 2015 allowing us to test drive an autonomous truck in the Las Vegas desert already two years ago.

Figure 49: Daimler R&D spending has trailed the average as a percentage of sales



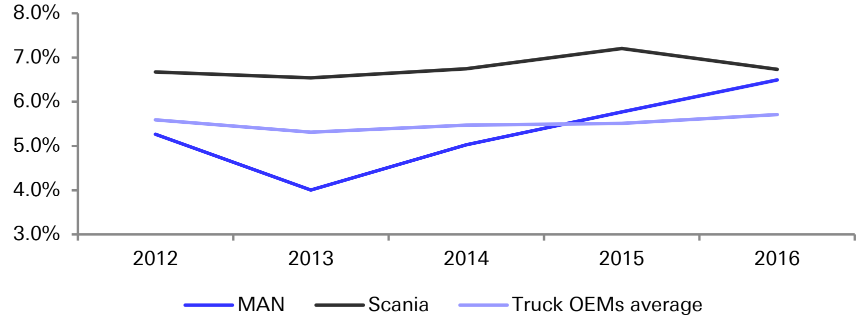
Source: Deutsche Bank and Company Filings

VW – MAN & Scania (covered by DB analyst Tim Rokossa): Within the VW commercial vehicles business our channel checks suggest some difference between the brands. Both are very European and LatAm heavy having no presence in the US except a Navistar cooperation.

In terms of technology trends both of them were perhaps also less vocal over the last 2y on electrification and autonomous driving functionalities than Daimler and Volvo for example. But at least Scania is seen as being “on top of the game”.

Scania and MAN each spent about 7% of sales on R&D. In absolute terms this means €1.6bn of R&D budget for only 130k units in 2016 for the combined group. However, we believe R&D efforts have so far been very isolated and therefore believe this number reflects many intra group inefficiencies and rather need to be seen independent from another (€755m for Scania, €881m for MAN).

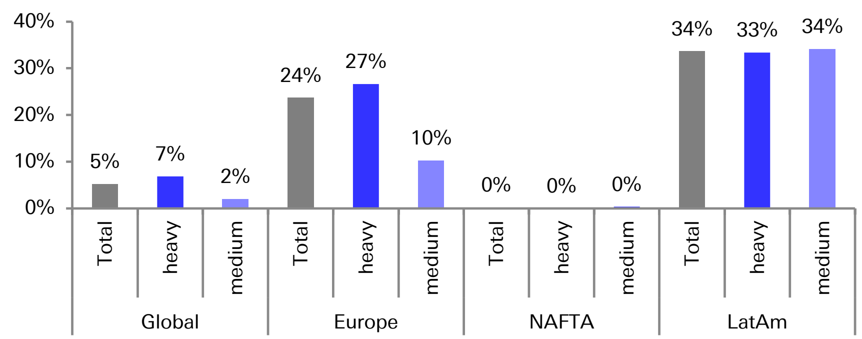
Figure 50: R&D spending for Scania is above the OEM average



Source: Deutsche Bank and Company Filings

But it is not just the R&D spend and margin difference, it is also the product mix. Indeed Scania is very exposed to heavy truck vehicles with 98% of sales while MAN only has 78% of sales with heavy trucks.

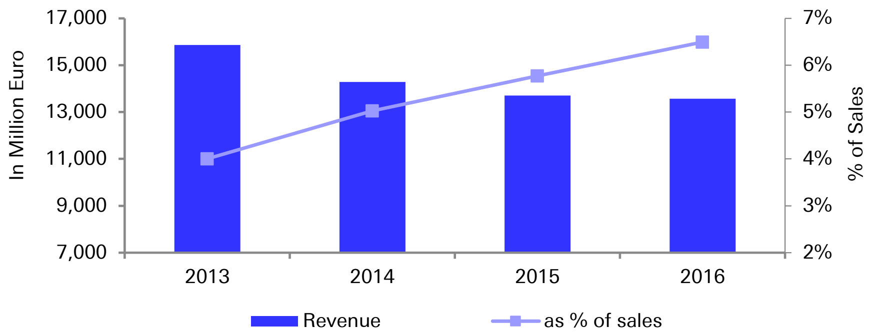
Figure 51: Scania is very exposed to heavy trucks with 98% of sales vs. MAN with 78% of sales with heavy trucks (as of 2016)



Source: Company Filings and IHS

We have also heard complaints from various industry contacts about the age of the MAN product. MAN lacking character is probably also expressed in the fact that R&D increased both in relative and absolute terms while sales are still much lower than in 2013.

Figure 52: MAN had to step up its R&D game



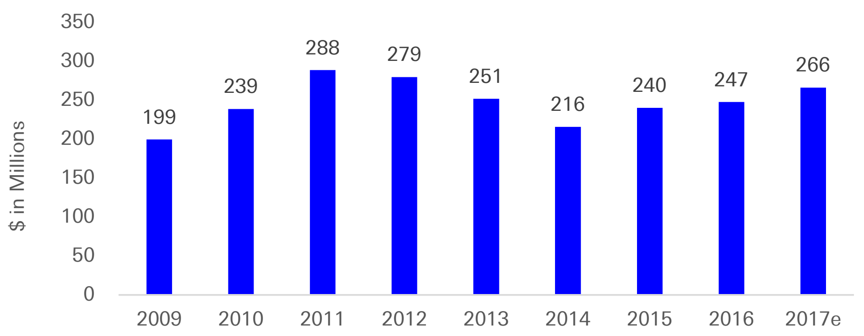
Source: Deutsche Bank and Company Filings

Scania on the other hand has already presented a holistic approach on autonomous transport solutions including handling the logistics and infrastructure communication. They agree with our take that autonomous systems will first be introduced in relatively controlled industrial settings such as mines and ports.

PACCAR (covered by Nicole DeBlase): Most of PACCAR's autonomous truck work thus far has focused on low-level automation and driver assistance systems, although the company has also partnered with technology companies on more advanced technology. In support of its technology partnerships, the company announced the opening of the new PACCAR Silicon Valley Innovation Center in 2017. The center is expected to focus on technology applications for ADAS, artificial intelligence, vehicle connectivity and augmented reality. To support its investments in autonomous technology, PACCAR has been increasing its R&D, stating in April 2017 that:

"One of the things that we've done and we've seen over the last 12 months, or really 24 months, is the software controls that are in our vehicles are becoming ever more important. And we've increased our engineering resources, particularly in the software area. And so I think we'll continue to see that as we progress over the coming years and with some of those resources dedicated to developing autonomous vehicle technologies. There's a lot of things that have to happen for autonomous trucks to become a reality, but we've had platooning demonstrations, we've had autonomous truck demonstrations. So we're involved and engaged in that in a big way, and we'll continue to make investments in that arena as we go through this year and for the next 5, 10 years. So we're working closely with a lot of different parties in the industry. And so we'll continue to develop our capability."

Figure 53: PACCAR R&D spending



Source: Deutsche Bank and Company Information

Navistar (covered by DB analyst Nicole DeBlase) launched the International LT in 2016, which featured a predictive cruise control system that 'looks' ahead of the truck, recognizes the terrain and continuously calculates the most efficient speed and gear for optimal fuel economy. The company has also invested in platooning technology.

We believe that the company's alliance with Volkswagen could enhance its position in autonomous truck technology, as per the MAN/Scania discussion above.

Amit Mehrotra
US Transportation Analyst

Transportation Service Providers

Autonomous technology has potential to be a game changer for the trucking industry. We note that driver pay accounts for the largest component of trucking company's opex, and is most at risk of above-average inflation (due to driver shortages). In this regard, autonomous technology can be a significant positive for long-term earnings and margin trends. But several hurdles exist that likely push implementation out for several years, such as: regulatory/safety considerations, social unrest (given 2m+ U.S. truck driver population), and costs- due to the deeply cyclical nature of demand and industry's highly fragmented structure. To these points, we note that Knight Transportation- the country's largest trucking company, by far, once they complete their merger w/ Swift, said this last year about autonomous and EV technology:

"We have some discussions from time to time...whether it be the driver assist or autonomous...we're very interested and we stay very close. I think there's massive, massive amounts of data that have to be collected in order for those things to reach a level of safety and comfort to be ready for the primetime market...But those small things I just mentioned are actually only really adopted and used by a very small percentage of the two million trucks on the road. And so we're part of, I would say, a very small fraction of the trucks on the road that are actually leveraging some of the proven technology that we can use today that can have a dramatic impact on safety..." – David Jackson, CEO Knight Transportation, July '16

Despite these hurdles, it's undeniable in our view that autonomous technology has potential to be a positive game changer for the trucking industry, given issues with driver shortages and turnover. Put simply, being a truckload driver is hard. It's tiring, can keep you away from home and family for long periods of time, and can lead to an unhealthy diet and suboptimal lifestyles. Not to mention average pay is down (median income is around $19 per hour or $40k per year according to Bureau of Labor Statistics data, which is about 10% below other production/nonsupervisory positions). Demographics are also at play here with the average age of truck drivers at 49 vs. 42 for the general population, and females representing less than 6% of the truck driver population. These characteristics, as well as more stringent regulations, lead to a structural shortage of drivers. American Trucking Associations (ATA) estimated the truck driver shortage to be 38,000 in 2014, increasing to 47,500 in 2015. On one hand, the increasing driver shortage puts a natural cap on supply growth (carriers can't order trucks if they can't 'seat' them), but on the other hand, it has the potential to increase expenses as carriers try to attract drivers to the industry (over one-third of operating costs is driver pay). The industry also has an issue with driver turnover/churn, which averages over 90% per year. This is specifically an issue in times of tight capacity (when carriers can offer signing bonuses), and makes driver recruitment and retention a significant activity for most truckload carriers (with many having their own driving schools as a way to continuously sources new drivers).

We have also identified several regulatory initiatives that are likely to continue constraining driver population, making autonomous technology a big positive for trucking operators over the long term.

Electronic Logging Devices (ELDs): The most interesting and potentially consequential regulation in the trucking industry was finalized in December 2015, requiring the mandatory use of electronic logging devices (or ELDs) to increase compliance with HOS rules (as well as to reduce paperwork for both trucking companies and drivers). The devices document driving time via monitoring movement, miles, and engine hours. The rule also has implications for safety, in our view, as it significantly reduces (if not eliminates) the potential for deliberate and/or non-deliberate HOS violations (510k HOS violations logged per annum on average 2011- 2015 as per DOT data).

- The ELD mandate takes effect in December 2017 (i.e. 2yrs after the rule was finalized) and in our view has significant implications for effective supply (as measured by miles per truck). To this point, we note that the overall impact is largely related to small and mid-sized companies, as the vast majority of large carriers have already implemented ELDs.

  Given the majority of for-hire truck capacity is accounted for by small, midsize and owner-operated carriers, where ELD penetration is estimated to be anywhere from 0-25% (vs. 90-100% for large carriers), the ELD mandate has substantial implications for overall capacity, in our view. To this point, we estimate ELDs will lower overall for-hire truck capacity by 4.1%, with much of this impact starting only in 2H17, as small/mid-size carriers delay implementation until just ahead of the December 2017 deadline. Implementation could also be deferred pending the outcome of a lawsuit by the Owner Operator Independent Drivers Association, which claims (among other things) that the mandate violates a trucker's right to privacy.

- Change in the way safety ratings are determined: Move from a three-tier rating system (satisfactory, conditional, or unsatisfactory), which has been in place since 1982, to one designation ("unfit"). The new designation would be assessed monthly, and pulled from roadside inspections (3.5M performed each year) and from reported crashes. The shift would allow the FMCSA to evaluate over 75k carriers per month vs. 15k per year currently. The revision would likely increase pressure on small- and mid-sized carriers and have some impact on the overall supply (as an increased # of carriers would be deemed "unfit"). As an example, the proposed rule noted that if the new system had been applied in 2011, it would have deemed over 3,000 carriers 'unfit', which is about 2.5x the number that was deemed 'unsatisfactory'. The new proposed rule was published in Jan 2016 with the final rule pending.

- Minimum Liability Insurance: Raise the minimum amount of liability insurance from $750,000 (set in 1984). The FMCSA notes minimum coverage today would be over $1.5M if it had been indexed to inflation, and over $3M if indexed to medical cost inflation. Any increase in minimum requirements would likely add costs and disproportionately impact small and mid-sized carriers (FMCSA solicited input from industry stakeholders Nov '14 through Feb 2015, and currently awaiting outcome).

- Various others expected in coming months/years: (1) New entry-level driver training; (2) Speed Limiters on all heavy trucks over 26k lbs manufactured after 1990, and; (3) increased transparency of drivers with past positive drug and alcohol test results.

Autonomous Trucking another driver of semi-conductor content growth

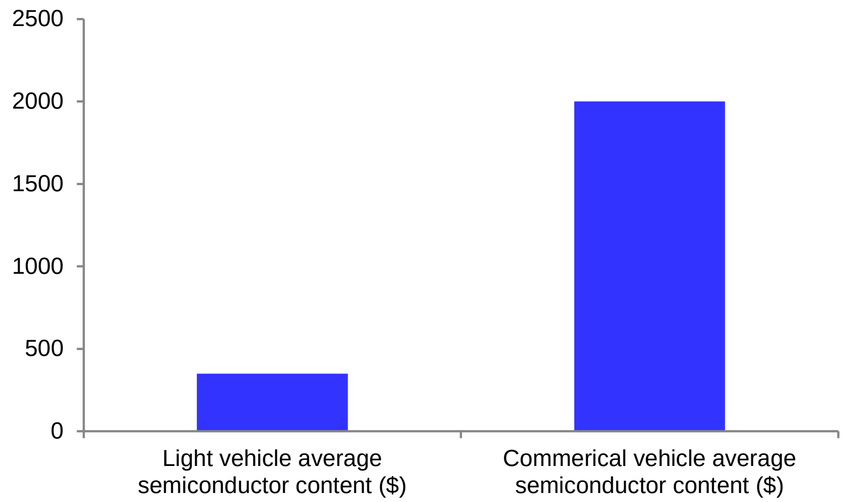
Trucking electrification and ADAS to increase semi content

The move towards electrification of commercial vehicles (CV) and autonomous trucking will increase the amount of semiconductor content per truck over the coming years. Given that commercial trucks represent a small unit opportunity relative to that of total light vehicle production (eg. North America Class 5-8 truck unit production was ~2.5% of N. America light vehicle unit production in 2016), semiconductor industry estimates (including our charts below) focus on semi content growth and market share in light vehicles. Data availability here is better as well as we see the LV market as somewhat more advanced in terms of EV and ADAS adoption.

Trucks/CVs have up to 6x the semi content of an LV

Having said that, CVs/trucks do come with a significantly higher semiconductor content per vehicle compared to LVs. Our industry checks indicate about 6x more semi content in a larger truck compared to an average LV, taking total semi BOM towards the ~$2,000 mark vs ~$350 for an average LV. This is largely driven by the differences in size and weight, starting at simple things like electric window lifters in CVs requiring more powerful motors and power semis due to higher weight of the window. The board communication network and the various sensors in a truck also have specific challenges to overcome given the large distances between the front and back of a truck. Given these specifics of CVs, we expect similar if not greater increases in semiconductor content in electric and autonomous trucks vs. light passenger vehicles.

Figure 54: Trucks/CVs come with ~6x higher semi content vs LVs

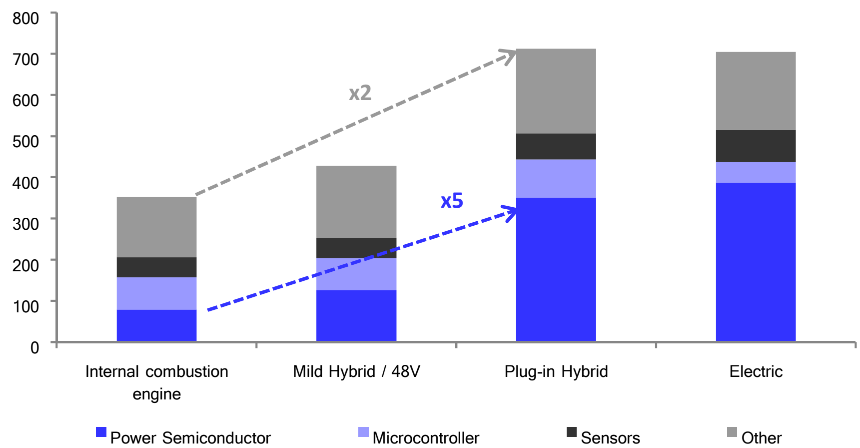


Source: Deutsche Bank, company data

Move to eCVs should increase power semi content by ~5x

Electric vehicles (EVs) offer compelling content increases from internal-combustion engine cars. Specifically, we estimate a 5x or higher addition in power management semiconductor content with the move to a full EV, driving an overall doubling of total semi content per car. We expect the ratios to be broadly similar for trucks and would also assume a ~5x+ increase of power semi content with the move from an ICE CV to a fully electric truck. We deem the plug-in hybrid case below as less relevant for trucks but see strong momentum behind 48V, based on industry conversations. Given an estimated baseline power semi content of several hundred $ in an ICE for a CV, this could increase power semi content in an electrified truck towards low 4-digits $. 48V adoption should add a low 3-digit $ amount to semi content.

Figure 55: Semi content per LV ($) – power semis x5 with electrification



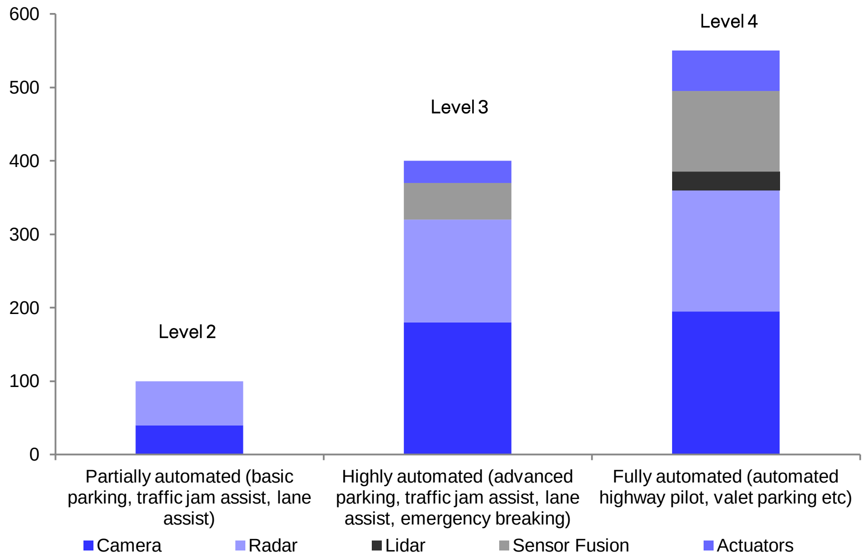
Source: Company data, Deutsche Bank

Level 2 ADAS may not move the needle as much in CVs but level3+ should

ADAS (Advanced Driver Assistance Systems) drives a further increase in semiconductor content as a variety of sensors, computing and processing is required to support radar, video recording/processing, sensor fusion, etc. For example in light vehicles, Level 2 ADAS (partially automated basic parking, traffic jam assist, and lane assist) adds ~$100 to the $350 average semi content per car purely from radar and camera features. Moving beyond ADAS towards autonomy in light vehicles, sensor fusion, LiDAR and actuators will become more important with more uptake of Level 3 (advanced parking, traffic jam, lane assist, emergency braking) and Level 4 ADAS features (full automation), potentially adding ~$600+ semi content ($400 from Level 3 automation alone). We see similar a similar $ amount being added in the truck/CV case for level 2 as first implementations by OEMs for 'basic' ADAS also seem to mostly focus on front-facing cameras and radar. This means the $ opportunity is likely not too different to an LV, in our view, as the size/weight of the truck plays a smaller role here.

However, once we move to level 3 and full automation, we would expect a cocoon of radar, vision and likely also LiDAR around the entire truck. This will be required for features like 'platooning' and should add low to mid-4-digit $ BOMs to CVs, in our view, depending on the actual size of the vehicle. Longer trucks need more sensors and additional trailers likely need their own set of cameras, radars and likely even a LiDAR. So we see similar percentage semi content increases or more from level 3 onwards for trucks but believe level 2 only may be a somewhat small content driver in the context of the much higher CV semis BOM.

Figure 56: ADAS semi content in light vehicles per level of automation ($)

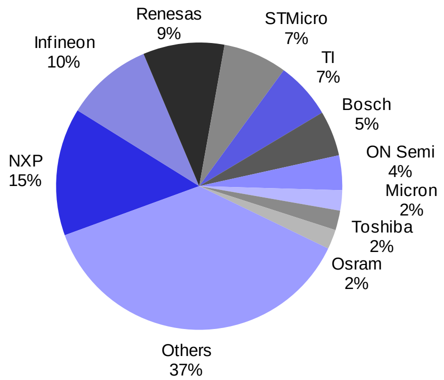


Source: Deutsche Bank, Company data ADAS – Advanced Driver Assistance Systems

Who benefits most in semiconductors?

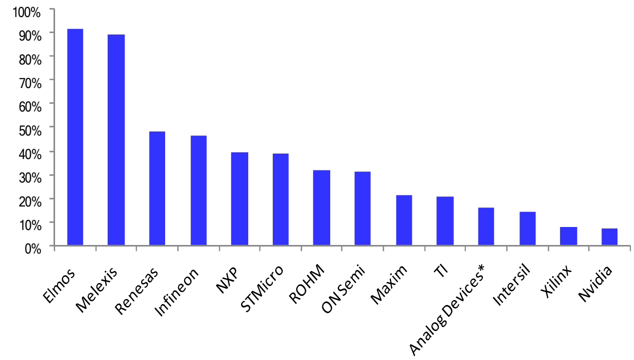
Below, we show the main Auto semiconductor offerings of key players and highlight semiconductor market share for ADAS and autonomous driving relevant product categories. Buy rated companies with strong EV and/or ADAS exposure under our coverage include: Infineon (price: EUR 19.04), Intel (price: $34.89), ON Semiconductor (price: $17.06) and Maxim (price: $45.56).

Figure 57: Automotive semiconductor supplier share



Source: Infineon, company data, IHS, June 2016

Figure 58: Automotive as percentage of total sales



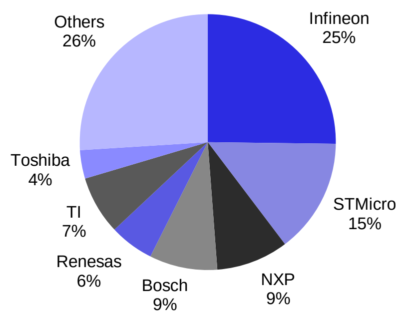
Source: Deutsche Bank, co data *:- ADI+LLTC PF numbers; Note Intersil acqd by Renesas on 2/24/17

Figure 59: End market exposure of the automotive semiconductor suppliers

Company	Major automotive semiconductor products/End market area
Infineon	Number 1 in Power semis, also strong in Microcontrollers and Sensors (e.g. radar, hall)
STMicroelectronics	Infotainment & Connectivity, Power semis, Body, Chassis & Safety
NXP	Auto infotainment, In-vehicle networking, Auto access/security, Sensors (radar, magnetic) and Microcontrollers
Analog Devices	ADAS, Infotainment, Powertrain, Body and Chassis & Safety
Elmos	Sensors, Motor control, Embedded systems
Melexis	Actuators, Analog and digital semiconductors, Sensors, Smart motor drivers
Renesas	Number 1 in Microcontrollers, also present in powertrain, safety, chassis & safety
Maxim	Serial Link, LED Lighting, Smart Key, Infotainment, Sensors, High-Integration Power, EV battery
Intersil	Camera Video signal processing, Power systems
Xilinx	Auto-grade programmable SoCs, FPGAs
NVIDIA	Infotainment and navigation, ADAS, Rear seat entertainment, Digital instrument clusters
ON Semi	Powertrain, Infotainment, ADAS, Park Assist, Image sensors, LED Lighting
Texas Instruments	Passive safety, Infotainment, ADAS, Powertrain, Lighting and body electronics
ROHM	High exposure to audio/infotainment, also HVAC control, body, electronic power steering, battery management/charging

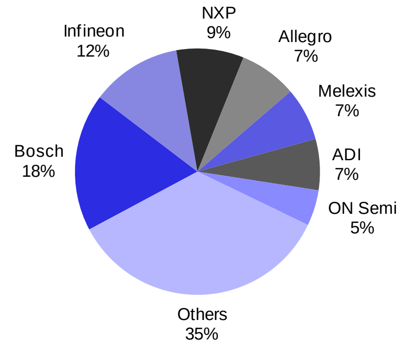
Source: Company data, Deutsche Bank; Note Intersil acquired by Renesas on 24 February 2017

Figure 60: Market share in Auto power semis



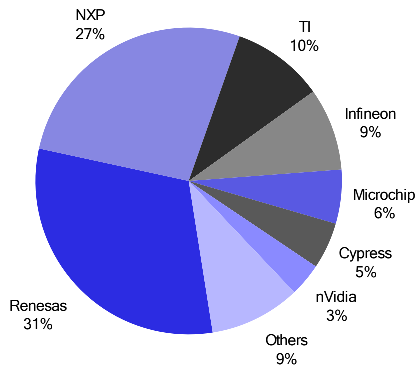
Source: Infineon, company data (2016)

Figure 61: Market share in Auto sensors



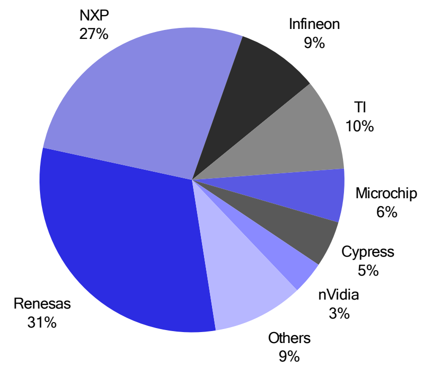
Source: Infineon, company data (2016)

Figure 62: Market share in Auto microcontrollers



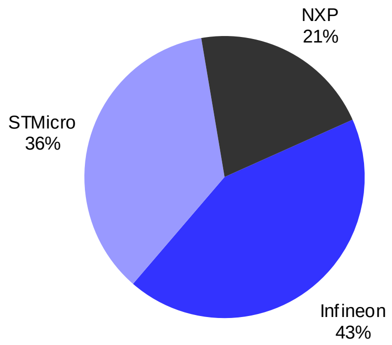
Source: Infineon, company data (2016)

Figure 63: Market share in Auto CMOS sensors



Source: Company data (2015)

Figure 64: Radar sensor market share



Source: STMicro, company data, Deutsche Bank (2015)

Appendix I: Lithium-ion battery materials

In this Appendix, we explain 1) Lithium-ion as the leading battery alternative, 2) the evolution of the battery technology, 3) lithium supply/demand key considerations, and 4) key companies involved in the existing lithium-ion battery supply chain.

We would expect batteries used in commercial vehicles to follow a similar path to the light vehicle market, adopting lithium-ion as the dominant technology and leveraging off the rapid developments that have been made in the general EV sector.

Lithium-ion battery costs continue to fall, with leading producers reporting battery costs at or below US$200/kWh, less than half of average cell costs just three years ago. Global EV sales continue to grow and the battery supply chain is beginning to see increased capital investment ahead of imminent demand growth across the broader industry.

The commercial vehicle market would be expected to leverage off Electric Vehicle research and development advances that accelerated throughout 2015-2017. Power, weight and energy density remain key considerations to allow optimal efficiencies. As a result, we would expect Nickel Cobalt Aluminum (NCA) and Nickel Manganese Cobalt (NMC) to be leading lithium-ion technologies utilized (further details below) and for lithium hydroxide to be a key part of the supply chain.

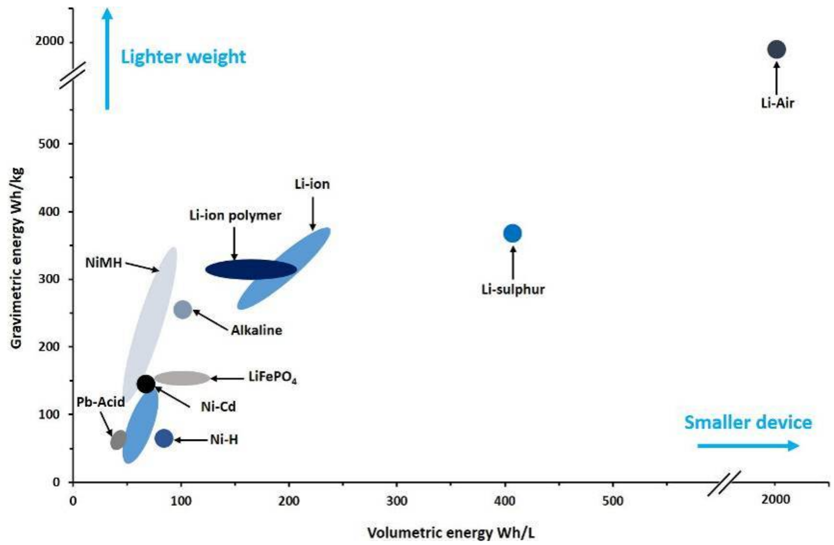
Based on DB BEV penetration estimates for medium-duty and heavy-duty vehicles, we calculate a potential additional 2.3kt Lithium Carbonate Equivalent (LCE) in 2020. This is reasonably immaterial in the context of our existing forecast of 359kt LCE in the same year. By 2027, based on DB BEV penetration rates for medium and heavy-duty vehicles we forecast a potential additional 15.3kt of LCE demand. This compares to our existing 2025 (long term) demand forecast of 534kt. Calculations are based on an average lithium consumption of 0.7kg/kWh and 200kWh/400kWh for medium-duty/heavy-duty vehicles. Overall, while the adoption of BEV technology in medium-duty and heavy-duty vehicles is supportive for the lithium market, it is not likely to have a material impact on demand until higher penetration rates are realized.

Lithium-ion is the leading technology

Why lithium?

Lithium is the lightest known metal, the least dense solid element with the greatest electrochemical potential, which leads to excellent energy-to-weight performance. Lithium is highly reactive in pure form, with a single valence electron that is easily given up to bond with other molecules. Its very high electrochemical potential (i.e. its willingness to transfer electrons) makes it a powerful component of battery cells. A typical lithium-ion battery generates around 3 volts compared to 2.1 volts for lead-acid or 1.5 volts for zinc-carbon cells.

Figure 65: Lithium-based battery technologies have superior energy density



Source: CSIRO

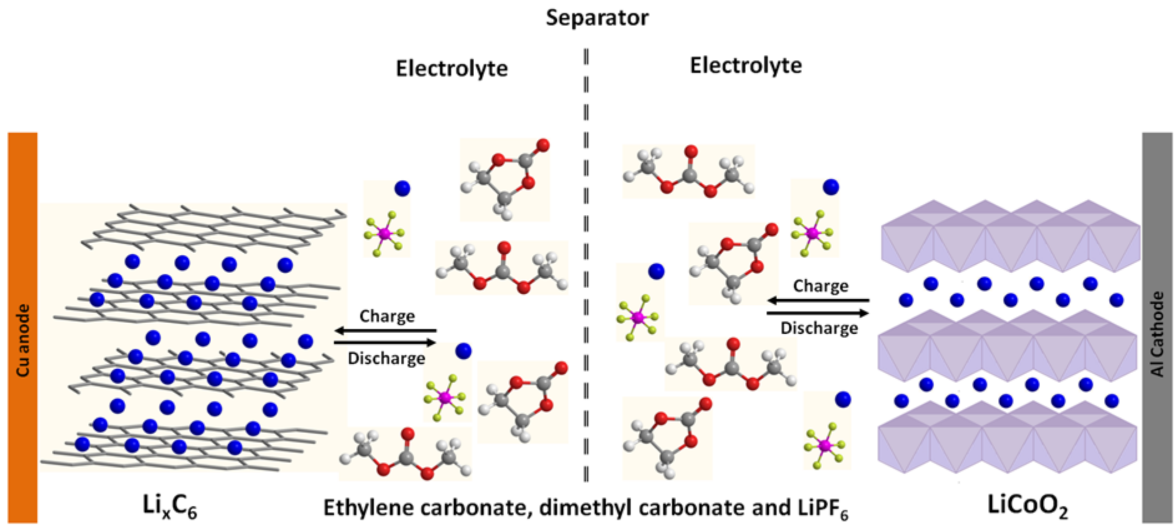
How the lithium ion cell works

Rechargeable battery cells use a negative electrode material (anode) and a positive electrode material (cathode) to convert chemical energy into electrical energy and vice-versa.

- The lithium-ion cell uses a lithium-based metal oxide as the cathode and normally a carbon-based material as the anode.
- Graphite is generally the anode material of choice because of accessibility, price and a molecular structure that allows for storage of a large amount of ions within the crystal lattice (charge capacity).
- Electrons pass between the anode and the cathode via a liquid solvent, the electrolyte, which also contains lithium ions (the industry standard electrolyte is 1M $LiPF_6$ in solution).

As the battery is charged, lithium ions move through the electrolyte from the positive electrode (cathode) and attach to the negative electrode (anode). For example, if a graphite anode is used, the lithium ions attach to the carbon lattice. When discharging, the lithium ions move back from the anode to the cathode, and this movement of electrons generates an electric current.

Figure 66: An example of lithium-ion cell using a lithium-cobalt oxide cathode and a graphite anode



Source: Bhatt and O'Mullane, Chemistry in Australia, June 2013

Current cathode material options

The active metal oxide used within the cathode of lithium-ion cells can vary depending on the application and battery properties required. The active material makes up 90-98% of the cathode weight (the rest being adhesive to 'paste' the active material to the cathode metal). The actual lithium content can be calculated based on the molecular weight of the lithium as a proportion to the molecular weight of the active material used.

Recharging times, discharge rates and stability are all factors that will be considered when selecting a cathode material. Lithium-cobalt oxide has held market dominance as it was the first technology commercialized, but its market share has been declining from a peak of 70% in 2008 as new technologies have been developed. Lithium is the only active material in the battery, so consequently, increasing the battery's lithium content increases energy density. The challenge is that lithium is highly reactive, so current technologies require other materials to be included to ensure stability, increase safety, and maximize life expectancy. Nickel-cobalt-aluminum (NCA) and nickel-manganese-cobalt (NMC) cathodes are the two leading technologies being used in the Electric Vehicle industry.

Figure 67: Major lithium metal oxides used in cathodes

Acronym	Material components	Chemical formula	Uses	Characteristics
LCO	Lithium Cobalt Oxide	$Li_{1-x}CoO_2$	Mobile phones, laptops	Incumbent technology first introduced in 1991, high energy density but incurs longer charge times and shelf life of 1-3 years, can be dangerous if damaged.
LMO	Lithium Manganese Oxide	$Li_{1-x}MnO_4$	Power tools, medical instruments	Low internal cell resistance allows fast recharging and high-current discharging but 1/3 of LCO's energy capacity.
NCA	Nickel Cobalt Aluminum	$Li_{1-x}NiCoAlO_2$	**Electric powertrains for vehicles**, energy storage	High specific energy and long life span; safety and cost were historical concerns but these are now resolved..
NMC	Nickel Manganese Cobalt	$Li_{1-x}(NiMnCo)O_2$	**Electric powertrains for vehicles**, power tools	Can be tailored to high specific energy or high specific power; most Japanese and Korean producers sell NMC into EV market.
LFP	Lithium Iron Phosphate	$Li_{1-x}FePO_4$	**Electric powertrains for vehicles** , eBikes, garden lights etc.	LFP batteries offer a safe alternative due to thermal and chemical stability of the Fe-P-O bond compared to Co-O bond; the China is currently a large user of LFP over NCA/NMC.

Source: CSIRO presentation, DB Future Metals conference, 25/06/2013

The evolution of the battery technology

A battery consists of one or more electrochemical cells in which chemical energy is converted into electricity and used as a power source. A battery has two terminals, one positive (cathode) and one negative (anode), which allows charged particles to pass from one terminal to the other, generating an electric current.

Batteries have been under development for over 2,000 years; however, today's modern batteries date back to 1859, when the first rechargeable battery was invented. The lead-acid battery was made of low-cost materials and could be used in a number of applications where a small amount of energy storage was required to support power generation from another source. Lead-acid batteries continue to be the most common type found in internal combustion vehicles today.

The next 100 years saw significant research into other battery technologies not only to compete with lead-acid batteries, but to also open up applications that were not being pursued at the time due to the low energy-to-weight ratio of lead-acid batteries. New battery technologies such as zinc-carbon cells, nickel-iron cells and nickel-cadmium batteries were commercialized by the early 1900s.

The second half of the 20th century focused on further refinements to existing battery chemistries, with the common alkaline battery being commercialized in 1959 and the nickel-hydrogen and nickel-metal hydride (NiMH) batteries entering the market in 1989. These batteries were much more powerful than lead-acid and other existing technologies and could be used in more compact, lightweight applications.

The breakthrough of lithium-ion

Using lithium metal in batteries was first considered in 1912, but significant research investment in this technology did not take place until the 1970s. Lithium is the metal with the greatest electrochemical potential (the amount of free energy per charged particle), which suggested excellent energy-to-weight performance.

Early attempts to develop rechargeable lithium batteries used lithium metal as the <u>anode</u>, which allowed for very high energy densities. However, it was discovered in the 1980s that small dendrites, needle-like lithium metal particles, formed on the anode during discharge which upon growing would eventually penetrate the separator and cause an electrical short. The research community sought a non-metallic alternative for the anode which would allow lithium to be used in the <u>cathode</u> and in the electrolyte solution. Since that time, carbon-based anodes have been the dominant type used in commercial applications; graphite is the most efficient form of carbon used.

The development of the lithium-cobalt-oxide cathode in the early 1980s, along with the discovery of graphite as an anode material, led Asahi Chemical to build the first lithium-ion cell in 1985. The technology was commercialized by Sony Corporation in 1991. Today there are over 80 different lithium-ion battery chemistries in production with unique performance (energy density, power density, battery life) and cost metrics.

Small changes in chemistry have unlocked cell efficiencies

In Electric Vehicles, battery cells are placed within modules, which are then embedded into larger packs that include electronic battery management systems, electrical connectors, switches, and thermal controls (heating and cooling). Typically, the pack-level systems account for around 20% of the cost of the battery pack (i.e. battery cells/modules account for 80%). Slow but steady progress continues to be made in improving the energy density of batteries through reformulation of the materials used (typically taking non-active materials out), reducing the cost of materials while changing cell design, production speed, and production yield. This has resulted in increased energy density and reduced costs at both a cell and battery pack level.

The first lithium ion cells produced in the 1990s had energy density levels of roughly 90Wh/kg and cost US$2,000/kWh. Today's Panasonic 18650 batteries used in Tesla Electric Vehicles have an energy density of approximately 150Wh/kg and they cost less than US$250/kWh. We expect this trend to continue.

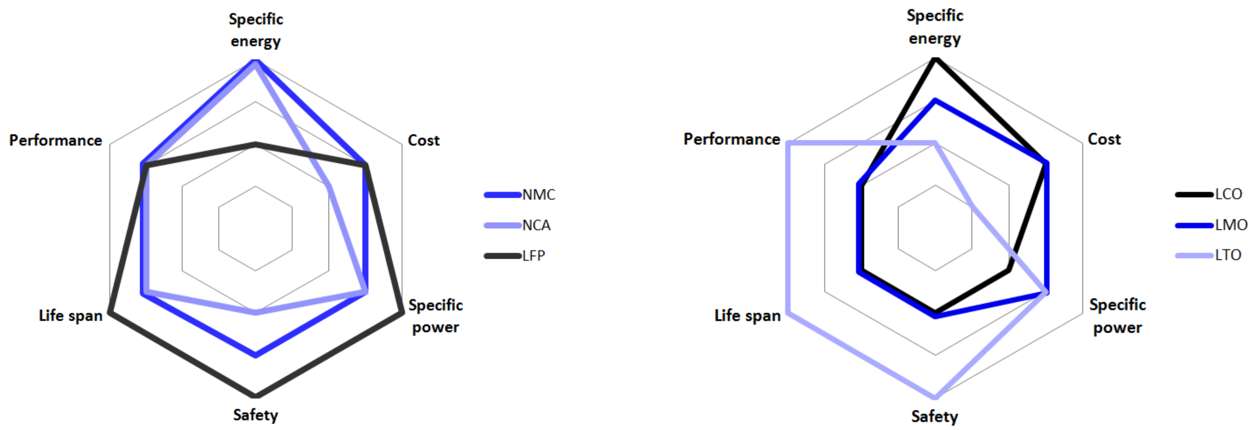
Middle stream: eager for technology breakthroughs

The middle stream refers to the manufacturing of the four key components of batteries: cathodes, anodes, separators, and electrolytes. Cathodes, anodes, electrolytes, and separators account for roughly 26%, 9%, 6%, and 4% of the total manufacturing cost of a lithium battery, respectively. The module and pack components account for a further 21%, cell manufacturing also 21% and other materials 13%. To significantly improve the performance of the lithium battery, technology breakthroughs are anticipated in all components.

Cathode: NMC/NMA is the trend for EV battery, but LFP is still present

The cathode is the key to improving battery performance, including production cost, life span, energy density and safety. There are a number of options for cathode materials, including NMC (Lithium Nickel Manganese Cobalt Oxide, $LiNiMnCoO_2$), NCA (Lithium Nickel cobalt Aluminum Oxide, $LiNiCoAlO_2$), LFP (Lithium Iron Phosphate $LiFePO_4$), LCO (Lithium cobalt Oxide, $LiCoO_2$), LMO (Lithium Manganese Oxide, $LiMn_2O_4$) and LTO (Lithium Titanate, $Li_4Ti_5O_{12}$), etc. Unfortunately, none of the cathodes available today can claim to be the optimal product as certain applications prefer particular chemistries. Figure 68 compares the major characteristics of lithium batteries using different types of cathodes. Lithium is the common element regardless of technology choice.

Figure 68: Characteristic comparisons of different types of lithium batteries



Source: Deutsche Bank, Cadex Electronics, Battery university

Different types of lithium batteries are suitable for different types of usage based on the natural chemical characteristics resulting from varying cathodes. For the EV battery, the key considerations are safety and energy density (kWh/kg). Therefore, the current mainstream solutions are 1) ternary material series, NMC/NCA, which have higher energy density, but concerns around safety remain. The risks of fire hazard are higher; and 2) LFP, which is safer, but energy density is relatively low, and there has been slow progress on performance improvements. In China, most commercial EVs use LFP, as manufacturers prioritize safety, while passenger EV producers prefer to use NMC/NCA, as driving range is crucial.

In China, we believe LFP will not yet be removed, especially after several recent accidents involving explosions; safety has rapidly grown in importance. The CAAM (China Association of Automobile Manufacturers) submitted a suggestion to the MIIT (Ministry of Industry of Information and Technology), asking that it would not allow passenger EVs to install ternary material lithium batteries due to safety considerations. The policy risk may be significant to NMC/NCA cathode producers (which are mainly Japanese and Korean companies). The risks of technical breakthrough, intensive competition, government policy interference, and lack of clear industry standards will continue to affect the cathode manufacturing sector.

Electrolyte: current technical solution is steady

Electrolytes comprise lithium salt compounds (lithium hexafluorophosphate, $LiPF_6$) which have relatively high ba of entry, and solvents, which are easier to produce. Using different electrolyte solvents, lithium batteries can be divided into two basic types: liquefied lithium ion battery (LIB) and polymer lithium ion battery (PLB). PLB's electrolyte could be either gel or solid. However, lithium hexafluorophosphate is effectively a necessity in all popular solutions that have been developed. Research on electrolytes is still underway, seeking to improve battery performance, such as enhancing low-temperature conductivity and reducing the viscosity of the electrolyte, improving cycle life, and increasing safety features, especially for larger batteries. Significant efforts have been made to try additives, new solvents, and a mixture of current popular solvents.

Anode – currently low profit and waiting for graphene to take off

For rechargeable lithium batteries, the anode is the negative pole during discharge and the positive pole during charge, helping to release the electrons into the circuit. In terms of anode production, barriers to entry are reasonably limited, and so the profitability of anode producers is usually low. Either natural or synthetic graphite is typically used in anodes. Graphite is the incumbent product, is readily available and not a major cost input for batteries. There are strict quality controls on the graphite products used in batteries as they affect cell performance.

Separator – Japanese producers still dominate

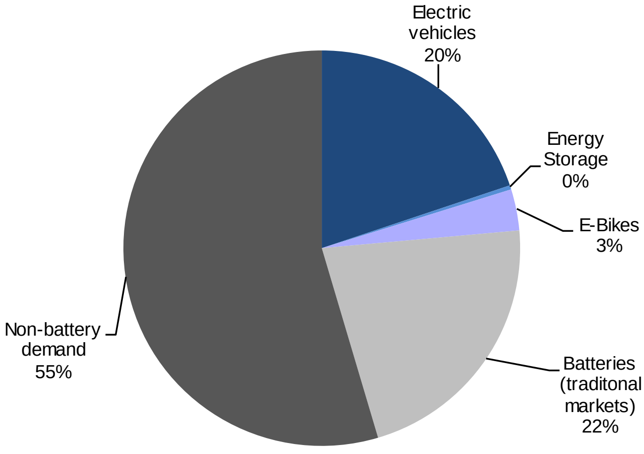
The battery separator is used to detach the cathode from the anode. A separator is usually composed of nylon, polypropylene (PE) and polyethylene (PP). The quality of separator decides the ion-transportation capability and will have a direct influence on battery performance. For EV batteries, some unique characteristics are essential, such as 1) higher shut-down temperature and melting point for safety purposes; 2) high puncture resistance; 3) homogenous pore size and distribution. The production know-how requirement is high. Japanese companies play a big role in this area.

Lithium supply/demand considerations

Demand

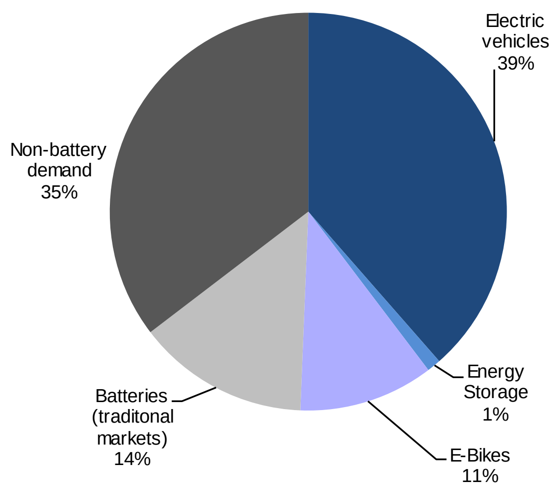
We believe global lithium demand increased 15% Y/Y to 212kt lithium carbonate equivalent (LCE) in 2016. The primary growth driver, global sales of Electric Vehicles (EVs) and Plug-in Hybrids (PHEVs) were around 780,000 vehicles. In 2017, we forecast global lithium demand to increase 24% Y/Y to 263kt LCE, driven by global EV/PHEV sales increasing 55% to 1.4m vehicles.

Figure 69: Demand by application (2016)



Source: USGS, Company data, Deutsche Bank

Figure 70: Demand by application (2019E)



Source: USGS, Company data, Deutsche Bank

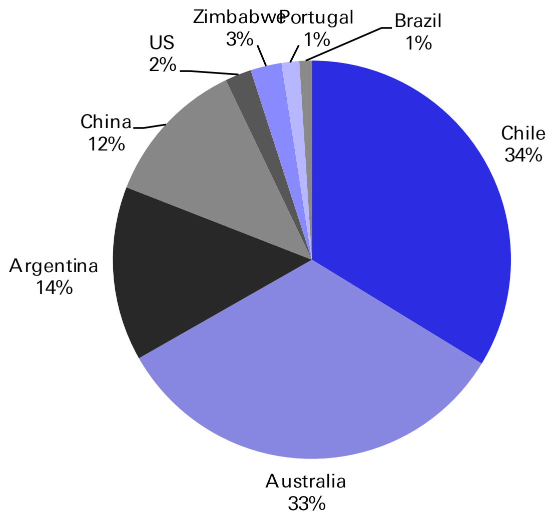
Supply

Lithium is not particularly rare; however, new projects generally have a long lead time and there have historically been permitting, funding and regulatory setbacks in key regions which has slowed development.

In 2016/2017, global supply has responded to increased demand, with Y/Y production growth in Chile (mainly SQM), Argentina (ramp up of Orocobre) and China (high-cost domestic feedstock production incentivized into the market). Volumes at Greenbushes, the world's largest hard rock operation (2016 lithium concentrate exports from Greenbushes were close to 70kt LCE, 20% higher than 2015 export volumes), have also increased. In the near-term, new lithium projects include Mt. Marion, Mt. Cattlin, La Negra II and Wodgina, which in aggregate will add significant new supply.

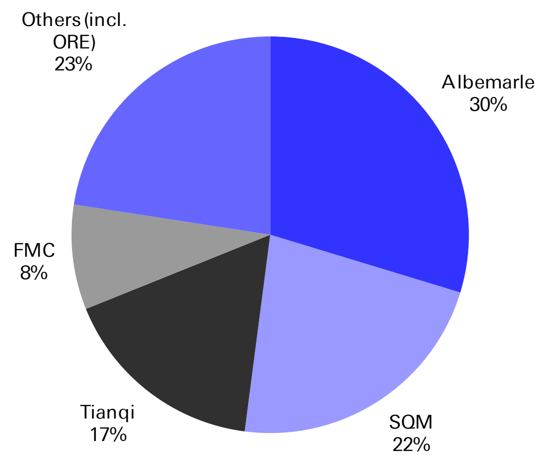
We expect US$4.5bn of capital needs to flow into upstream lithium markets in order to meet 2025 demand. We have identified over US$1.9bn in capital transactions over the last two years, with hard rock projects and downstream refining capacity responding the fastest. Over the next three years, 75% of incremental lithium supply will come from hard rock projects. Albemarle and SQM have accelerated growth plans that are relatively low-risk, but development of greenfield brine projects is lagging demand given long project lead times.

Figure 71: Supply by country (2016)



Source: USGS, Company data, Deutsche Bank

Figure 72: Supply by company (2016)



Source: USGS, Company data, Deutsche Bank

Key companies in the battery supply chain

Figure 73 below divides the lithium-ion battery supply chain into four categories: Raw materials, Battery Components, Cells and End-Use Applications. The key companies currently involved are listed in each category.

Figure 73: Major Companies across the lithium industry supply chain

RAW MATERIALS	BATTERY COMPONENTS	CELLS	END-USE APPLICATIONS
LITHIUM (Li_2O, $LiOH$, Li_2O_3)	ANODE	CELL CONSTRUCTION	EVs/PHEVs/HEVs
SQM	Altair Nanotechnologies	Panasonic	Tesla
FMC Corp	ConocoPhilip	LG Chem	Ford
Orocobre	Hitachi Chemical	Foxconn	GM
Albemarle	Kureha	Boston Power	BYD
Bacanora Minerals	Nippon Carbon	Sansumg SDI	Daimler
Pure Energy Minerals	Pyrotek	Tesla	Honda
Jiangxi Ganfeng	Superior Graphite	BYD	Nissan
Tianqi Group	LG Chem	Continental	Toyoto
Galaxy		Johnson Controls	Volkswagen
Neometals	CATHODE	GM	Geely Automobile
Pilbara Minerals	Umicore	Lishen	Chevrolet
Altura	Nichia Chemical	LithChem	Aston Martin
GRAPHITE/SYNTHETIC GRAPHITE	Sumitomo	Maxwell	Mercedes Benz
Syrah Resources	L&F	NEC	Audi
China - various	Shanshan	Sanyo	Zoyte Auto
Brazil	3M	Toshiba	BAIC Motor Corp
Triton Minerals	BASF		SAIC Motor Corp
Mason Graphite	Bamo-Tech		Chongqing Changan Auto
Graphite One	Easpring	BATTERY PACKS	
Energiser/Malagasy	Nippon denko	A123	STATIONARY STORAGE
Talga Resources	Toda Kogyo	AC Propulsion	Tesla
	Formosa	All Cell Technologies	LG Chem
COBALT COMPOUNDS	King-ray	Boston Power	Samsung
Tanaka Corporation		BYD	AES
Kansai Catalyst	SEPARATORS (FOILS)	Coda	BYD
Santoku	Applied Materials	LG Chem	Saft Groupe
Glencore	Asahi Kasei	Continental	Coda Energy
Cobalt27	Celgard	XALT energy	Stem
Clean TeQ	DuPont	Electrovaya	Green Charge Networks
	Entek	EnerDel	Sonnen-Batterie
NICKEL COMPOUNDS	Evonik Industries	OptimumNano	Vestas
Tanaka Corporation	SK Energy	Guoxuan	EDF Energy
Kansai Catalyst	Toray Tonen	China Aviation	Enel
Sumitomo	Cangzhou Mingzhu	Sinopoly	Duke Energy
WSA		CATL	National Grid
	ELECTRODES	GM	First Solar
MANGANESE COMPOUNDS	Cheil Industries	GSYuasa	GE
Mitsui	LithChem	Hitachi	Siemans
Sumitomo	Mitsubishi Chemical	Johnson Controls-saft	
S32	Mitsui Chemical	Lishen	ELECTRONICS/CONSUMER PRODUCTS
	Novolyte Technologies	NEC	Sony
ALUMINUM	Panex	Panasonic	Google
Alcoa	Shenzhen Capchem	Sanyo	Huawei
	Do-Fluoride Chemicals	Samsung SDI	Samsung SDI
	Tianci Materials	Tesla	Xiaomi
	ShanShan		Apple
	Shinestar		Panasonic
	Tomiyama Yakuhin		

Source: Deutsche Bank

Appendix II: Current Electric Truck Offerings

Outside of limited bus options, there are very few electric commercial vehicles (CVs) available today. That said, most OEMs/powertrain suppliers have noted that they have dedicated a portion of their R&D budgets to electrification – albeit this is only one component of a more diverse alternative fuel investment strategy, given that viability has not yet been proven. Today, despite increasing buzz from the investment community, electric trucks are still merely in the development phase.

In this section of the report, we provide a summary of current electric CV offerings along with company commentary around the future of electric vehicles and their position in R&D budgets.

Current electric truck offerings are few and far between

A number of industry participants have begun offering electrified CV powertrains in limited applications such as transit bus, refuse collection, and some shorter-haul trucking applications. In the figure below, we outline some of what can be purchased today.

Figure 74: Commercially available BEVs are limited today

Trucks

Manufacturer	Model	GVWR (lbs)	Battery Size (kWh)	Charging Time (hrs)	Range (miles)	Price
BYD-CN	T9	120,000*	188	2.5	192	$300,000
BYD-CN	T7	23,600	175	1.8	124	$195,000
BYD-CN	T5	16,000	145	1.5	155	$165,000
FirstPriorityGreenfleet-US	Box Cargo Truck	23,000	99	9.0	90	$150,000
ZeroTruck-US	ZT Optional Heavy Duty Chassis	19,500	80	9.0	80	$120,000
Zenith-US	Electric Step Van	22,000	100	12.0	90	N/A

Bus

Manufacturer	Model	Length (ft)	Battery Size (kWh)	Charging Time (hrs)	Range (miles)	Price
New Flyer-US	Xcelsior Electric	30,40,60	290	1.0	120	$975,000
BYD-CN	K9	40	324	4.0	161	$850,000
VDL Berkhof-NL	SLF Electric	30,40,60	124	0.1	63	NA
Proterra-US	Proterra	35,40	370	2.6	200	$772,000
GreenPower-US	EV Series	30,45	344	NA	208	$850,000
Volvo-SE	7900	40	19	0.1	5	NA
Irizar-ES	Irizar i2e	40	256	6.0	135	$550,000
ADL & BYD-UK & CN	Enviro200EV	35,40	135	4.0	200	NA

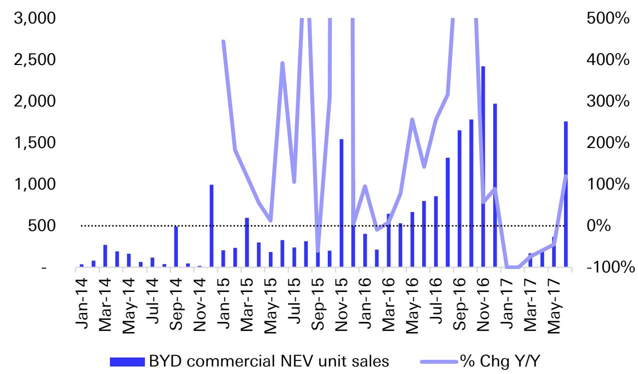
Refuse Trucks

Manufacturer	Model	GVWR (lbs)	Battery Size (kWh)	Charging Time (hrs)	Range (miles)	Price
Motiv-US	Motiv	60,000	200	8	60	NA
BYD-CN	Class 8 Refuse Truck	NA	178	2.8	76	N/A
WrightSpeed-US	WrightSpeed	66,000	NA	NA	27	NA

Source: Deutsche Bank, Company Information
Note: Prices and ranges are mid-points of available offerings (based on different options found)
Note: BYD's T9 weight is GCWR, not GVWR

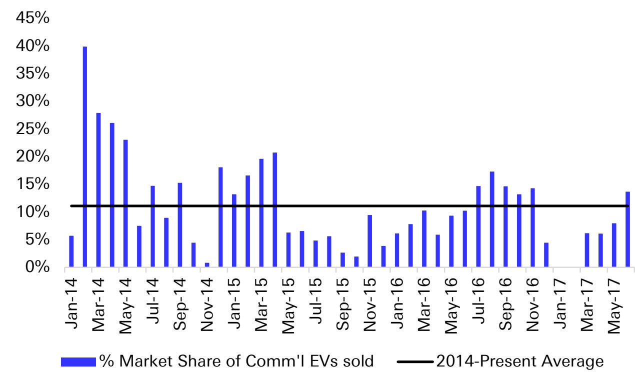
- **BYD:** A Chinese company that, through subsidiaries, engages in three businesses: 1) Li-ion and nickel rechargeable batteries; 2) handset components and assembly services; and 3) the production of autos, including hybrid and electric vehicles. In the truck market, BYD offers medium-duty (Class 5-7) step vans, stake-bed, box and refrigerated trucks. Within Class 8, BYD offers the T9 model, which is designed for short-haul applications (This is the only Class 8 vehicle in our table above). BYD is notable because of its high market share in China.

Figure 75: BYD sold 13k NEV trucks and buses in China last year



Source: Deutsche Bank, China Association of Automobile Manufacturers (CAAM), BYD
Note: NEV sales include BEVs and PHEVs

Figure 76: And accounts for ~10% of China's commercial NEV market



Source: Deutsche Bank, China Association of Automobile Manufacturers (CAAM), BYD
Note: NEV sales include BEVs and PHEVs

- **FirstPriority Greenfleet:** A US company that designs, manufactures, sells and services electric box cargo trucks, school buses, shuttle buses, utility vehicles and walk-in vans. The company operates through contract manufacturing, and designs customized vehicles for end users by specific application.
- **ZeroTruck:** A California-based company that offers a medium-duty (Class 3 or 5, depending on chassis used) electric trucks, targeted for use in shorter haul applications (~70 mile range), and available in a variety of configurations.
- **Zenith:** Another privately-owned US company, focused on the electric shuttle and cargo van market. Bus and van models offered by Zenith have a range of ~80 miles, and are limited to speeds of ~55 mph.
- **New Flyer:** A Canadian manufacturer of heavy-duty transit buses and motorcoaches, New Flyer offers electric buses under its Xcelsior brand that utilize lithium-ion batteries ranging from 100-480 kWh capacity.
- **VDL Berkhof:** Manufactures buses and coaches, part of the industrial manufacturing company VDL Groep, based in the Netherlands. The company's SLF electric bus has batteries on the roof with room for a pantograph, enabling potential charging along pre-determined routes.
- **Proterra:** Privately owned, California-based Proterra produced the first transit bus to meet California's Zero-Emission Bus Rules.
- **GreenPower:** A Canadian electric bus (transit, shuttle & school) manufacturer (listed on the TSX and OTCQB) that integrates key components from Siemens (drive motors), Knorr (brakes), ZF (axles) and Parker-Hannifin (dash board/control systems).

- **Volvo:** Global vehicle manufacturer that is among the largest companies investing/developing/testing commercial electric vehicles.
- **Irizar:** Spanish-based manufacturer of luxury coach bodies, Irizar has also launched an electric bus, the Irizar i2e.
- **ADL:** A UK-based manufacturer of bus and coaches that has partnered with BYD in the production of all-electric buses
- **Motiv:** A California-based manufacturer of all-electric powertrain control systems that partners with various industry participants for the production of electric commercial vehicles, notably refuse trucks, which Motiv participated in the US' first all-electric version of, in 2012.
- **WrightSpeed:** All-electric powertrain manufacturer founded by Tesla co-founder Ian Wright.

We also note current hybrid offerings, which can take a variety of forms, including applications where the 'electric' is auxiliary power aimed at reducing engine use during idling, and not for vehicle propulsion (these are commonly referred to as mild hybrids).

Figure 77: Current hybrid commercial vehicle offerings are concentrated in transit bus

Transit Bus

Manufacturer	Model	Length (ft)	Engine	Battery Size (kWh)	Price
New Flyer-US	Xcelsior	35,40,60	Cummins ISB	150	$725,000
Nova Bus-US	LFS Artic HEV	40,62	Cummins ISB 6.7| ISL 8.9	100	$657,500
Nova Bus-US	LFS HEV	40, 62	Cummins ISL 8.9L| ISB 6.7L	100	$700,000
REV Group-US	E-Z Rider II	30,32,35	Cummins ISL G 8.9L	NA	$580,000
Gillig Corp-US	Standard, BRT, BRTPlus	30,35,40	Cummins ISL G 8.9L| ISL 9L| ISB	NA	$560,000

Truck

Manufacturer	Model	GCWR (lbs)	Engine	Battery Size (kWh)	Price
Hino-JPN	Hino 195H	25,500	HINO J05E-UG	NA	$100,000
Altec-US	LR758	33,000	Cummins ISB | ISL	NA	$143,600
Altec-US	TA50	22,000	Cummins ISB | ISL	NA	$192,000
Odyne-US	Dueco International	33,000	Cummins ISB | ISL	14.2	NA

Refuse Truck

Manufacturer	Model	GCWR (lbs)	Engine	Battery Size (kWh)	Price
Autocar-US	ACX ISL 9 ER Hybrid	66,000	Cummins ISB | ISL	NA	$260,000

Source: Deutsche Bank, Company Information

Appendix 1

Important Disclosures

*Other information available upon request

Disclosure checklist

Company	Ticker	Recent price*	Disclosure
Cummins Inc.	CMI.N	159.36 (USD) 1 Sep 17	14
Allison Transmission	ALSN.N	35.04 (USD) 1 Sep 17	1,7,8,14,15
Navistar International	NAV.N	34.52 (USD) 1 Sep 17	8,14,15
PACCAR Inc	PCAR.OQ	65.86 (USD) 1 Sep 17	2
WABCO Holdings	WBC.N	143.88 (USD) 1 Sep 17	NA

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Important Disclosures Required by U.S. Regulators

Disclosures marked with an asterisk may also be required by at least one jurisdiction in addition to the United States. See Important Disclosures Required by Non-US Regulators and Explanatory Notes.

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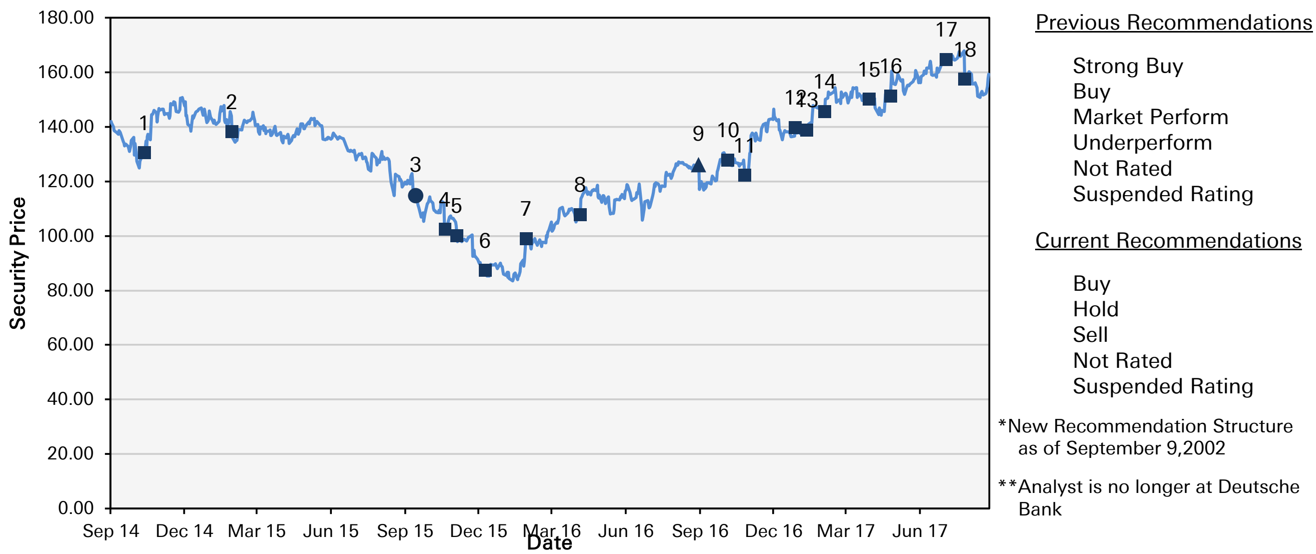
Analyst Certification

The views expressed in this report accurately reflect the personal views of the undersigned lead analyst about the subject issuers and the securities of those issuers. In addition, the undersigned lead analyst has not and will not receive any compensation for providing a specific recommendation or view in this report. Nicole DeBlase/Rod Lache/Tim Rokossa/Amit Mehrotra/Chris Terry/Ross Seymore/Johannes Schaller

Historical recommendations and target price: Cummins Inc. (CMI.N)

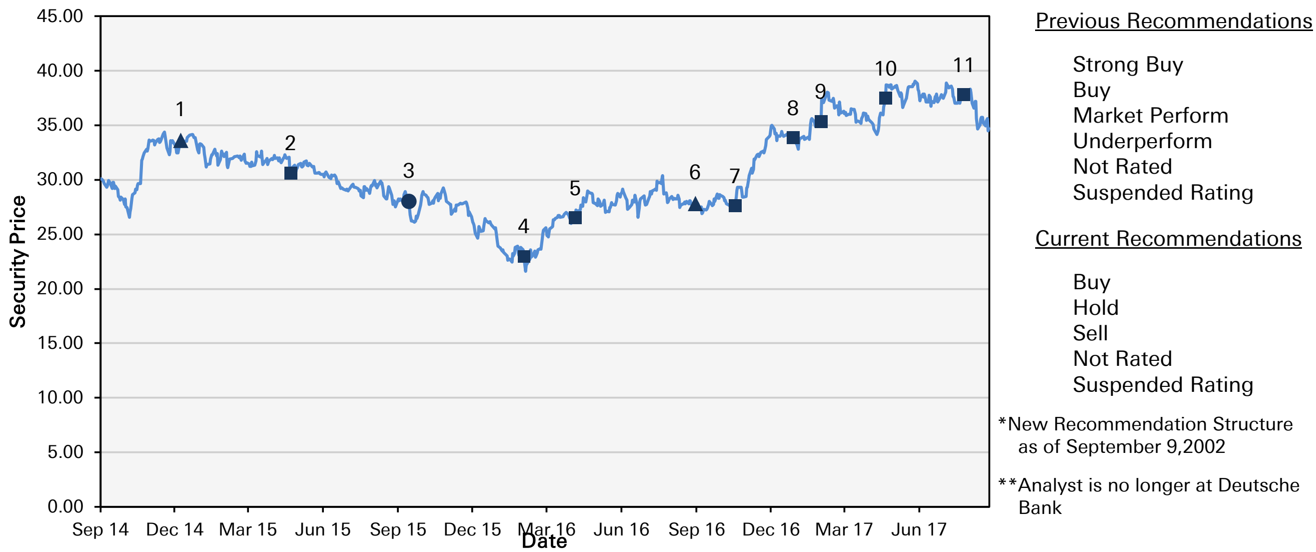
(as of 9/1/2017)



1. 10/19/2014: Buy, Target Price Change USD164.00 Vish Shah
2. 02/05/2015: Buy, Target Price Change USD154.00 Vish Shah
3. 09/21/2015: Downgrade to Hold, Target Price Change USD123.00 Vish Shah
4. 10/27/2015: Hold, Target Price Change USD108.00 Vish Shah
5. 11/11/2015: Hold, Target Price Change USD102.00 Vish Shah
6. 12/16/2015: Hold, Target Price Change USD87.00 Vish Shah
7. 02/05/2016: Hold, Target Price Change USD93.00 Vish Shah
8. 04/12/2016: No Recommendation, Target Price Change USD0.00 Rakesh Kumar**
9. 09/06/2016: Upgrade to Sell, Target Price Change USD111.00 Nicole DeBlase
10. 10/12/2016: Sell, Target Price Change USD112.00 Nicole DeBlase
11. 11/02/2016: Sell, Target Price Change USD111.00 Nicole DeBlase
12. 01/04/2017: Sell, Target Price Change USD118.00 Nicole DeBlase
13. 01/18/2017: Sell, Target Price Change USD125.00 Nicole DeBlase
14. 02/09/2017: Sell, Target Price Change USD139.00 Nicole DeBlase
15. 04/05/2017: Sell, Target Price Change USD142.00 Nicole DeBlase
16. 05/02/2017: Sell, Target Price Change USD154.00 Nicole DeBlase
17. 07/10/2017: Sell, Target Price Change USD155.00 Nicole DeBlase
18. 08/02/2017: Sell, Target Price Change USD147.00 Nicole DeBlase

Historical recommendations and target price: Allison Transmission (ALSN.N)

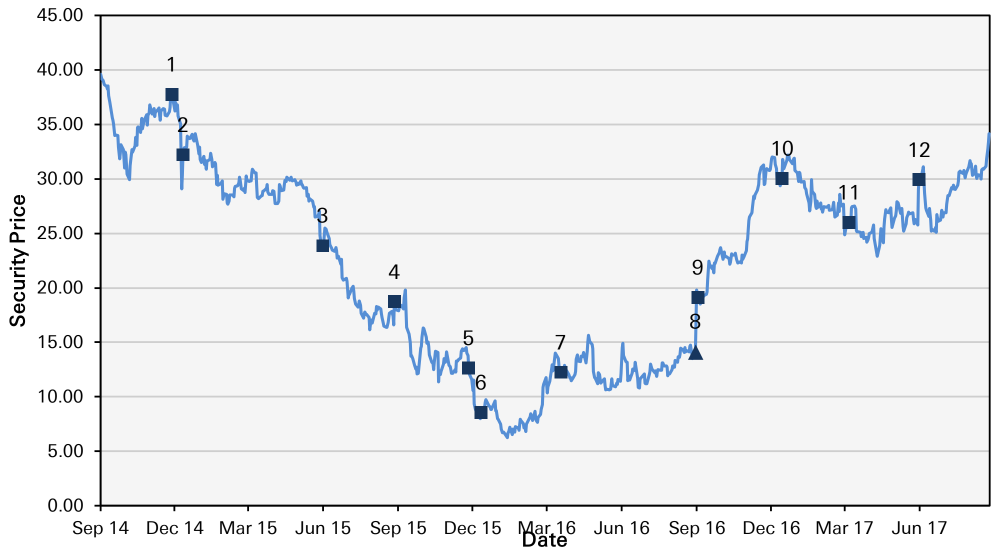
(as of 9/1/2017)



1.	12/15/2014:	Upgrade to Buy, Target Price Change USD41.00 Vish Shah	7.	10/25/2016:	Hold, Target Price Change USD31.00 Nicole DeBlase
2.	04/29/2015:	Buy, Target Price Change USD38.00 Vish Shah	8.	01/04/2017:	Hold, Target Price Change USD36.00 Nicole DeBlase
3.	09/21/2015:	Downgrade to Hold, Target Price Change USD28.00 Vish Shah	9.	02/07/2017:	Hold, Target Price Change USD43.00 Nicole DeBlase
4.	02/09/2016:	Hold, Target Price Change USD25.00 Vish Shah	10.	04/27/2017:	Hold, Target Price Change USD44.00 Nicole DeBlase
5.	04/12/2016:	No Recommendation, Target Price Change USD0.00 Rakesh Kumar**	11.	08/01/2017:	Hold, Target Price Change USD43.00 Nicole DeBlase
6.	09/06/2016:	Upgrade to Hold, Target Price Change USD30.00 Nicole DeBlase			

Historical recommendations and target price: Navistar International (NAV.N)

(as of 9/1/2017)



Previous Recommendations

Strong Buy
Buy
Market Perform
Underperform
Not Rated
Suspended Rating

Current Recommendations

Buy
Hold
Sell
Not Rated
Suspended Rating

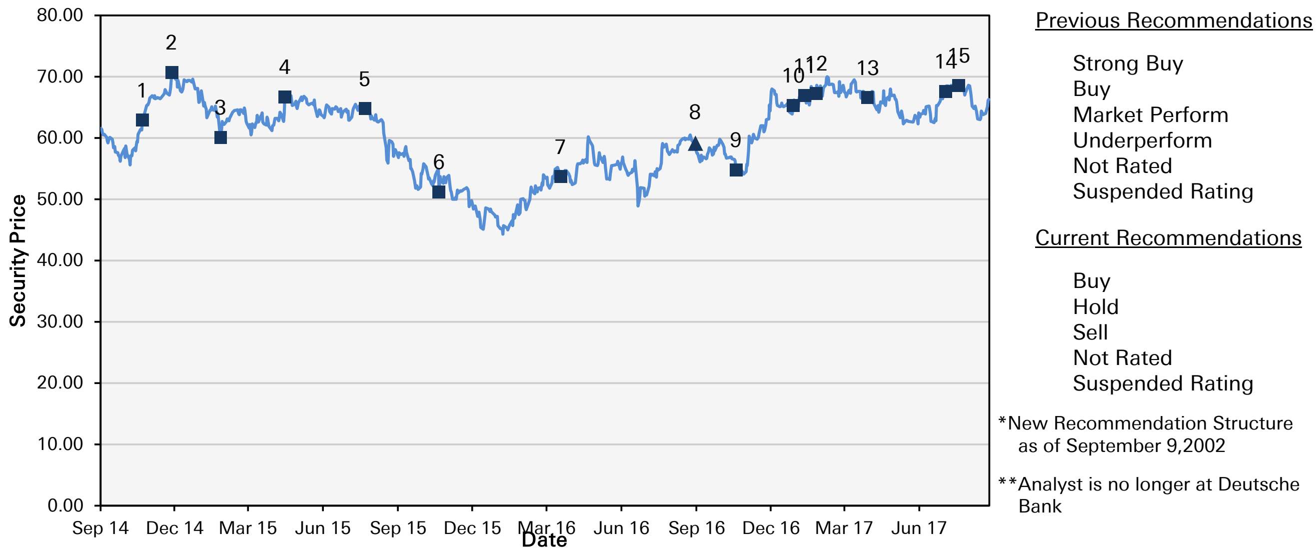
*New Recommendation Structure as of September 9,2002

**Analyst is no longer at Deutsche Bank

1. 12/04/2014: Hold, Target Price Change USD37.50 Patrick Nolan, CFA**
2. 12/18/2014: Hold, Target Price Change USD32.00 Patrick Nolan, CFA**
3. 06/07/2015: Hold, Target Price Change USD29.00 Patrick Nolan, CFA**
4. 09/03/2015: Hold, Target Price Change USD17.00 Patrick Nolan, CFA**
5. 12/03/2015: Hold, Target Price Change USD14.00 Tim Rokossa
6. 12/18/2015: Hold, Target Price Change USD9.00 Patrick Nolan, CFA**
7. 03/25/2016: No Recommendation, Target Price Change USD0.00 Patrick Nolan, CFA**
8. 09/06/2016: Upgrade to Hold, Target Price Change USD14.00 Nicole DeBlase
9. 09/09/2016: Hold, Target Price Change USD21.00 Nicole DeBlase
10. 12/21/2016: Hold, Target Price Change USD32.00 Nicole DeBlase
11. 03/13/2017: Hold, Target Price Change USD24.00 Nicole DeBlase
12. 06/07/2017: Hold, Target Price Change USD26.00 Nicole DeBlase

Historical recommendations and target price: PACCAR Inc (PCAR.OQ)

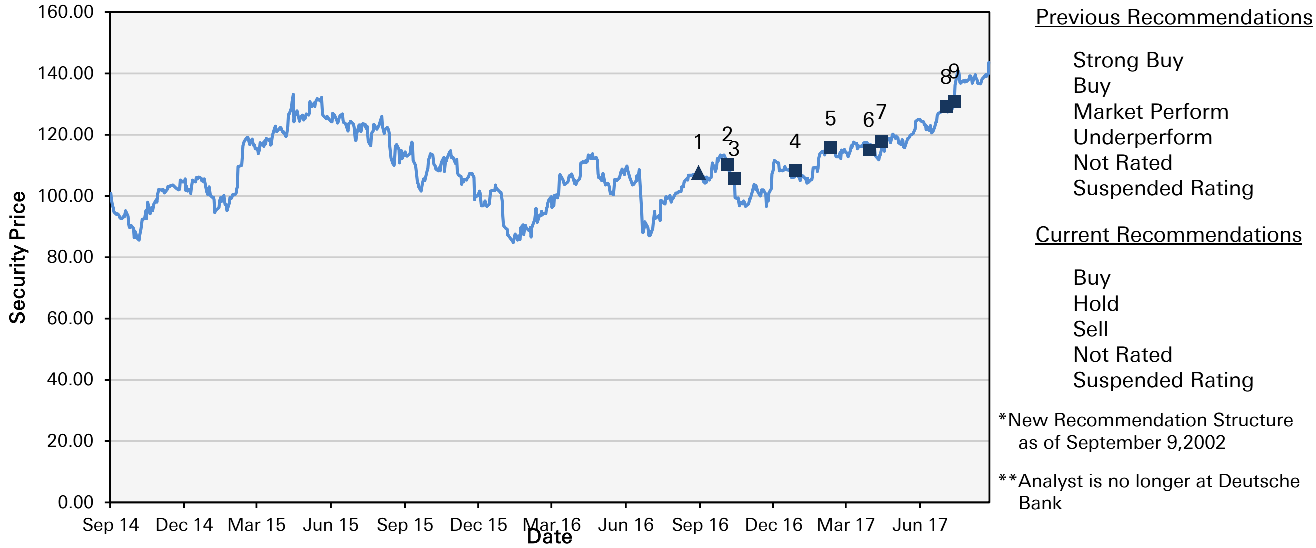
(as of 9/1/2017)



1. 10/29/2014:	Hold, Target Price Change USD61.00 Patrick Nolan, CFA**	9. 10/26/2016:	Hold, Target Price Change USD60.00 Nicole DeBlase
2. 12/04/2014:	Hold, Target Price Change USD63.00 Patrick Nolan, CFA**	10. 01/04/2017:	Hold, Target Price Change USD65.00 Nicole DeBlase
3. 02/02/2015:	Hold, Target Price Change USD64.00 Patrick Nolan, CFA**	11. 01/18/2017:	Hold, Target Price Change USD67.00 Nicole DeBlase
4. 04/22/2015:	Hold, Target Price Change USD68.00 Patrick Nolan, CFA**	12. 02/01/2017:	Hold, Target Price Change USD71.00 Nicole DeBlase
5. 07/29/2015:	Hold, Target Price Change USD70.00 Patrick Nolan, CFA**	13. 04/05/2017:	Hold, Target Price Change USD73.00 Nicole DeBlase
6. 10/28/2015:	Hold, Target Price Change USD60.00 Patrick Nolan, CFA**	14. 07/10/2017:	Hold, Target Price Change USD77.00 Nicole DeBlase
7. 03/25/2016:	No Recommendation, Target Price Change USD0.00 Kirill Babikov**	15. 07/26/2017:	Hold, Target Price Change USD75.00 Nicole DeBlase
8. 09/06/2016:	Upgrade to Hold, Target Price Change USD63.00 Nicole DeBlase		

Historical recommendations and target price: WABCO Holdings (WBC.N)

(as of 9/1/2017)



1.	09/06/2016:	Upgrade to Hold, Target Price Change USD113.00 Nicole DeBlase	6.	04/05/2017:	Hold, Target Price Change USD130.00 Nicole DeBlase
2.	10/12/2016:	Hold, Target Price Change USD114.00 Nicole DeBlase	7.	04/21/2017:	Hold, Target Price Change USD126.00 Nicole DeBlase
3.	10/20/2016:	Hold, Target Price Change USD110.00 Nicole DeBlase	8.	07/10/2017:	Hold, Target Price Change USD128.00 Nicole DeBlase
4.	01/04/2017:	Hold, Target Price Change USD115.00 Nicole DeBlase	9.	07/20/2017:	Hold, Target Price Change USD146.00 Nicole DeBlase
5.	02/17/2017:	Hold, Target Price Change USD129.00 Nicole DeBlase			

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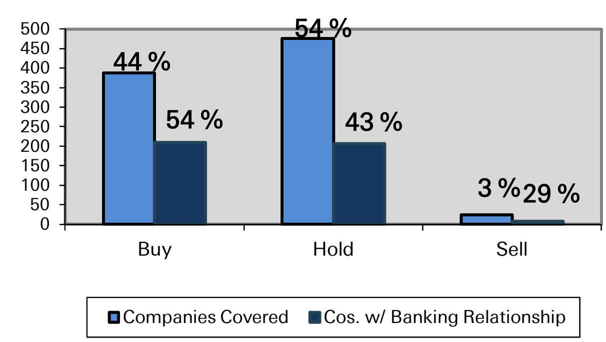
Buy: Based on a current 12- month view of total share-holder return (TSR = percentage change in share price from current price to projected target price plus pro-jected dividend yield) , we recommend that investors buy the stock.

Sell: Based on a current 12-month view of total share-holder return, we recommend that investors sell the stock

Hold: We take a neutral view on the stock 12-months out and, based on this time horizon, do not recommend either a Buy or Sell.

Newly issued research recommendations and target prices supersede previously published research.

Equity rating dispersion and banking relationships



North American Universe

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