THE CAR OF THE FUTURE

Transforming Mobility As We Know It

Citi GPS: Global Perspectives & Solutions

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For anyone who grew up watching after-school or Saturday morning television, cartoons like *The Jetsons* and the vision of George Jetson getting into his spaceship and commuting to work on a space highway is a familiar memory. That 1960s vision of how the future world would look was influenced by the race to be the first to land on the moon and the beginnings of real advancements in computer development. Although we're not all jumping into our spaceships to get to the office, there has been an amazing transformation in automobile technology over the past 40-plus years. And this is just the beginning.

In this Car of the Future report, we attempt to explain and evaluate those global automotive technologies that will shape tomorrow's cars — from assembly to safety to fuel. In identifying and evaluating these future technologies, we also put together a basic investor framework that evaluates the potential for each technology by asking some simple questions — things like "Is there a specific regulatory driver?" Or "Is it reasonably affordable to consumers?" We think this is a good starting point for sorting through the plethora of opportunity and change that's out there.

Regulation plays an important role as a driver for some of the change that's coming up. New regulation on fuel efficiency is leading manufacturers to decrease the weight of vehicles through lightweighting of materials. New operating models like car sharing are changing the way that we traditionally think of vehicle sales and affordable/low-cost green cars are increasing the global statistics for car ownership while being environmentally considerate.

After years of fits and starts, electric vehicles are finally starting to get some traction as advances in battery technology improve drive time and the prospect of a battery operator model could be the path to a low-cost vehicle. Alternative fuel sources (like compressed natural gas and fuel cell vehicles) are also helped by global regulatory requirements that are now largely enacted and are stringent on emissions reduction.

Where we may be coming closest to the Jetson spaceship is in technology — the Connected Car. Auto parts manufacturer Continental forecasts growth in telematics is of around 34% from now until 2020 versus market growth of 4%, reflecting the convergence of active safety through advanced drive assistance systems and embedded connectivity. The driver's seat will soon resemble a cockpit with heads-up displays and personalized interfaces driven both by technological advances and consumer demand.

What about a self-driving car? The foundation for autonomous driving already exists and can be seen through the new advanced driver assistance systems, but it's not likely to be a commercial reality before 2025. And who knows? We could all be driving spaceships to work by then.

The Car of the Future

Not just a tune-up but a complete overhaul

IN THE MARKET GROWTH OF MAJOR APPLICATIONS FIGURE

Electronic Devices

Motor	7%
Automotive Radar	23%
Automotive Camera	29%
Lithium ion Battery	22%
Connector	7%
Semiconductor	7%
ECU	7%

Safety, Infomatics

Telematics	34%
PND	-8%
Car Navigation	8%
ADAS	21%
Touch Screens	14%
Heads-up Displays	11%

Fuel Efficiency

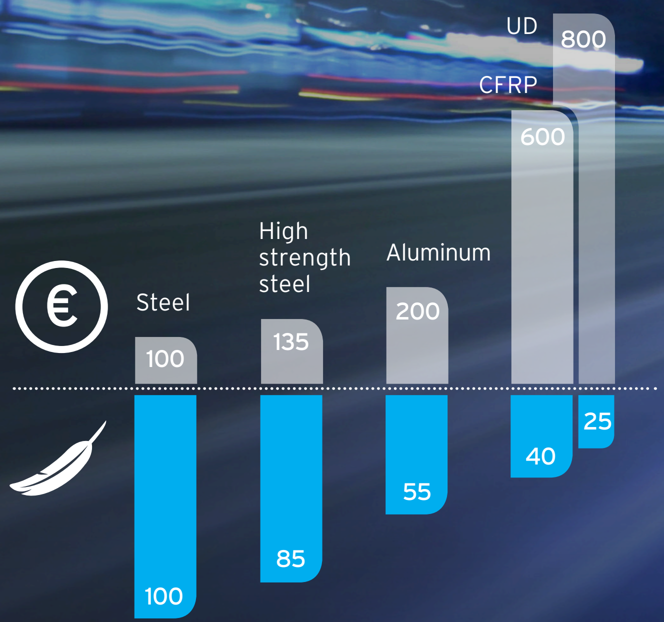
LED Front Light	51%
EPS	11%
ISS	17%
xEV	19%
HEV	17%
PHEV	40%
EV	40%
LV DCT	15%
LV Step ATs	1%
LV CVT	8%
LV Turbo Gasoline	13%
LV Turbo Diesel	4%
LV EGR Gasoline	28%
LV EGR Diesel	5%
LV VCT	6%
GDI	17%
MD/HD Common Rail	14%
ESC	5%

Global Auto Market: 4%

Company Reports, Citi Research

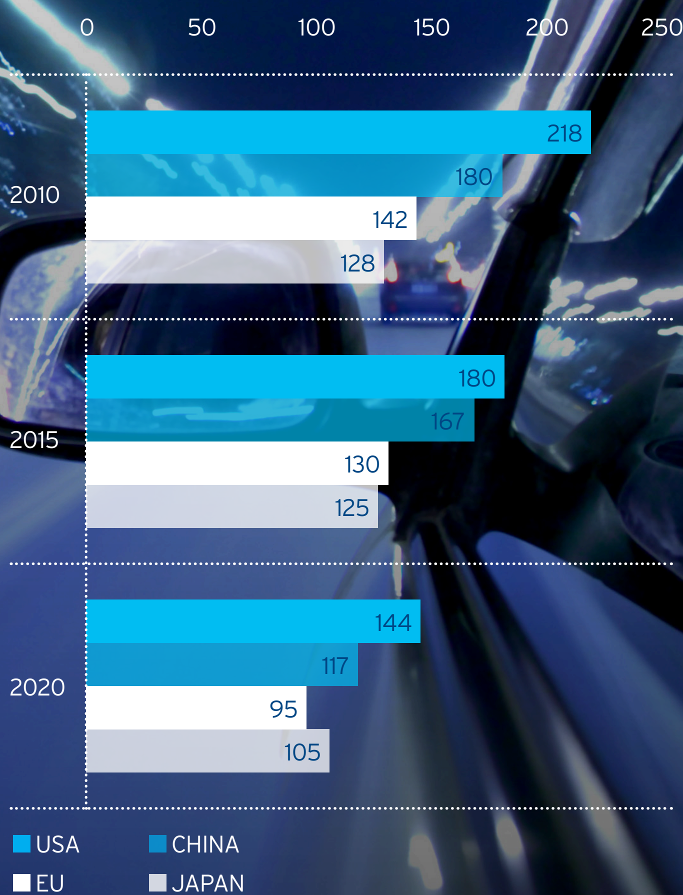
MATERIALS MAKE A DIFFERENCE TO COST AND WEIGHT

Relative comparison for parts with same function



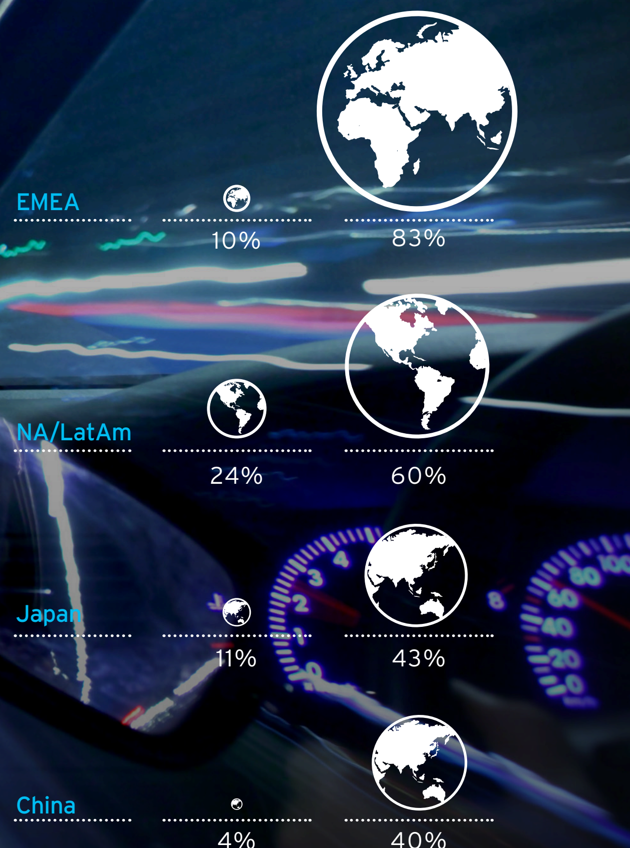
Source: BASF

REGULATION ON CO2 IS DRIVING FUEL EFFICIENCY (G/KM)



Source: Continental

EMBEDDED TELEMATICS INSTALLATION EXPECTED TO RISE SIGNIFICANTLY FROM 2013 TO 2017



Source: Continental

Contents

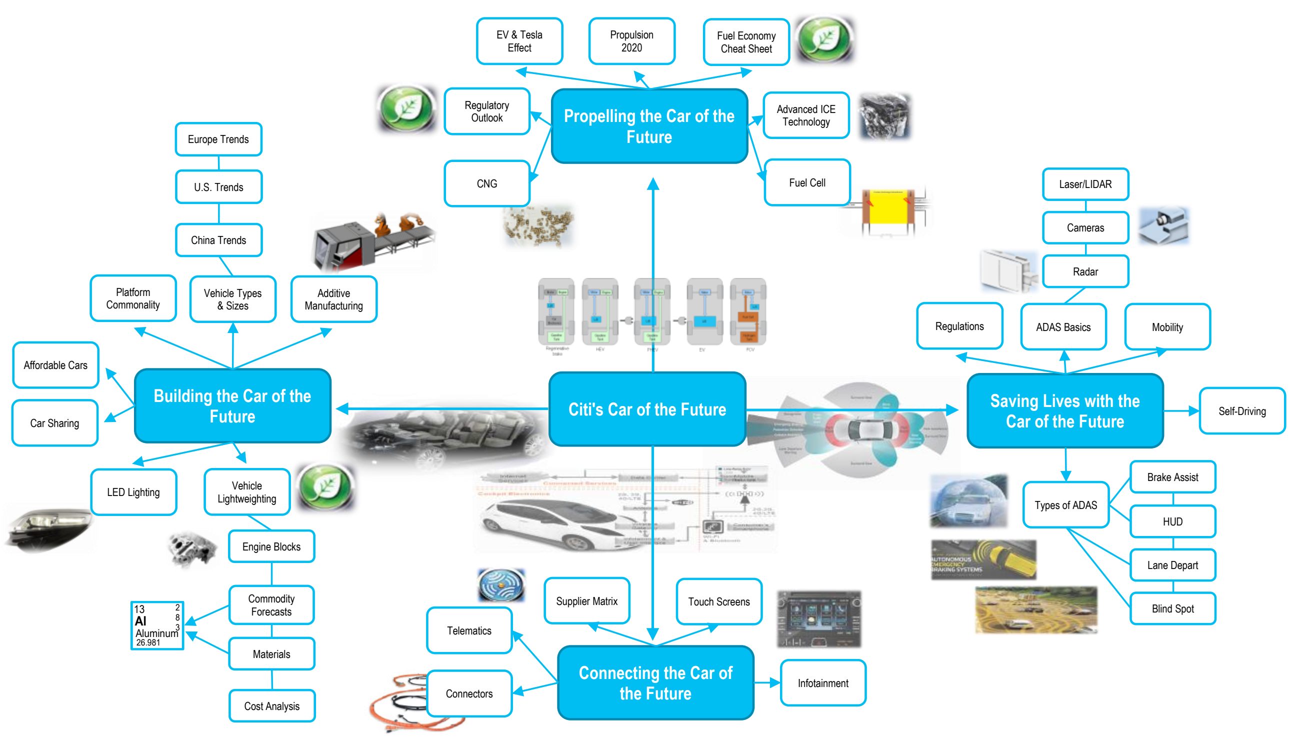
Citi's Car of the Future Report

Citi's Car of the Future report aims to offer a one-stop shop to understanding and evaluating those global automotive technologies that will shape tomorrow's cars — how they're built, powered, equipped and serviced. By "future", we generally aim to focus on the next 5-10 years in order to keep the topics both interesting and investable. With the contribution of several Citi analyst teams around the world, the plan is to update this report every ~6 months with new discussions and updates. The report also integrates and updates past thematic work published by Citi analysts.

In our view, what's often missed in these types of research endeavors is the investing side of the equation, as it's often easy to get caught up writing fun futuristic reports. Our aim is to tie each section to a general investing framework for evaluating the merits of different technologies, with a focus mainly on public Tier-1 automotive suppliers. We also introduce a Car of the Future Stock Index that ranks global company revenue exposures to key trends.

Finally, we believe our report differentiates with "outside the box" ideas such as our separate valuation of GM's OnStar division, our case for how swappable electric vehicles (EVs) can become a disruptive catalyst, our belief that Ford should dedicate Lincoln as a pure xEV brand ("Lincoln 2.0"), our view that car sharing could actually prove favorable for new auto sales, our favorable view on Advanced Driver Assistance Systems (ADAS), our view on the potential convergence of fuel economy and connectivity through guaranteed fuel saving payback periods as well as our view on content preservation stories.

Figure 1. The Car of the Future—Basic Schematic



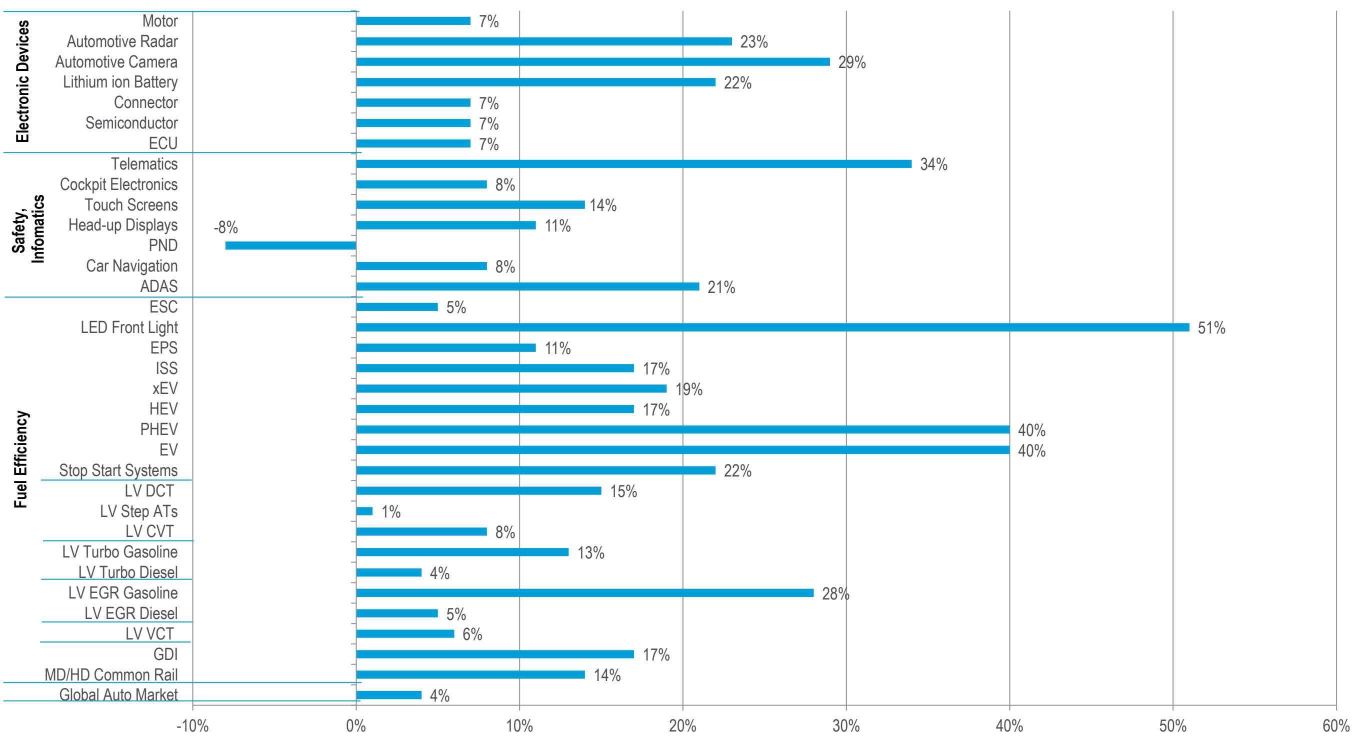
Note : Figures of major products come from home pages by Continental, Panasonic, NSK and U.S. Department of Energy.

Source: Delphi, Visteon, Valeo, Nemak, Texas Instruments, VJET

Investing in the Car of the Future

What's Already Worked, and Why? Had we built a Car of the Future Index say 6-7 years ago, there would have been a fair share of successes & failures. Some were great ideas with flawed business models, others were ideas that simply didn't pan out, some panned out but not entirely to plan, and a few worked remarkably well. When it comes to success stories, there's perhaps no better example than BorgWarner, whose stock valuation migrated from an "auto" multiple to "industrial" since 2008. Interestingly, the BorgWarner technology story was never really that complex; in fact today's turbocharger and dual-clutch transmission (DCT) discussions aren't fundamentally different than what they were in 2008. Rather, the key to the BorgWarner success, in our view, was in the company's ability to: 1) provide automakers with a superior *fuel savings-per-dollar* proposition, including the ability to remove content elsewhere (engine downsizing); 2) provide consumers with a similar value proposition around fuel economy *and* enhanced performance, resulting in high take rates and profit/brand gains for the original equipment manufacturers (OEMs); 3) play in technologies that are difficult to replicate (so-called tribal knowledge) leading to finite competitors and industry price discipline; and 4) offer globally scalable products.

Figure 2. Market growth of major applications and products (Estimated CAGR between 2013 and 2020)



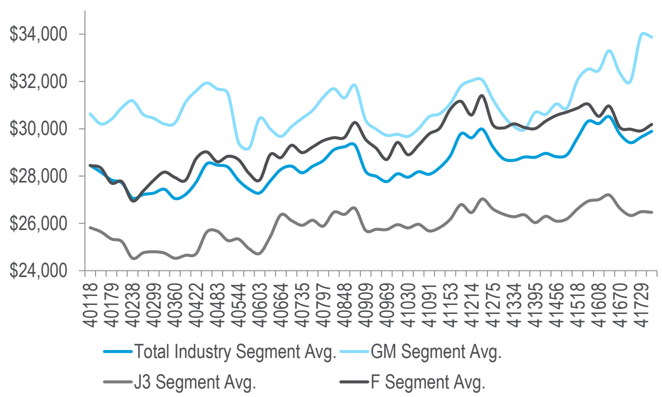
Note : Market units for fuel efficiency, safety, informatics applications and ECU. Market value for electronic devices such as semiconductors or connectors.

Source: Company data, Wards, Anfavea, AEB, JAMA, JAPA, CAAM, SIAM, GAIKINDO, TMT, TSR, Marklines, WSTS, JEITA, Bishop, BWA, DLPH Citi Research estimate

What Goes Up Must Come Down — The Variable Cost Tug of War: The average car in the U.S. carries a variable cost of ~$20,000. Each year automakers must engage in a tug of war where commodity inflation, currency (FX) and regulatory requirements push up the variable cost of a car before any voluntary content is inserted. To offset these, automakers must seek efficiencies (global platforms), supplier price-downs and de-contenting opportunities where possible. Given these industry challenges, the appetite to load non-mandated content naturally becomes

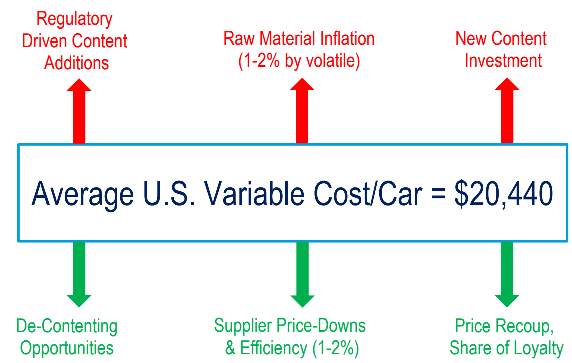
more dependent on the ability to earn an acceptable variable margin, market share or brand equity support. So when thinking about penetration stories, it's also important to keep de-contenting in mind. If lithium-ion battery costs decline significantly over the next 5-10 years, might EVs become less costly than plug-in hybrid EVs (PHEVs)? If semi and fully autonomous cars go mainstream over the next 10-15 years, will passive safety, mirrors and certain materials be less emphasized? Will wearable devices de-emphasize in-car displays? The answer is that it depends on product and time horizon. Engine downsizing in exchange for gasoline direct injection (GDI)/turbo occurs every day, eliminating passive safety and powertrain technology in exchange for an autonomous car could take decades — during which all might enjoy a period of higher penetration! So timing is a critical consideration here even for long-term investors. Thankfully, the next 5-10 years might see relatively less de-contenting than subsequent periods. But eventually, what goes up does need to come down.

Figure 3. U.S. Vehicle Transaction Prices



Source: Company reports, Citi Research

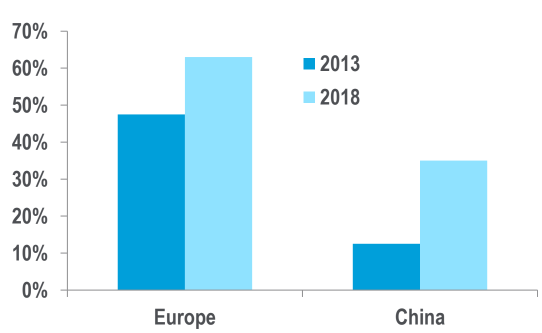
Figure 4. Basic OEM Variable Cost Matrix



Source: Citi Research

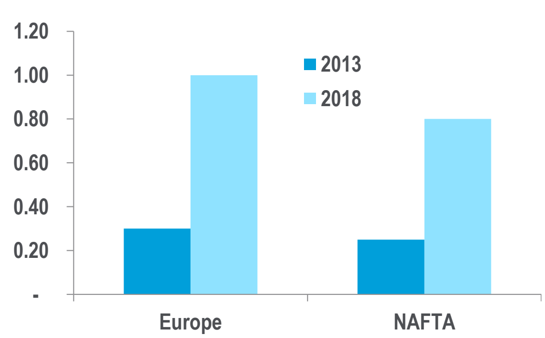
It's All About the End Consumer: Most tier-1 auto suppliers claim their products save weight, improve safety, reduce noise, vibration & harshness (NVH) and so on. Certain technologies even have regulations on their side, such as passive safety and certain emissions systems. But what ultimately differentiates good technologies from great ones is whether consumers actually demand and pay for them. This is a function of capability and price. For example, according to Continental, only 20% of people would "probably purchase Fully Autonomous Driving, based on a market price of $3,000". If women alone are isolated, the number drops to 14%.

Figure 5. Turbochargers Installation Rate, Europe vs. next biggest market



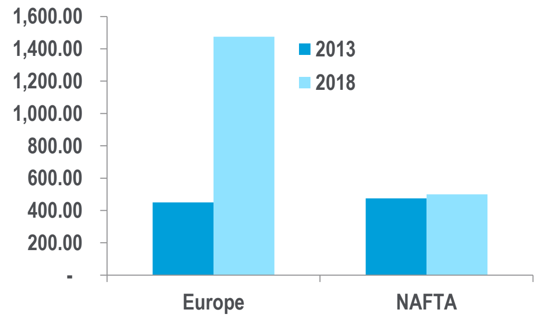
Source: Continental

Figure 6. ADAS sensors per car, Europe vs. next biggest market



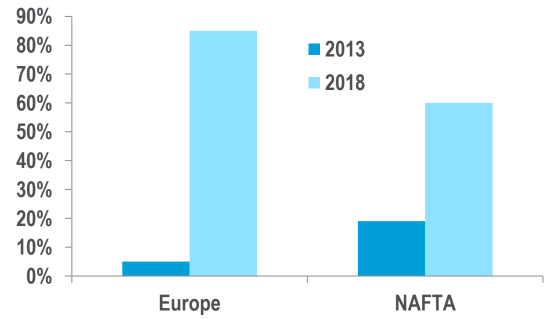
Source: Continental

Figure 7. Heads-Up Display ('000 units), Europe vs. next biggest market



Source: Continental

Figure 8. Embedded Telematics installation Rate, Europe vs. next biggest market



Source: Continental

Margin comparisons across the supplier group seem to support this view. Consider passive safety and emissions systems — good technologies with regulatory tailwinds but with arguably less direct consumer pull demand — EBIT margins for exposed suppliers (TRW, Tenneco, Autoliv) tend to run in the 7-10% range. Good, not great. In Europe, Faurecia, with its focus on more commoditized seating, interiors and exteriors, has a margin of only ~3%. Now consider GDI/turbo and electronics companies like BorgWarner and Delphi, which generate 11-13% EBIT margins and command premium valuation multiples. Also consider companies in this category such as Harman (scalable infotainment EBITDA margin 12-14%, per company reports).

So Ask Yourself: Is a car company using supplier's XYZ technology to sell you a car? Think Ford EcoBoost, active safety commercials and various GDI offerings. If so, what does the competitive landscape look like? What value do suppliers add, what are their R&D requirements and how scalable is this technology? And can the automaker "fund" the content add by taking costs elsewhere in the vehicle or by clearly improving the cost of ownership to the end user (insurance, fuel)?

But It Also Goes Beyond Autos: Future technology suggests that changes may affect not only OEMs and suppliers but other industries too. It could affect the way we work such as adding an extra hour to work/communicate that would normally be an inefficient part of our commute. The ramifications for congested roads and advertisers, for insurance companies and oil companies, for technology companies vying for consumer attention could be significant. Some innovations can help both automakers and suppliers, though many are exclusive to suppliers. LED headlights, for example, could be one of Valeo's fastest-growing segments, yet given that, by 2030, c. 40% of front headlights and 55% of rear headlights will be LED, the benefit to OEMs could be limited.

Citi's Car of the Future Supplier Investing Framework: So as a first step in evaluating the investment worthiness of automotive technologies, we ask many of the questions posed in the above section. This is an admittedly simplistic approach that mainly focuses on public Tier-1 suppliers as opposed to all players in a particular supply chain. But it should provide investors with a tool to compare different technologies at least during the initial screening process. The answers are color-coded from green to red depending on how well the technology screens to the question. The table below covers many of the technologies covered later in the report. From a supplier perspective, the technologies that screened best include turbocharging, ADAS and stop/start, followed by broader electronics/infotainment.

Figure 9. Auto Technology Investing Framework — Select Examples

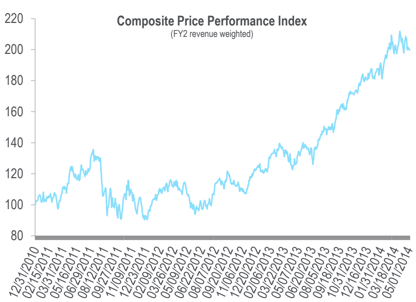
	ADAS	Turbos	Stop/Start	Weight Reduction	Embedded Infotainment	GDI	Connectors	EV	Clusters Displays	Emissions Systems	Embedded Telematics
Is There a Specific Regulatory Driver?	Good	Good	Good	Good	Poor	Good	Neutral	Good	Poor	Good	Poor
Consumer Value (Perform, Safe, Connect)?	Good	Good	Neutral	Poor	Good	Neutral	Neutral	Good	Good	Poor	Good
Do OEMs Use This As a Selling Point?	Good	Good	Neutral	Neutral	Good	Neutral	Neutral	Good	Good	Poor	Good
Is It Reasonably Affordable to Consumers?	Good	Good	Good	Neutral	Neutral	Neutral	Good	Neutral	Neutral	Good	Neutral
Is it Globally Scalable?	Good	Good	Good	Neutral	Good	Good	Good	Neutral	Good	Neutral	Neutral
How is the Competitive Landscape?	Neutral	Good	Good	Neutral	Neutral	Good	Good	Neutral	Neutral	Neutral	Neutral
Can It Be Funded By Content Reductions?	Poor	Neutral	Poor	Neutral	Poor	Neutral	Neutral	Good	Neutral	Neutral	Neutral
Applicable to OEM Investing?	Yes	Yes	No	Yes	Yes	No	No	Yes	No	No	Yes

Good Poor Neutral

Source: Citi Research.

Introducing the Car of the Future Index: In order to more easily depict the benefit of exposure to key secular trends in the automotive industry, we compiled a group of public companies. These companies represent a sample of those well exposed to our auto technology investing framework criteria. We then take this group and weight it based on forward year 1 and forward year 2 revenue forecasts in order to create a weighted price performance index. In addition to price performance, we also look at valuation multiples. This index is not meant to serve as a recommendation of stocks, but rather meant to highlight historical price performance and historical valuation multiples.

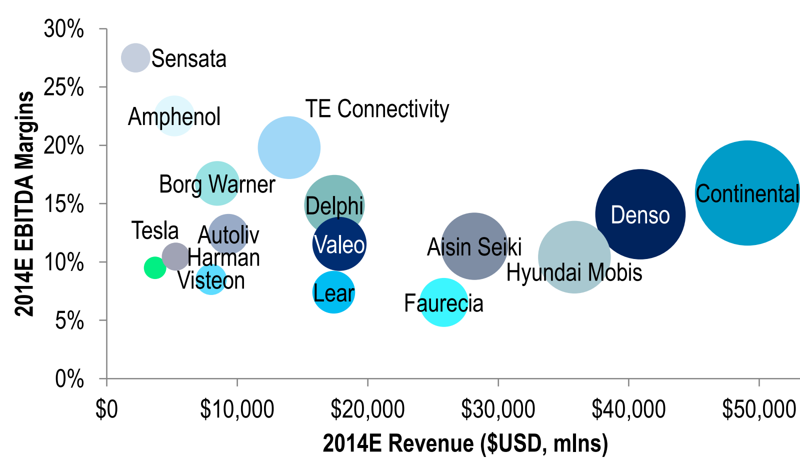
Figure 10. Car of the Future Index = Price Performance



Source: Factset, Citi Research

We considered many different options for weighting the index, ultimately settling on revenue as the final criteria. The reason for utilizing revenue was that it allowed for more normalized multiple comparisons, especially when paralleled to our initial run at the index using traditional market cap weighted methodology. While revenue may not be a perfect metric for weighting given that only a portion of a certain company's total revenue may be applicable to these secular trends, we believe that revenue is more easily compared to expected emerging technology CAGRs and serves as a fair proxy for market cap. In our analysis, focusing purely on the supplier sample set, the correlation of market cap to 2014E revenue was a respectable .83; including the entire basket it drops to .69 (due to Tesla valuations).

Figure 11. 2014E Revenue & EBITDA Margins



Note: Circle means the size of FY1 EBITDA

Source: Consensus Estimates, FirstCall, IBES, FactSet

Global Auto Stock Screen: As an added tool to the Car of the Future Index, the Citi Global Autos Team broke out the revenue exposure of key Tier-1 auto suppliers by various degree of attractiveness based on the investment framework described above. The four categories looked at were: 1) truly exceptional businesses exposed to secular trends in a concentrated competitive environment allowing for strong growth and margin expansion; 2) solid assets growth and expanding margins, but with a more competitive landscape suggesting margins will remain good, but short of top notch; 3) more commoditized assets growing at or slightly above market with average margins. Not bad assets; and 4) either poor assets or other special situations such as non-auto or divestiture candidate.

Figure 12. Global Auto Suppliers — Select Revenue Exposure Breakdowns

Legend:

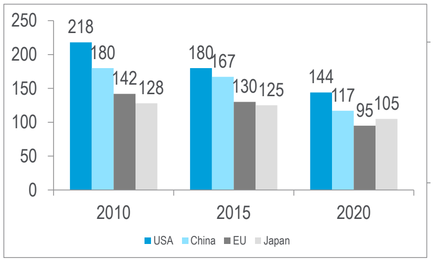
Color	Description
Blue	Truly exceptional LT secular growth outlook, concentrated competitive landscape (pricing power), scalable. Expect strong growth AND steady margin expansion
Green	Solid above market growth and margin expansion outlook but, perhaps, more competitive with good, but not outstanding, margin prospects
Yellow	More commoditized businesses growing at slighly above market with mean profit and return profiles. Not bad assets
Red	Either poor assets or some special situation (Non-auto, diversiture candidate, etc.)

	Summary Stats			Key Technology Exposures (Estimated Revenue % Exposures & Detail)			
	Market Cap	Revenue	Op Margin	(Blue)	(Green)	(Yellow)	(Red)
United States							
BorgWarner	$14,407	$8,468	12.7%	70% Engine Segment + DCT (Turbo, VCT, Thermal, Emission)	0%	30% Torque Transfer Systems	0%
Delphi	$21,090	$17,433	11.5%	39% Powertrain + Connectors (GDI/Diesel & connectors)	53% Electrical & E&S (Wire Harness, Active Safety)	8% Thermal	0%
Visteon	$4,286	$8,531	6.0%	0%	91% Climate & Electronics	0%	9% Interior (poor asset, divestiture)
Autoliv	$9,718	$9,255	9.2%	0%	5% Active Safety	95% Passive Safety	0%
Johnson Controls	$31,209	$44,250	6.2%	15% Battery Business (Stop/Start)	0%	38% Automotive Seats	47% Auto Interior + Non-Auto Biz
Europe							
Continental	€34,931	€35,277	11.2%	72% Chassis & Safety; Powertrain; Interior, ContiTech (Includes ADAS, Heads-up Display, Infotainment)		28% Tire Division	0%
Valeo	€7,646	€12,995	7.1%	45% Visibility; CFA (Includes LED)	28% Powertrain	27% Therman	0%
Faurecia	€4,013	€18,500	3.2%		64% Emissions, Seats	10% Exteriors	26% Interiors

Source: Citi Research, Company Reports, Bloomberg

Propelling the Car of the Future

Figure 13. CO_2 Regulation by Geography



Source: Continental

For the past few years, the world's automakers have witnessed convergence of regulatory and consumer demands towards improving fuel economy, striving for energy independence and reducing emissions. After much back and forth, global regulatory requirements are now largely enacted through the middle of this decade, and it's clear that proposals through 2025 call for even greater stringency requiring a greater mix of non-conventional technologies such as alternative fuels, electrification and perhaps even hydrogen fuel-cell. The next five years will both be uneventful and possibly game-changing. Uneventful in the sense that no one technology will likely take the crown—for investors much of the high-volume growth opportunities will likely come from "workhorse" powertrain technologies described below. Game-changing in the sense that non-conventional technology (EVs, fuel cells) could make sufficient strides to lay the ground work for an eventual disruption perhaps sometime next decade. Mixed into all of this is the discussion of the implications to propulsion from autonomous vehicles. For an automaker, the strategic choice for propulsion might be its most important. It is not just a function of regulations but of a view of consumer willingness to pay for premium technologies, desired brand perceptions and energy prices.

Figure 14. Outline of main electrification technologies/products related to fuel efficiency improvement

Product/Technology	Fuel efficiency improvement	Field	Outline
FCV	100%	Electric engine	Uses electrical energy generated from hydrogen using a fuel cell stack to power the vehicle
EV	100%	Electric engine	Uses electrical energy stored in a battery to power the vehicle
PHEV	70%	Electric engine	Uses electrical energy stored in a battery to power the vehicle, but also has an internal combustion engine
HEV	25-40%	Electric engine	Uses electrical energy stored in a battery to assist with vehicle acceleration
Idling stop systems (ISS)	7%	Undercarriage	Turns off the engine when a vehicle is not moving
Regenerative breaking systems	15%	Undercarriage	Stores regenerative energy generated during braking as electric energy
Electronic power steering (EPS)	3%	Undercarriage	Assists vehicle steering by using a motor instead of hydraulics
Electronic braking-related (ACC, ABS, etc.,)	5-12%	Undercarriage	Improves fuel efficiency by reducing unnecessary travel
Body electrification (wipers, compressor, etc.,)	1%	Body	Improves fuel efficiency by powering wipers and the air conditioner compressor electrically
Electronic transmission	7-9%	Body	Improves fuel efficiency by optimizing transmission control
Electronic variable valve timing	1-6%	Engine	Improves engine fuel efficiency by electronically controlling the opening/closing of valves
Electronic exhaust gas recirculation (EGR)	2%	Engine	Improves engine fuel efficiency by recirculating exhaust gas to the cylinders after combustion
Electronic fuel injection (EFI)	NA	Engine	Improves engine fuel efficiency by electronically controlling injection of liquid fuel. Almost at full penetration.
Automated driving technology	NA		Improves fuel efficiency by avowing traffic congestion

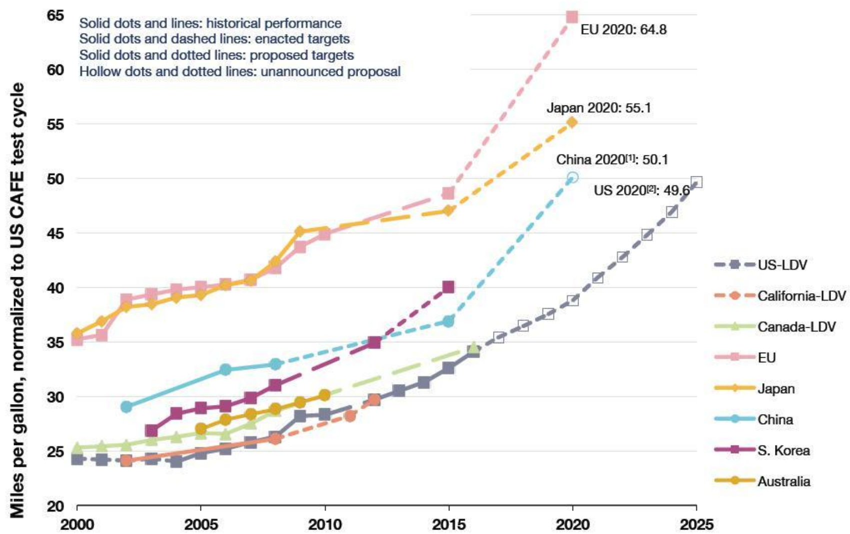
Source: Company data, METI, Citi Research

Not a Winner Take All Game, Yet…

For the automakers, the decision to implement one technology over another is complex. For one, choosing a technology package to achieve one goal (say, improving MPG) may not necessarily mate perfectly with achieving another (say, energy independence or improving well-to-wheel emissions). Second, consumers themselves are also wild card factor, as demand for fuel efficiency has historically tended to rise/fall with gasoline prices (at least in the short term), yielding a conundrum where high gas prices damage the very affordability needed to adopt newer technologies. Encouragingly, more recent surveys suggest these attitudes may be changing on a more permanent basis. Third, long automotive product cycles essentially force automakers to make large calls on a few chosen technologies a number of years before market implementation. This makes overnight game-changers less likely. This is why monitoring up and coming companies is critical, as they are arguably more capable of introducing technologies faster than large volume automakers, at least in the initial phase. One last issue worth noting is that global automakers are increasingly looking to achieve global scale through common

parts and global platforms, so one region's regulatory hurdle may influence product decisions in another where the regulatory framework may be different.

Figure 15. Global Regulatory Outlook



[1] China's target reflects gasoline fleet scenario. If including other fuel types, the target will be higher.
[2] US and Canada light-duty vehicles include light-commercial vehicles.

Source: Citi Research

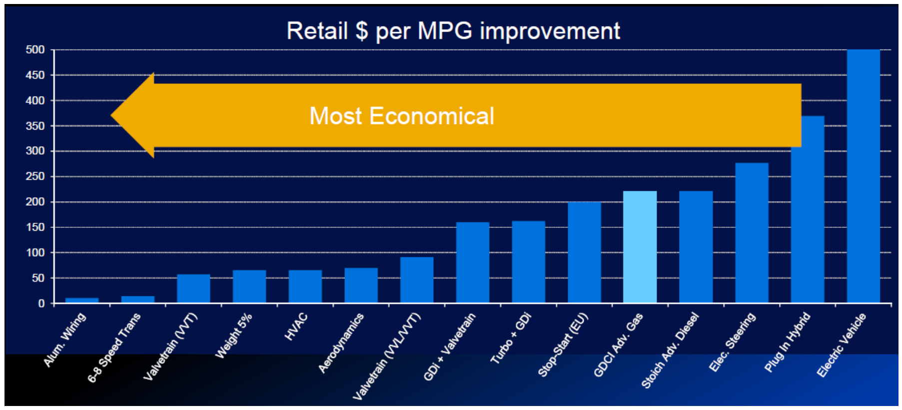
So far, it appears that automakers are adopting different strategies and pathways towards satisfying regulatory and consumer demands. Part of this stems from varying competitive advantages (Europeans with diesel, Japanese with hybrids) and part simply stems from different thinking around consumer acceptance. What's become clear to us is that a successful technology package must meet the following criteria:

1. **Reasonable costs & payback:** Historically, the majority of U.S. consumers purchasing new and used vehicles plan to hold on to that vehicle for under 5 years, though this recently ticked up closer to 6 years. Outside surveys have shown that, while consumers are willing to pay a premium for fuel economy, they also tend to require a ~3-year payback. This attitude is unlikely to shift to the right anytime soon in light of recent controversies questioning "real-world" vs. "rated" MPG and the resulting distrust of fuel labels (incidentally this is something a Connected Car could potentially address in the future). For this reason, affordable packages such as GDI/turbo, engine timing, stop/start, advanced transmissions, aerodynamics and weight reduction have proven most popular thus far. Advances in these technologies should allow them to continue penetrating the market for years to come, but at some point automakers will likely require even more advanced combinations to satisfy 2025+ standards.

2. **Preserve (or enhance) performance:** The success of engines like the Ford EcoBoost can be attributed not only to their ability to improve MPG, but also their ability to enhance performance. Providing a boost to performance greatly enhances the consumer value proposition and helps ensure the automaker earns a reasonable variable margin on sale. This is also a key advantage for Electric Vehicles.

3. **Strongly Branded:** The best example to illustrate here is the painfully slow pace of diesel acceptance in the US. Traditional cost-benefit analysis often points to diesels as ranking among the more compelling technologies for the US market — mainly because of appealing payback, compelling performance and the greater mix of US highway driving (hybrids, for instance, tend to return best in city driving). However, diesel technology simply doesn't have a strong reputation in the US (at least not yet) and often does not score well in outside opinion surveys. Although we do expect diesel penetration to increase in the coming years, automakers will need to educate consumers who may have a negative bias towards the technology.

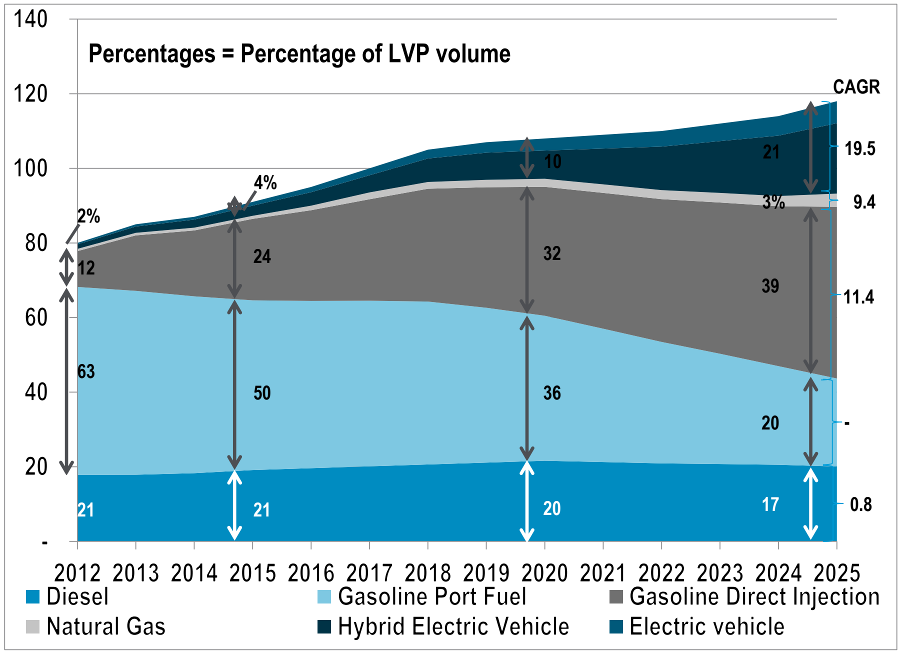
Figure 16. Cost/Benefit of Different Fuel Saving Technologies



Source: Delphi

Internal Combustion & Related Still Dominate Outlook: When we speak of a 5-10 year outlook in the automotive industry, we're really talking about 1-2 product cycles. Per the above criteria highlighting the path automakers strongly consider when choosing a propulsion path, internal combustion and related technologies are still forecasted to be the dominant force through this period, in our view. These include the popular package of weight reduction, high-efficiency axles/drivelines, downsized GDI/turbo engines with higher efficiency, stop/start, advanced transmissions and select hybrids. **For a list describing each of these capabilities, please refer to Appendix A**.

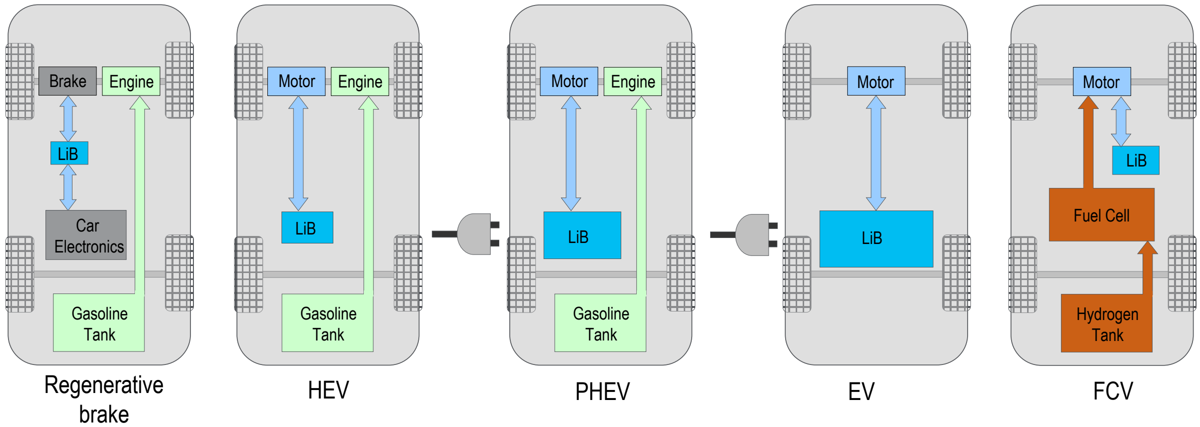
Figure 17. LVP production by powertrain (mn units)



Source: Continental, IHS

But EVs & CNG Are Clear Long-Term Disruptive Forces: From an operating cost perspective, electric vehicles (EVs) remain superior with a fuel cost-per-mile of only $0.04, even superior to CNG at $0.07 and of course far superior to conventional gasoline ($0.15). Besides energy costs, EVs offer maintenance savings from the absence of required oil changes and other functions. Performance also tends to be superior thanks to unique torque characteristics. And despite debates over well-to-wheel emissions, the zero tailpipe emission selling points are nonetheless a powerful consideration both to consumers and regulatory bodies. Costs, long charging times and infrastructure are the greatest barriers to mass adoption, even when contemplating federal tax credits. Lower-priced US electric vehicles offering limited range have not sold particularly well. Skeptics will point to these figures as well as the slow pace of battery technology advancements (since the great optimism of 2008) as proof that EVs may only be suitable for luxury buyers. We disagree, and while we have never been in the camp calling for an overnight shift to EVs, we think the outlook for these vehicles remains bright. First, despite slow advancements in traditional lithium-ion chemistries, the pipeline of promising technologies is far from dry (solid state, lithium-air). Second, innovative battery switching method offer a way around range and depreciation anxieties. Of course, all eyes are on Tesla's plans to offer a $~35k 200-mile EV in the 2017 timeframe (more on this later). Like EVs, compressed natural gas (CNG) vehicles also face the task of reducing vehicle premium costs by as much as 50%. Where CNG has some advantage is through long range capability, though this assumes consumers accept some reduction in trunk space. The other advantage for CNG is a less dramatic adoption/education curve than EVs—it's a familiar powertrain that's just powered by a different fuel. Once CNG vehicles become more competitive than hybrids, diesels and advanced gasoline vehicles, we believe the drive for greater US energy independence and economic investment could provide CNG with a powerful branding message.

Figure 18. Regenerative braking system, HEV, PHEV (Pure PHEV), EV, and FCV configuration



Source: Company data, Citi Research

Figure 19. Fuel Economy Cheat Sheet

	Traditional ICE Downsizing & Boosting	Diesels	Full Hybrids	Plug-in Hybrids (PHEV)	Electric Vehicle (EV)	CNG
Fuel efficient gains	15-20% better mileage. Turbocharging preserves performance. Future advancements promise another 20% improvement. Stop/Start can add 5-12% too	35-40% better mileage. Superior to many full hybrids in highway driving, which is more prevalent in the U.S.	25-50% improvement in today's NiMH hybrid systems. Advantage over diesels in city driving. Less so in highway driving.	40-100+% improvement with all electric drive (10-40 mile range)	100+% improvement with zero tailpipe emissions (Renewable sources can drive WTW gains over time)	Significant emissions reductions, but somewhat lower energy density vs. conventional ICE
Appeal to performance & adoption hurdles	High – 20% superior torque typically. No real adoption hurdles.	High – 50% higher torque and "fun to drive". Consumer acceptance an issue in U.S.	Medium – Performance compromised somewhat but low adoptability hurdles. Consumers perceive it as "Next Gen" technology.	Medium - Dual motor/battery lessens battery anxiety risk for consumers.	Medium– "Fun to drive' factor of EVs partially offset by potential battery range anxiety, with the latter likely to be addressed by infrastructure and improving battery range (or switching)	Medium – No major performance give but need for refueling infrastructure (unless able to refuel at home)
Appeal to environmental & national goals	Low - Not an environmental "game changer". Stricter proposed regulations beyond MY20 might make these technologies less impactful.	Developing – Recent marketing in U.S. and old stigma of diesels starting to diminish, but environmental appeal remains a challenge	High – Emission reduction and lower dependency on foreign oil. Great environmental appeal particularly in larger cities.	High – Pure electric range offers breakthrough from conventional hybrids. Less infrastructure anxieties	Very High – Reduces emissions and dependency on foreign oil. Lithium availability and battery recycling are debatable issues but don't present an issue. Some promise in solid-state batteries and lithium air	High – Lower foreign oil dependency. WTW GHG improves over gasoline
Cost	Reasonable. Technologies exist and logistics manageable. Ideal choice for capital constrained auto industry and strained consumer.	High – Similar to slightly below typical hybrids, better durability adds to value proposition. A more expensive option than traditional GDI-turbo	Higher than diesel but payback improves with higher gas prices and greater city driving. In the U.S. where highway driving exceeds city, diesel makes more sense at present gasoline prices.	High – But more affordable with government credits/incentives. Battery cost reductions key over time.	High – But more affordable with government credits/incentives. Key is reduction in battery cost over time and creative ways to unlock the consumer value proposition (i.e. Better Place model)	High – CNG vehicles carry $7-8k price premium, more than diesels for less "fun to drive" factor.
Challenges	Squeezing more MPG savings to meet increasingly stricter global standards	Emissions costs and consumer perception	Costs, safety, and potential changes in consumer demand.	Costs, safety and infrastructure	Costs, safety and infrastructure	Infrastructure and less zero tailpipe emission appeal as EVs

Source: Citi Research

Internal Combustion Engine "Workhorse" Technologies

The importance of the internal combustion engine in meeting fuel economy requirements means that volumes for components that meet this challenge will be significant. Many of these products are based upon components that are standard on most vehicles and are modified to improve fuel economy. This is important because it reduces the development cost and piece price given high volume production that allows for amortization of what otherwise might be higher costs.

The "workhorse" suite of technologies that form the core of the low-cost/high-return approach to fuel economy contains a number of key components including:

1. Direct injection
2. Electric power steering
3. Exhaust gas recirculation
4. Low rolling resistance tires
5. Turbocharging
6. Variable valve lift and timing
7. Stop-start
8. Thermal systems
9. Transmissions, high-efficiency axles and other torque transfer devices

Figure 20. "Workhorse" Technologies

Product Category	Select Companies Involved
Direct Injection	Bosch, Delphi, Continental
Electric Power Steering	Denso, JTEKT, Mando, Nexteer, NSK, NTN, TRW, ZF
Exhaust Gas Recirculation	BorgWarner, Denso
Low Rolling Resistance Tires	Continental, Bridgestone, Goodyear, Michelin
Turbochargers	Honeywell, BorgWarner, Cummins, IHI, MHI
Variable Valve Lift and Timing	BorgWarner, Denso
Thermal Systems & HVAC	BorgWarner, Mahle, Visteon, Denso, Delphi
Torque Transfer (Driveline)	American Axle, Magna, BorgWarner, GKN, JTEKT
Stop/ Start	Johnson Controls, Denso, Valeo, BorgWarner

Source: Company Reports, Meszler Engineering Services and Citi Research

Gasoline Injection Engines and Turbocharger Gasoline Engines could be an effective way to reduce CO_2 by up to 20% in the near term.

According to Continental projections, less sophisticated standardized gasoline engines are still set to fall to a market penetration of 36% of total light vehicle production (LVP) powertrains by 2020 with more fuel efficient gasoline direct injection increasing to 32% penetration (a CAGR of 17% from 2012)

Two key methods to increase fuel efficiency include:

1. Gasoline Direct Injection; and
2. Turbocharger gasoline engines

50% of European cars will have gasoline direct injection engines by 2016; US will have a similar figure in 2025.

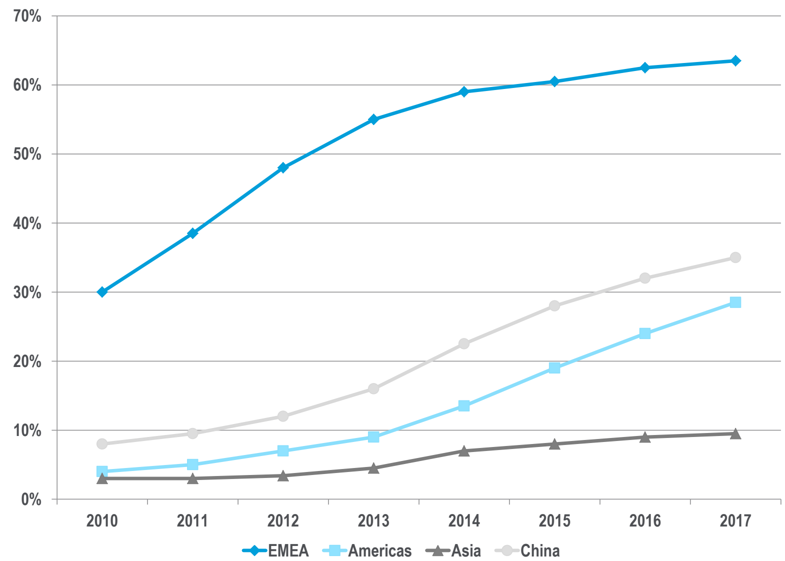
Gasoline Direct Injection works by injecting fuel directly into the engine rather than mixing it first with air. This means that the fuel is targeted directly at the spark, resulting in gasoline being used more effectively. Europe is likely to lead the way, with 50% of new cars sold with gasoline direct injection by 2016, while the US will have a similar figure in 2025, according to Bosch.[1]

Turbochargers can reduce emissions by up to 15% - 20% along with Gasoline Direct Injection engines.

Turbochargers in gasoline engines are another key way to help cars use gasoline more efficiently. They work by compressing fuel and air to allow more to be packed into a cylinder at one time; this will ultimately allow engines to have greater power coming from lower cubic capacity (i.e. a smaller engine with the same power). According to Continental, these engines could lower emissions by up to 15% (a similar level to many HEVs). By 2017, more than 60% of gasoline engines in Europe are likely to be turbocharged, according to Continental.

[1] http://www.bosch-presse.de/presseforum/details.htm?txtID=6727&locale=en

Figure 21. Increasing Installation rates of Turbocharger in Gasoline Engines



Source: Citi Research, Conti

Advances in transmission technology are critical to the improvement in fuel economy for internal combustion engines. Transmission technology provides a strong improvement in fuel economy and is relatively well understood by consumers (more speeds are better than fewer!). There has been some concern with the "feel" provided by dual clutch transmissions and automakers need to be attentive to American drivers and their comfort level with these newer products. Continuously variable transmissions are also important as their market share has increased, and in the past some have performed better than others. Again, automakers have taken notice and current products are being designed to perform at a higher level.

Figure 22. Transmission Technologies

Product	Companies
Automated manual transmissions	Aisin, BorgWarner
Automatic - high speed (6 or more)	Aisin, ZF
Continuously variable transmissions	Aisin, JATCO
Dual clutch transmissions	Aisin, BorgWarner, Getrag, ZF

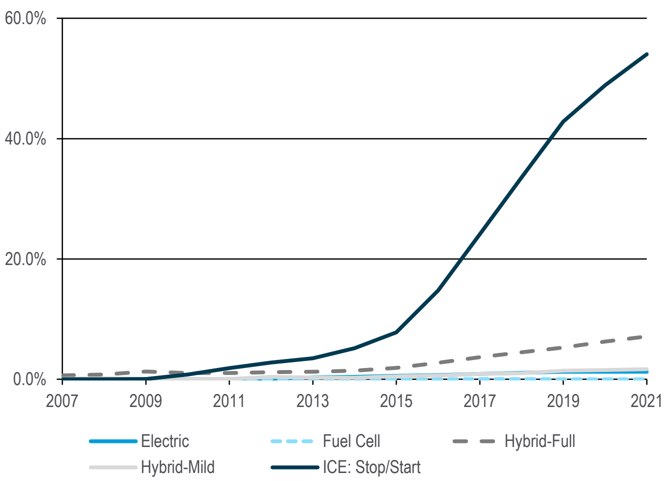
Source: Meszler Engineering Services

Components that require power from the vehicle's engine works against fuel economy. As a result, items like electric power steering are growing in popularity as they result in less "assistance" from the engine. HVAC has historically required "power" from the engine to operate and alternative systems are gaining share. Other items such as LED lighting are growing in popularity as their use of energy is far less than standard lighting systems.

Propulsion 2020: A Short Trip Around the World…

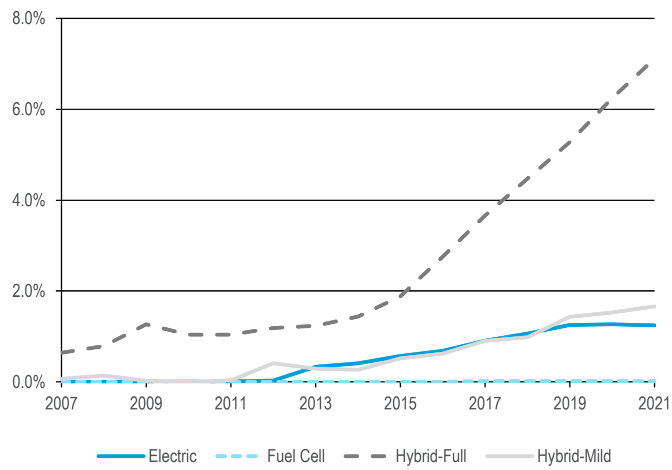
North America: The next 1-2 product cycles in North America will likely be dominated by the internal combustion "workhorse" solutions discussed above. We expect gasoline turbocharging penetration to rise from a mid-single rate today closer to 20% by the end of the decade, with diesel turbos staying mostly constant. As shown below, this will be supplemented by stop-start systems and more advanced transmissions and driveline systems. GDI is also expected to grow at a mid-double digit CAGR. As discussed in more detail below, electric vehicle penetration should also start to gain momentum and we believe the expected launch of the Tesla Gen-3 vehicle in the 2017 timeframe will be a critical event for determining the speed of EV adopting later in the decade. In addition, Nissan is expected to unveil the next-generation Leaf in 2017 with a new battery pack and chemistry. Range is expected to improve from the current ~80 miles, though the amount of improvement is unclear. Similarly, GM is expected to unveil a next generation Volt around this timeframe. Other low-volume but worthy North America technologies to maintain an eye on (also discussed later) included CNG (compressed natural gas) and fuel cell vehicles.

Figure 23. North America Emerging Propulsion Penetration Outlook



Source: IHS, JD Power, Ward's & Citi Research

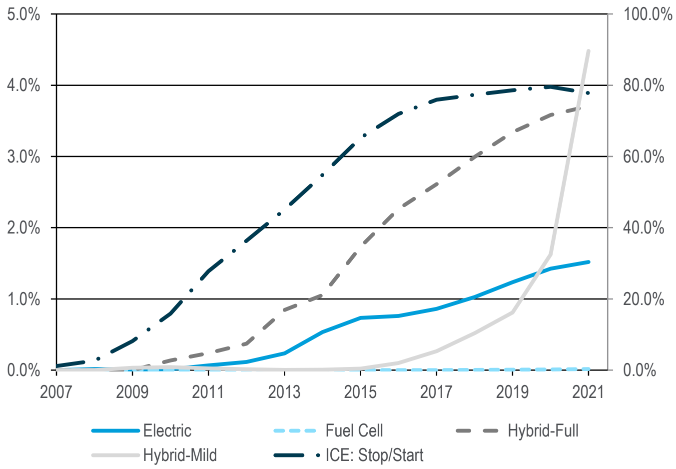
Figure 24. North America Emerging Propulsion Penetration Outlook (ex. Stop/Start)



Source: IHS, JD Power, Ward's & Citi Research

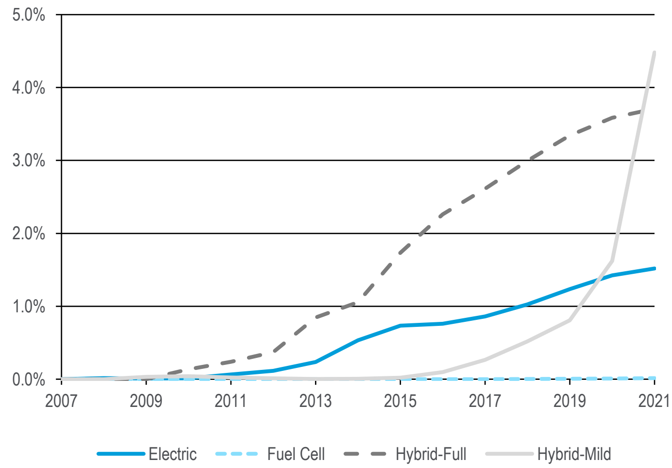
Europe: From a powertrain efficiency perspective, Europe is clearly ahead of North America with diesels accounting for over 50% of sales and stop/start systems being far more penetrated, thanks in part to easier compatibility with manual transmissions. The outlook for full-hybrids is positive but not quite as robust as in North America in part due to the smaller presence of the Japan-based automakers. Gasoline turbo penetration is forecasted to rise from 35% to 40% by the end of the decade in a similar trend as what we're seeing in North America. The outlook for electric vehicles is also somewhat more robust thought still forecast to be less than 2% of volume by 2020. The challenge for automakers managing fuel economy needs in North America Europe is to design around different regulation standards, product mix and city vs. highway driving patterns (US is more weighted towards highway driving).

Figure 25. Europe Emerging Propulsion Penetration Outlook



Source: IHS, JD Power, Ward's & Citi Research

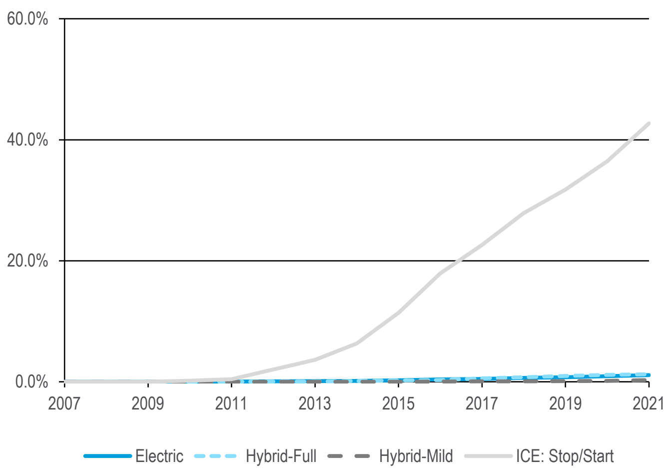
Figure 26. Europe Emerging Propulsion (ex. Stop/Start)



Source: IHS, JD Power, Ward's & Citi Research

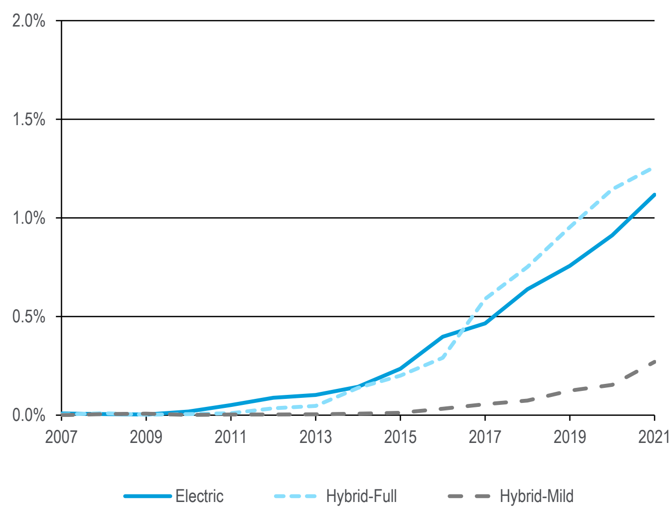
China: Advanced powertrain technologies are expected to rapidly increase penetration in the coming years. Gasoline turbocharger penetration, currently around 12%, should exceed 20% by the end of the decade. This will be supplemented by stop/start penetration growing to over 40% penetration. Dual-clutch and continuously variable transmissions are expected to see the highest penetration gains amongst transmission systems.

Figure 27. China Emerging Propulsion Penetration Outlook



Source: IHS, JD Power, Ward's & Citi Research

Figure 28. China Emerging Propulsion (ex. Stop/Start)



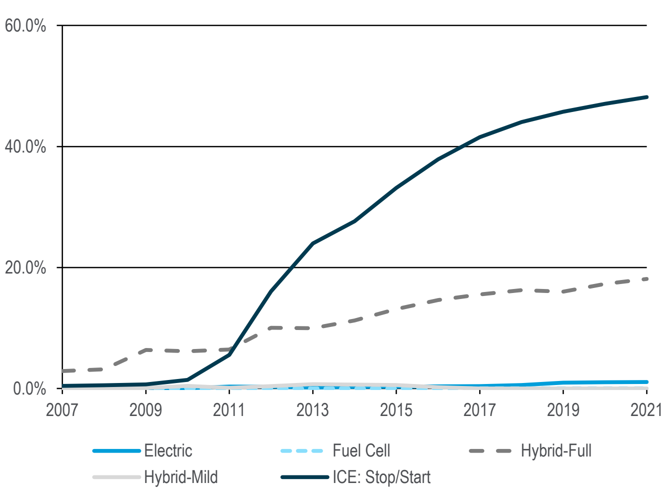
Source: IHS, JD Power, Ward's & Citi Research

Japan: It appears that Toyota is planning to launch a new Prius in 2015, and we believe that this will produce profitability in line with that for gas-powered cars thanks to cost-cutting efforts and better fuel efficiency. We anticipate cost savings via initial benefits from the TNGA (Toyota New Global Architecture) platform that Toyota has been developing as well as via the maturation of hybrid systems. In 2013 Toyota sold about 1.3 million hybrids, but from 2015 we look for improvement in product appeal and the vehicle mix thanks to system changeovers starting with the Prius. Until we get to an era where every vehicle is electric, improving combustion engine efficiency will remain one of the most important themes. Mazda's SkyActiv gasoline engine is the world's first gasoline engine to achieve a high compression ratio, while its SkyActiv diesel engine boasts the world's lowest diesel engine compression ratio. As a result, with the uptrend in the rate of SkyActiv-equipped vehicles, unit sales and margins have increased sharply. With the introduction of homogenous charge compression ignition (HCCI) engines and other advances in prospect, Mazda aims to develop next-generation SkyActiv technology, with a focus on advancing internal combustion technologies.

Spotlight on Denso's Hybrid-Related Products

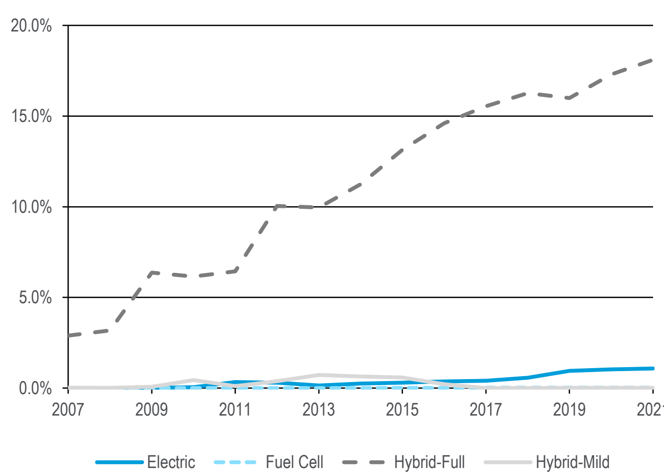
Denso's annual sales of hybrid-related products are currently around ¥100bn ($100m) although we believe the contribution to profits is limited. Management's most recent guidance appears to target expansion to c¥500bn (c$500m) by 2020. Denso's main products include: 1) inverters; 2) motor generators; and 3) battery packs. The main customer at present is Toyota, with Denso's 1) inverters being used in the hybrid versions of the Camry, Crown, Harrier, and Lexus brand models; and 2) motor generator business only encompassing stators (the stationary part of a motor generator that generates magnetic force to spin the rotor) for the Aqua. As for battery packs, Denso's battery monitoring systems have been adopted for all Toyota's hybrid vehicles, while Denso also supplies battery packs for Suzuki's eNe-charge. Outside of Toyota, Denso also appears to be making progress in expanding sales of inverters to the likes of Nissan (Pathfinder), Mazda (Axela Hybrid), and US automakers. We see the key factor for sales growth as expansion at the motor generator and battery pack businesses.

Figure 29. Japan Emerging Propulsion Penetration Outlook



Source: IHS, JD Power, Ward's & Citi Research

Figure 30. Japan Emerging Propulsion (ex. Stop/Start)



Source: IHS, JD Power, Ward's & Citi Research

Electric Vehicles & the Potential for Disruption

After plenty of false starts, the electric vehicle's path to eventual disruption may be upon us. The appeal of Electric Vehicles (EVs) lies both in their long-term cost proposition and unique benefits, which are discussed below. But before proceeding any further, it's worth injecting a dose of reality when discussing the automotive industry. Disruptive change, even that which is compelling, cannot occur overnight in an industry characterized by long product cycles, capacity requirements and high costs. There are also other compelling stories in traditional gasoline/diesel technologies, NGVs and hybrids. That all said, the race for the early mover EV crown may be decided in the next 4-6 years thanks to the success and future product plans of Tesla Motors. In this section, we discus both the disruptive appeal that EVs offer and how the broader industry might react to this megatrend.

Why Now? Tesla's Significant to the Industry

Although still a low-volume luxury carmaker, we view Tesla's early success with the Model S as having confirmed the following about electric vehicles:

1. It's possible to combine all the unique benefits of EVs (superior performance, sufficient range, greater usable trunk capacity, lower maintenance costs, green) with an attractive design and appealing marketing message. We don't believe any other EV in the market has yet to deliver all of these factors in a single car.

2. They can generate substantial consumer/media interest particularly when, in our view, they're sold at outlets that don't face a possible conflict of interest tied to selling both gasoline and EV vehicles.

Although the Model S in itself is unlikely to pose a disruptive threat to global automakers, Tesla does plan to deliver a more affordable $30-35k "Gen-3" vehicle available roughly in the 2017 time frame. This vehicle too may not necessarily prove disruptive, but it may be significant in two ways: 1) A $35k price point is historically what's required to begin the path towards achieving sizeable volume of over 100k units (typically 2-3 years after launch), in theory enough to crown Tesla as the 1st mover in the affordable pure EV market. One doesn't need to look far to appreciate the value of this crown — just look at Toyota's remarkable hybrid leadership with the Prius vs. today's strong but late hybrid competition; 2) For any automaker, achieving an early mover advantage could be strategically critical ahead of the potential for more mass EV adoption early/mid next decade — once battery costs come down further and capacity is added.

Let's face it. Despite launching a number of innovative electric vehicles in recent years, the traditional OEM-dealer business model works best if EV penetration rises slowly over time. A substantial industry investment in gasoline/diesel powertrain capacity/IP is one reason for this, but another comes from some possible resistance from concerned auto dealers facing prospects of lower service levels on EVs (no oil changes, filters, etc.). This potential dealer conflict might partially explain why traditional automakers' EV sales have underwhelmed (Chevy Volt, Nissan Leaf). To reiterate, it's not that traditional automakers aren't recognizing the EV trend or innovating within it (Volt is a great example of impressive innovation), it's just that the industry's interests are better aligned to a gradual ramp vs. anything remotely disruptive. And for the past few years, the industry has been right. Fuel economy regulations (particularly here in the US) haven't forced an excessive amount of EVs onto the market, consumer/media interest has been limited, if not outright skeptical (remember the media reaction to the minor Chevy Volt fire incident?), and a handful of EV-related companies failed to deliver on promises and were ultimately forced to restructure/liquidate. There are plenty of examples of why slow is the truly preferred pace in the auto industry.

Aren't EVs Expensive? How the Battery Operator Model Could Unlock the Disruptive Catalyst

Despite all their benefits and appeal, EVs today are still expensive. Even the Tesla Gen-3 projected price point of $~35,000 would still run about $8,000 higher than the average U.S. retailed vehicle. So are we writing this section many years too early? Perhaps not. One way to potentially get around high battery costs (at least through the 1st-2nd product cycles) might be to revisit the battery operator model. The concept behind this involves creating a battery operator company as a servicer between the OEM and consumer (this could be anyone, including an auto finance company). The technical idea is to separate the battery from the car at time of sale, and then charge a consumer a flat monthly fee to pay for operating costs and usage of a network. By separating the battery from the car, the consumer purchases a new EV at a much lower price ($11-13k depending on size/cost) and does so worry free of any residual value risk tied to future battery technology advancements. The operator would own the batteries, bill customers and operate battery switching stations that allow consumers to quickly (and robotically) switch batteries when desired or when taking very long drives. The thinking goes that a battery operator can squeeze far more value out of the life of the battery vs. a battery bolted-on through the life of the car. The consumer then pays a fixed monthly fee for unlimited miles and access to switch stations. The monthly fee would approximate costs the consumer would have already incurred with a gasoline vehicle, without the volatility that's tied to gas prices. OEMs can still earn a respectable variable margin while avoiding carrying battery risk on their books. Note that Tesla has introduced a battery swap concept but not one where the consumer no longer owns the battery. Rather, Tesla has announced plans to expand its Supercharger stations that allow a 200-mile charge in ~30 minutes, with expected improvements over time.

Haven't we seen this model before? The battery operator model was originally championed by Better Place, a company that operates switch stations and charge spots in Denmark and Israel. Founded by entrepreneur and former technology executive Shai Agassi, Better Place saw some initial success but ultimately filed bankruptcy. In our view, the apparent failure of Better Place had more to do with operational mistakes than a visionary flaw, plus a car that was one generation too early. Importantly, consumer satisfaction was apparently high and the vehicle/switch stations performed well by all accounts.

Creating a $10,000 EV? In this illustrative example, we walk towards a hypothetical 200-mile Ford/Lincoln C-segment car/crossover in the 2017-18 time period. We start by comparing today's Ford Focus (gasoline) to the Ford Focus EV to capture the underlying economics, and then walk to a future EV:

1. We estimate the Ford Focus gasoline sedan currently transacts around $18k. Assuming a $5,000 variable margin, this implies $13,000 of variable costs.

2. We estimate the Ford Focus EV transacts around $37,000 but does come with added non-EV content (infotainment, rear camera, audio). We estimate the variable margin at $6,400, implying variable costs of $30,600—or $17,500 higher than the gasoline version. Assuming a $650/kWh cost on the 23kWh battery, the implied battery cost = $15,000. The remaining $2,500 cost gap comes from the added content vs. the baseline gasoline Focus.

3. For the simulated 2017 EV, we make two battery assumptions: (1) A 10% improvement in range/kWh and (2) A $385/kWh battery cost, which matches Citi analysts' lithium-ion cost estimates (Lithium-ion batteries redux - Market sparking back to life?). To attain a 200-mile range (vs. 76 in current Focus EV), the battery must be sized to 55kWh (from 23kWh) to yield a cost of $21,000—

or $6,000 above the cost of the current Focus EV battery, all else equal. Our battery assumptions are admittedly simplistic as realistically there would be other considerations (size of pack, performance, etc.), but it serves to illustrate the example.

4. With an added $6,000 of battery costs, the 2017 Lincoln/Ford EV vehicle would need to price at $43,000 to achieve the same variable profit as the current Focus EV. Note that this price would be $7,000 above Tesla's target of $35,000 on the Gen-3 vehicle. At this stage of the exercise, our 2017 EV vehicle appears uncompetitive.

5. However, removing the $21,000 battery cost brings the price down to $22,000.

6. And remember, we're using the current Focus EV as the baseline vehicle, which comes pretty well-equipped. We estimate the value of the extra content at $4,000-5,000. So if the 2017 EV vehicle was offered at a lesser-contented base model, the price in our example drops further to $17,000 from $22,000 (ex. battery).

7. Lastly, applying a $7,500 Federal tax credit would bring the price down to about $10,000 — enough to compete for demand even amongst used vehicle buyers (a much larger market) and utilize a presumably mostly unused tax credit allocation (in Ford's case could be ~150k units). The lower price point, while perhaps temporary (1-2 years) pending exhaustion of Federal credits, would nonetheless be critical in order to establish a long-term early mover EV advantage, support the battery operator and achieve even greater cost scale (to narrow remaining per kWh disadvantage). Notably, this would leave the automaker with the same variable profit margin as today—and arguably more if we consider the CAFE costs necessary to improve ICE engines to meet 2017+ standards. In fact, one could argue that at a $10,000 net price point, consumers might add more than $4-5,000 of content to enhance the vehicle, adding variable profit to the OEM.

What Does the Consumer Get? Enjoy all that EVs have to offer at a cheaper price to gasoline cars, attain access to a network designed to eliminate long-range anxiety, avoid residual value concerns from future battery advancements and attain certainty for monthly budgeting with unlimited miles. Notably, consumers preferring to feel like they "own" their batteries could simply opt to never use switch stations.

How Might It Work for the Battery Operator? The battery operator would charge the consumer a monthly fee for unlimited use of the battery, plus access to a network of swap stations. That monthly fee would likely correspond to what consumers were already paying to operate gasoline vehicles—say $250. But since the EV would also come with less maintenance and lower residual value risk, the monthly fee could be justified even higher, say $275-325. With Federal tax credits considered, the consumer would receive a new EV at a far lower monthly cost than a gasoline vehicle. Without tax credits, the consumer still pays a similar amount to enjoy some of the same EV benefits that have contributed to the popularity of the Model S. Either way, it becomes a far more attractive proposition. At $300/month, the consumer is effectively paying $0.24 per mile to operate the vehicle. The cost of providing electricity to the consumer would only amount to about $0.03 per mile and battery depreciation at about $0.09 per mile. The gross margins are therefore inherently high while operating costs would presumably be low due to switch station automation—allowing for the cash flow ramp necessary to pay for the infrastructure and battery investments. Although the return dynamics wouldn't necessarily look compelling in the first few years, the operator's profitability would improve so long as battery costs decline, EV sales scale up and gasoline prices/taxes rise over time. That is the effective goal of the business model.

What Does the OEM Get? Leveraging their inherent advantage in manufacturing and distribution to allow for a faster EV ramp by separating the battery from the car. The capital investment that's likely required to build switch stations doesn't seem demanding—at an estimated $500,000 per unit, initially installing 1,000 strategic switch stations across the US would only cost $500 million—not much compared to Ford's and GM's respective annual capex budgets of $7-$8bn. Note that Tesla's supercharger network is expected to cover 98% of the US population by 2015 with only a few hundred strategically located stations. Switch stations could also be placed at/near dealer locations to align customer service needs (tire rotations, etc.) and maintain a connection to the dealer, which may improve long-term loyalty.

Figure 31. Hypothetical Battery Operator Model

(1) What the Consumer Saves (EV vs. Gas)?

GAS:		EV:		Monthly Gap (EV-Gas)	
Miles Driven	15,000	Range	200		
MPG	23	Charges	75	Gas	$180
Gas Price	$4.00	Electricty (kWh)	$0.11	Maintain (50%)	$33
Gas Cost	**$2,609**	EV Cost	**$454**	**Total:**	**$213**
per Mile	**$0.17**	**per Mile**	**$0.03**	5-yr D&A	$67
Per Month	$217	Per Month	$38	**Grand Total:**	**$280**

(2) Battery Operator Simulated P&L

	Dollar Revenue	*Per Mile*
Per Month	$300	
Revenue *($mlns)*	**$1,080**	
Electricity	($136)	
Battery D&A	($432)	
Gross Profit	**$512**	
Margin	47%	
- Labor	($70)	
- Operating	($30)	
Pre-Tax Cash	**$412**	
- Tax (20%)	($82)	
Net Cash	**$329**	
EBITDA	**$761**	
	7.5	

Key P&L Assumptions	
Battery Cost (avg 2017E-2019E)	$19,360
- End of Useful Value (15%)	$2,904
Useful Life (Years)	12
Annual Depreciation	$1,371
Per Mile	$0.09
# of Subscribers	300,000
Batteries on Hand per Sub	1.05
Batteries Purchased	**315,000**
Extra Batteries / Swap Station	15
Capital Outlays	
Batteries (in millions)	$6,098
Swap Stations (1,000 nationally @ $500k)	$500
Gross Outlay:	**$6,599**
Year-12 Residual Battery Payback	($915)
Net Outlay:	**$5,684**

Source: Citi Research

Is Lincoln Ripe For This? Exploring "Lincoln 2.0"

Ford is clearly committed to Lincoln's success having outlined a bold plan for product launches and expansion into China. We like Ford's near-term strategy of reestablishing the brand with a broader and fresher product lineup. As we think one step further, however, we can't help but pinpoint Ford's Lincoln brand as being eventually (i.e. beyond mid-decade) ripe for this type of strategic maneuver—that is an exclusive xEV brand (EV and perhaps PHEVs/HEVs).

Here's why:

1. Lincoln has struggled as a luxury brand with domestic market share falling ~50bp since 2000 to under 100k of volume ('12 volume = 90k volume), resulting in low dealer throughput vs. peers and the narrowest price gap between its non-luxury sister brand, Ford. As stated above, we like Ford's near-term strategy for the Lincoln brand, but wonder whether it can establish long-term (i.e. beyond mid-decade) leadership considering that the Ford brand is likely to continue receiving cutting-edge technology (higher-pricing), non-domestic luxury competition will likely stay intense and now Tesla may be encroaching on the lower-end luxury market.

2. The Lincoln MKZ hybrid is generating good momentum in states like California. So electrification is in some already attaching itself closer to the brand in places that are critical to win in order to reestablish Lincoln.

3. With a name like Lincoln, in our view the brand carries meaningful potential to resonate more broadly with consumers. In the spirit of the brand, why not consider something big?

4. Using Lincoln as Ford's xEV brand dips into the EV pool just enough to avoid arriving late but also enough to avoid overlooking other promising technologies across Ford's product lineup (EcoBoost, NGVs, diesels, hybrids, etc.). Financially, we don't see a ton of risk—we estimate that Lincoln only generates ~5% of Ford's North America EBIT.

5. It would be fully in-line with Ford's "Power of Choice" strategy, only with a different go-to market strategy (dedicated brand and sales force) that's clearly more suited for EVs. As EVs presumably get cheaper over time, the option to expand the lineup to the Ford brand would still be there with Lincoln more easily being slotted as a luxury brand.

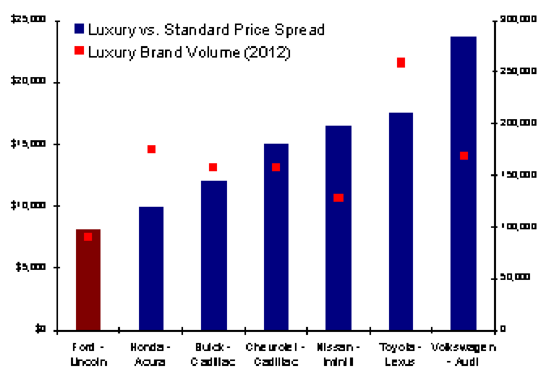
6. Since Ford is currently selling fewer xEV vehicles than GM, Nissan and Tesla, it may enter 2017 with greater room to utilize Federal tax credits to lower the effective price of the vehicles, assuming the credits remain intact. From this perspective, we roughly estimate that Ford could have a ~100K volume advantage—not a bad head start when thought of this way.

7. Ford expects 42% of the 2015 North America premium market to be in the C/CD segment—likely the next battle ground for electric vehicles.

8. Although Lincoln does have ~900 dealerships that also sell Ford brand vehicles, there are also ~200 that only sell Lincoln vehicles—a workable distribution channel, in our view.

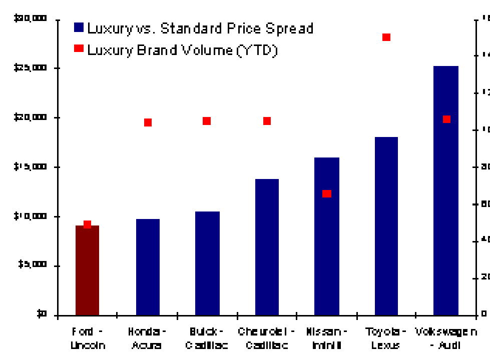
9. Ford has already demonstrated 1st to market leadership with a number of innovative technologies (EcoBoost, etc. In addition, Ford has been amongst the global leaders in platform consolidation in an effort to drive scale. Yet, the company is clearly seeing additional investment opportunities beyond these; having last year raised its mid-decade annual capital spending outlook by a staggering 25% ($1.5bn) to $7.5bn, apparently for investments with returns slated for later this decade. We have no insights on the specific nature of these investments or how much, if any, is slated for EVs. What we do know is that Ford listed EV expansion as the top 2020-2030 sustainability strategy back in January 2013—one has to wonder, could the timetable be moving up?

Figure 32. Ford-Lincoln Price Gap vs. Competition (2012)



Source: JD Power, Ward's & Citi Research

Figure 33. Ford-Lincoln Price Gap vs. Competition (YTD)



Source: JD Power, Ward's & Citi Research

Fuel Cell – Future fuel or just hot air?

By the end of the 21st Century, the world's roads could be free of gasoline cars, replaced by hydrogen-powered fuel cell vehicles.

Hydrogen fuel cell technology could be just another alternative fuel that has been mooted in the race to lower CO_2 emissions and reduce dependence on petrol. However, in a report last year,[2] Shell believes that, by the end of the century, roads will be almost oil-free and there could be an extensive hydrogen network as wide as the petrol/gasoline infrastructure today serving a majority-hydrogen fleet.

This is partly because of the abundance of hydrogen in the atmosphere, but also because hydrogen fuel cell-powered cars enjoy some of the benefits of petrol that electric cars have been unable to attain: indeed, hydrogen fuel cell cars have a driving range and refueling time equal to petrol cars. At the same time hydrogen-fuelled cars (FCEVs) are lighter than EVs, which come equipped with clunky batteries.

Figure 34. Comparison of gasoline engine, HEV, PHEC, EV and FCVs

	Gasoline Engine	HEV	PHEV	EV	FCV
CO_2 Emission (Gasoline engine=100)	100	60-75	30	0	0
Safety	◎	Fire (low risk)	Fire (high risk)	Fire (high risk)	Gas explosion
Price ($)	◎	16,000>	30,000>	20,000	50,000？
Battery amount (kWh)	Unnecessary	0.8-1.3	5-15	15-25	Estimated to be same to HEV
Battery power	Unnecessary	Strong	Strong	Modest	Modest
Driving range (Km)	more than 500km	more than 500km	more than 500km以上	200km	more than 500k
Charging time	Unnecessary	Unnecessary	Good	Bad	Unnecessary
Infrastructure	Gas station	Gas station	Gas station Charging station	Charging station	Hydrogen station

Source: company data, Citi Research

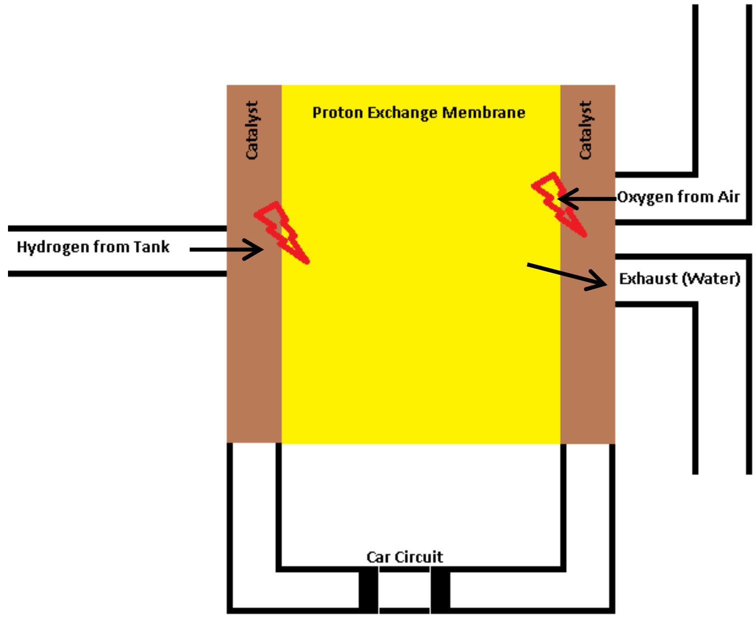
What is a fuel cell?

Fuel cell powered car use hydrogen as fuel and emit only water.

A fuel cell is used to create electricity in a car, just as a battery in an EV does. Electricity is generated through a chemical reaction between two electrodes. In short, hydrogen (H_2) from the tank is passed through a cell through the positive electrode (the anode), where, by a chemical reaction, the hydrogen atoms are stripped of electrons, which flow as the electric current through the anode, powering the engine. The hydrogen atoms have become positively charged. Oxygen (O_2) from the air enters the fuel cell at the negative electrode (the cathode), where it combines with the electrons from the original reaction. The oxygen atoms become negatively charged. These negatively charged oxygen atoms are then paired with the hydrogen atoms to form water, which is the main byproduct of fuel cells. The electricity generated by 5kg of hydrogen is equivalent to the energy produced by 20 liters of gasoline.

[2] New lens scenarios: a shift in perspective for a world in transition

Figure 35. Hydrogen Battery Process



Source: Citi Research

Figure 36. Comparison of fuel cell technologies

	PEFC	SOFC	PAFC	MCFC
Electrolyte	Polymer ion exchange membrane	Zirconia	Carbonate	phosphoric acid
Catalyst	Pt	Unnecessary	Pt	Ni
Fuel	Hydrogen gas, natural gas	Hydrogen gas, natural gas	Hydrogen gas, natural gas	Hydrogen gas, natural gas
Efficiency (%)	35-40	45-65	35-40	45-60
Power (kW)	＞50	>100,000	>1,000	>100,000
Temperature (℃)	-30～100	1000	200	650
Start time	Fast	Slow	Fast	Slow
Application	FCV, small size power plant	Middle size power plant （Factory, office etc.,)	Small size power plant	Large size power plant (Power supply in large area)

Source: Company data, Citi Research

FCV diffusion roadmap and company activities

FCV development began in earnest in the 1990s

The fuel cell vehicle (FCV) is not a new concept; GM developed a fuel cell powered car back in 1966. However, the history of the modern FCV started in 1983 when Canadian company Ballard developed the polymer electrolyte fuel cell (PEFC) fuel cell stack. Major automakers began to take FCV development seriously in the 1990s and several demonstration models were unveiled in the 2000s, but they did not get past the testing or restricted sale stage. Since 2010, however, major automakers have started to announce specific production and sales plans as cost reduction targets have come into view.

Mass production models to appear in 2014; market to expand from 2020

Mass-production FCV models will be introduced in some regions in 2014 and we forecast the market will enter an expansion phase from 2020. Hyundai plans lease sales of a mass-production model in the US from spring 2014, Toyota and Honda plan general releases in 2015, and a Nissan-Daimler-Ford alliance aims to introduce a mass-production model in 2017. Because of cost and hydrogen fueling station hurdles, we do not expect the FCV market to start expanding until 2020.

Various countries aiming to have viable hydrogen supply infrastructure by around 2025

A lack of hydrogen stations is a bottleneck to FCV diffusion. In Japan, the Research Association of Hydrogen Supply/Utilization Technology (HySYT) aims to build 100 hydrogen stations by 2015, mainly in the four major cities. The Fuel Cell Commercialization Conference of Japan (FCCJ) has a target of 1,000 stations by 2025. The German government has plans to build 50 stations by 2015, and a consortium of six private companies, including Daimler and Royal Dutch Shell, have announced plans to build 400 stations by 2023. California is considering building 68 stations in the Los Angeles area by 2015.

Use of fuel cells: Now

A hydrogen station costs $2mn to build so growth is likely to be slow.

Fuel cells have not been commercially available until this year. This is partly because of the cost of a fuel cell engine – estimated at $50,000 – and partly because, hydrogen needs a fuelling station infrastructure. Given that hydrogen cars have the same range as gasoline cars it would need an infrastructure of similar size which would be both expensive and a long-term investment. As an example, the US has more than 121,000 gasoline stations, but just 10 public hydrogen fueling stations, all of which are in California, less than 0.1% of the Golden State's total stations.

That said Hyundai this year has released a fuel cell version of its Tucson, which will only be available in California with a few thousand models built. This car will cost $499 per month for 36 months, with an initial outlay of $2,999. Its range of 270 miles is comparable to many petrol cars and it takes three minutes to refuel. This car proves that fuel cells can gain consumer interest – almost 90,000 people have looked at the Hyundai Fuel Cell Tucson website – although only 1,000 cars will be available.

OEMs involved

Toyota, Honda, and Nissan lead technology development

We believe Toyota, Honda, and Nissan lead the development of FCV technology as 1) they started FCV development in the 1990s ahead of peers and have accumulated know-how in this field and 2) they can apply their leading HEV/EV powertrain and management know-how to FCVs. The development of fuel cell stack and hydrogen stacks requires the ability to combine advanced material technologies and we believe these three automakers are well placed to enjoy first-mover benefits.

At the same time, Daimler, Ford, and Nissan announced a partnership to develop an FCEV by 2017 and Toyota and Honda have said that they will follow suit with fuel cell models next year, which we believe could have a price tag of c.$50,000.

VW concluded a joint development agreement with Ballard in 2013

VW has not been particularly active in FCV technology development or commercialization, but in 2013 it reached an agreement to develop fuel cell technology with Ballard. While VW is concentrating on EV and PHEV, we believe it will also develop FCV as an eco-car technology of the future.

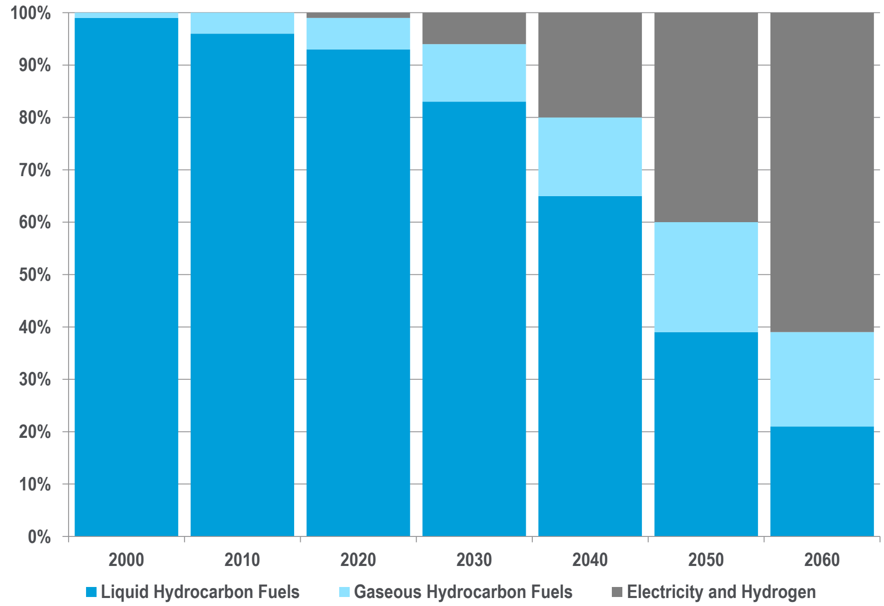
Use of fuel cells: In the Future

With high infrastructure costs, Fuel Cell technology is unlikely to take off by 2025…

In any case, fuel cells are unlikely to take off for over a decade. There are a number of impediments, key of which are cost and infrastructure. According to Fiat, building the infrastructure could cost up to £50bn ($84bn) in a country the size of the UK of Italy. This could stymie growth and the rate at which FCEVs build a foothold in the autos market could at first be glacial; according to the US Energy Information Administration (EIA), by 2025 sales could be no more than 0.05% of total number of cars sold.

This is a view corroborated by OEMs. Toyota thinks fuel cells cost will be cut in half by 2020 at which time, VW thinks hydrogen fuel cell cars will be fully marketable. Daimler is less optimistic and believes that it could be the middle of the next decade before fuel cells are mass-produced.

Figure 37. Fuel Mix to 2060

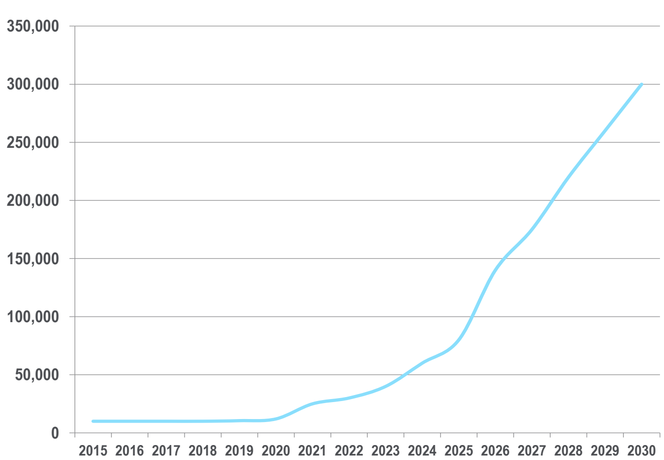


Source: Shell: New lens scenarios: a shift in perspective for a world in transition

That said, by 2030, we believe sales could pick up and a lot of this growth could be driven by regulation. For example, the US has introduced fuel cell tax credits of up to 30%, although these are currently set to expire in 2017; and California has mandated in its Zero Emission Vehicle Regulation that 22% of sales by 2025 must be either plug-in hybrids or fully Electric/Hydrogen cars.

UK H_2Mobility, a government-sponsored project evaluating the economic and environmental benefits of fuel cell technology to the UK, believes that sales in the UK could reach 300,000. If we assume that the UK will have a 2030 hydrogen fuel cell vehicle market share of 10-15% (according to UK H_2Mobility), we can infer that sales could be 280,000/0.125=2.24mn.

Figure 38. FCEV sales in the UK



Source: UK H_2Mobility

Figure 39. FCV-related events

Company	Year	Outline
GM	1966	Announces the world's first FCV, the GM Electrova
Ballard Power :	1983	Develops a proton exchange fuel cell
Daimler	1994	Announces the NECAR1, a FCV that uses Ballards's PEFC
Various OEMS	1990s	Toyota, Honda, Nissan, Hyundai start FCV development
Toyota, Honda	2002	Toyota, FCHV, Honda FCX, and Mercedes-Benz F-Cell restricted lease sales
Nissan	2003	X-trail FCV restricted lease sales in Japan
Hyundai	2000s	Starts testing the ix35 FCV and other models
GM	2000s	Starts testing the Equinox FCV
Toyota/ Honda	2008	Toyota FCH-adv and Honda FCX Clarity released
Nissan/ Daimle	2013	Reach fuel cell technology joint development agreement
Toyota/ BMW	2013	Reach fuel cell technology joint development agreement
Hyundai	2013	Starts FCV mass production on a regular production line
Honda/ GM	2013	Reach FCV joint development agreement
VW/ Ballard	2013	Reach fuel cell technology joint development agreement
Hyundai	2014	Scheduled to start FCV general lease sales in the US
Toyota, Honda	2015	Plan to introduce FCV mass production model
Nissan/ Daimle	2017	Plan to introduce FCV mass production model
Toyota/ BMW	2020	Plan to introduce a jointly developed FCV
Honda/ GM	2020	Plan to introduce a jointly developed FCV

Source: American Clean Skies Foundation Citi Research

Compressed Natural Gas (CNG)

Figure 40. CNG Gas Station Locations

Source: NGV America

Compressed natural gas (CNG) vehicles possess a number of advantages and challenges.

Key advantages include:

- **+ Energy security:** The most obvious advantage is making great strides towards reduction in foreign oil dependency and the resulting gains in US energy security. We believe consumers have become more appreciative of this issue in light of geopolitical conditions and the number of oil spikes observed in recent years with their immediate impact on consumer confidence.
- **+ Low fuel cost vs. gas or diesel:** On an apples-to-apples basis, CNG as a fuel is 30-50% less expensive than gasoline or diesel fuel. More stable, too.
- **+ Lower emissions:** A 20-30% reduction in CO2 emissions and a 75-95% reduction in NOx, compared with older gasoline vehicles. Arguably not the greenest but arguably green enough.
- **+ Bridge to FCV:** Lastly, it has been argued that CNG is an ideal bridge solution towards the eventual deployment of future fuel-cell hydrogen vehicles.

The most glaring challenges include:

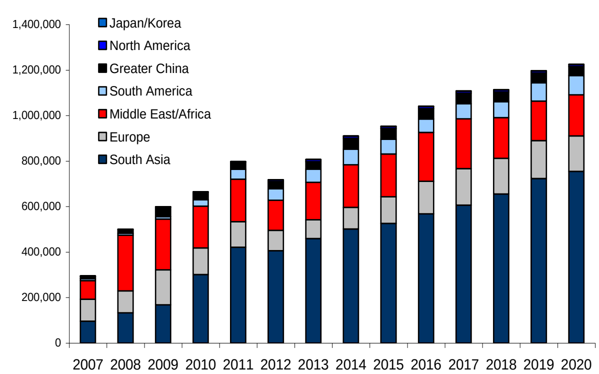
- **- Infrastructure:** There are currently about 1,300 CNG fueling stations across the U.S., a small percentage of the number of gasoline stations. While the list is growing, only about 50% of the stations are open to the public. Refueling at home is one solution to this, but it's unclear to what extent. Note that Honda does not recommend Civic NG customers refuel at home as moisture and other contaminants risk harming the fuel system, placing a customer's warranty at risk of being denied. We believe that this is a clear issue that must be addressed.
- **- Energy density:** Lower energy density means a lower MPG rating, the necessity for a larger tank (compromising space in the vehicle) and a partial offset to the lower cost of the fuel. Going back to the diesel example, it's also a slight consumer education hurdle as auto dealers would need to reconcile to customers the high cost premium against the lower MPG equation. Consider that the Civic NG is rated 7% lower in city/highway MPG than the Civic HF.
- **- Large cost premium:** Current premiums on NGV range from $7,000-12,000, which is higher than advanced gasoline engines (EcoBoost), most diesels and close to many hybrid vehicles. We believe this is too expensive for mass consumer acceptance.

> **Head to Head: Honda Civic NG vs. the Competition**
>
> To best understand the pros and cons of CNG versus competing technologies, we ran a simple comparison between the Honda Civic NG and comparably sized vehicles including the Civic HF, the Ford C-Max hybrid, Toyota Prius-C and Prius-V (larger variant) and the VW Jetta Diesel. The conclusion is fairly straightforward: The Honda Civic NG beats its competitors in annual fuel cost (assuming 15k miles with 51.3% highway), but the vehicle's premium appears expensive relative to the savings, particularly in light of a consumer's typical ~3-year desired payback period. When considering performance, the comparisons are arguably even tougher for the Civic NG particularly relative to the C-Max and the VW Diesel. And we haven't even yet discounted the Civic for infrastructure anxieties plus some reduction in trunk space resulting from the larger CNG tank. So the Honda Civic NG offers slight fuel cost savings versus a Ford C-Max hybrid for a comparable price but with somewhat worse performance (per 3rd party reviews) and infrastructure dependence. What can we conclude? That the economics for CNG light vehicles must still improve or the consumer's desire for US energy security/independence must be a top consideration to overcome less than obvious economic benefits.

Light Vehicle NGV Penetration Outlook

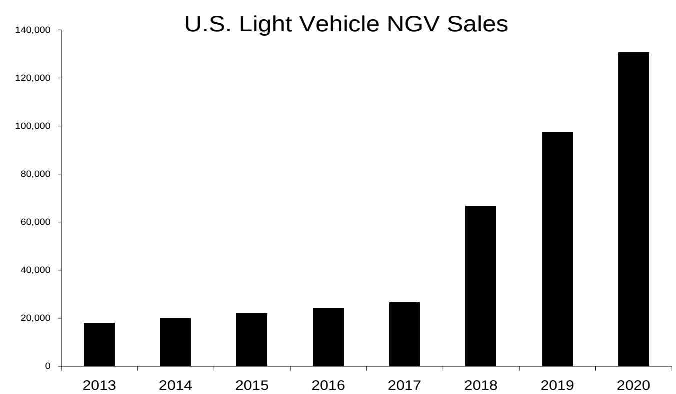
Considering some of the challenges mentioned above and the small product offering in the US, renowned 3rd party forecasters have yet to anticipate strong penetration gains of CNG vehicles, albeit demand should grow over time. Forecasting firm IHS estimates that global CNG (both dedicated and bi-fuel) are likely to grow from 0.9% of global auto production to 1.1% by 2020. A more optimistic US scenario outlook, which assumes breakthroughs in 2018 coupled with incentives in supportive states, suggests that US sales for CNG vehicles could surpass 100,000 by 2020.

Figure 41. Global CNG Vehicle Outlook



Source: Citi Research

Figure 42. U.S. NGV Sales Outlook (More Constructive Scenario)



Source: American Clean Skies Foundation, Citi Research

Investing in Future Propulsion

Figure 43. Investing in Future Propulsion

	Turbos	GDI	Timing Chains
Is There a Specific Regulatory Driver?			
Consumer Value (Perform, Safe, Connect)?			
Do OEMs Use This As a Selling Point?			
Is It Reasonably Affordable to Consumers?			
Is it Globally Scalable?			
How is the Competitive Landscape?			
Can It Be Funded By Content Reductions?			
Applicable to OEM Investing?	Yes	No	No

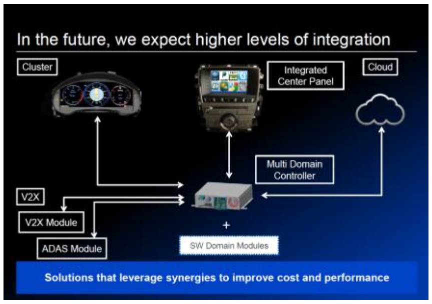
Source: Citi Research

Propulsion technologies offer some of the most attractive investment propositions in the Car of the Future. This is because many applications fit well into our Investing Framework that seeks affordability, performance and concentrated competition. For example, in turbocharging BorgWarner and Honeywell control about two-thirds of the global light vehicle market. BorgWarner also has strong positions in variable cam timing and emissions systems. In diesel engine management systems, Bosch, Denso, Delphi and Continental control about 90% of a $15+bn market. In gasoline engine systems, these same four players command >50% of a $20+bn market. As a result, conventional technologies should see plentiful growth and margin opportunities through the end of the decade. .

Perhaps the biggest medium-term risk to this investment story, in our view, comes from whether nonconventional technologies might cross a “threshold of inevitability” sometime over the next 5-10 years. By “threshold of inevitability”, we mean a point where mass adoption of a new technology becomes inevitable even if the reality of the auto business dictates a 5-15 year volume ramp. This threat is less relevant for CNGs than for EVs and fuel-cell vehicles. Of course, some of the Tier-1 auto suppliers (Denso, Delphi) already have some exposure to these nonconventional markets, thereby providing somewhat of a hedge. But others might still need to shore up exposure to avoid a potential future penalty on trading multiples. There’s also the interesting debate as to whether the rise of the connected and autonomous car might have a negative impact on certain powertrain technologies that enhance performance if that performance is no longer usable.

Saving Lives in the Car of the Future

Figure 44. ADAS & Connectivity Converge



Source: Delphi

The car of today isn't just fuel inefficient, but also unsafe. Road fatalities claim over 1 million lives around the world each year—placing car accidents within the top 10 global causes of death. Human error accounts for over 90% of traffic accidents. The trend is only bound to get worse as vehicle performance improves, the global population ages and cars become more connected (i.e. distracted). Indeed, vehicle fatalities are forecasted to rank in the top 5 causes of death by 2030. It is estimated that if a driver is afforded an extra ½ second to respond to a situation, 60% of accidents might be mitigated. Enter Active safety, or Advanced Driver Assistance Systems (ADAS). In our Auto Technology Investing Framework, ADAS ranks very highly due to its relative affordability, regulatory tailwinds, consumer demand and ability to fund through (eventual) de-contenting elsewhere. There are clearly some long-term issues that need addressing such as security, legal ramifications and unintended consequences. But there's no question to us that most of the Cars of the Future will feature considerable ADAS capabilities, including partial and eventually full autonomous features. Today, the ADAS market is relatively small at $1-2bn and dominated by higher-priced vehicle offerings. Most suppliers peg the next few years' CAGR at 20-35% for ADAS portfolios depending on the inclusion of different applications. Assuming eventual 80% global light vehicle penetration (~80mln units) and a $500 average ADAS content-per-vehicle, the market could eventually reach $40bn. The aftermarket represents another opportunity for certain ADAS applications; this too could flourish in a market in the tens ofbns (or higher). Key global Tier-1 auto suppliers include Continental, Denso, Autoliv, Delphi, Bosch and several other leading players in the supply chain. Other somewhat smaller publicly traded companies include Magna, Valeo, TRW and Gentex.

ADAS Basics

Figure 45. ADAS Basics

Application/ Sensor Type	Video	Infrared	Long range radar 76-81MHz	Short/ Mid range radar 24-26 / 76-81 GHz	Ultrasound 48/kHz
Adaptive Front Light (AFL)	X				
Night Vision (NV)	X	X			
Adaptive Cruise Control (ACC)	X	X	X		
Lane-Departure Warning (LDW)	X				
Low-Speed ACC, Emergency Brake Assist (EBA), Lane-Keep Support (LKS)	X	X		X	
Pedestrian Detection	X	X		X	
Blind-Spot Detection (BSD), Rear Collision Warning (RCW), Lane-Change Assist (LCA)	X	X		X	X
Park Assist (PA)	X			X	X
Traffic-Sign-Recognition (TSR)	X				

Source: Texas Instruments

While autonomous driving may not be commercially available for at least a decade, many of the foundation components involved are already in place with Advanced Driving Assistance Systems (ADAS). ADAS uses internal software connected to sensors and cameras to alert drivers to potential hazards or even temporarily take control of the car to avoid dangerous situations. This can be accomplished through:

1. **Radars** (Radio Angle Detection and Ranging) of various types that can detect vehicles and objects at various sensitive with no sensitivity to light conditions. Radars transmit radio waves and analyze their echoes. They generally fall into three categories identified by range capabilities. One of the most common today is the 77-GHz radar frequency used in parking assist and blind spot monitoring systems. These technologies are relatively affordable even today—the Ford BLIS system, which provides blind-spot monitoring and cross-traffic alerts, retails as a $595 option.

2. **Cameras** (mono/stereo) can detect and "read" various shapes, markings, people and traffic signs. This segment is led by some private companies and a few publicly traded players like Magna (24% share) and Autoliv (~50% share of the night vision market). Applications here include lane-departure warning, adaptive cruise control, forward-collision/brake assist and traffic sign recognition. Certain application, such as advanced adaptive cruise control, utilize both radar and camera technology to leverage respective strengths.

3. **Laser/LIDAR Sensors:** LIDAR is an acronym for Laser Imaging Detection Ranging. As its name suggests, LIDAR emits laser light and analyzes the reflection that can provide 360-degree imaging.

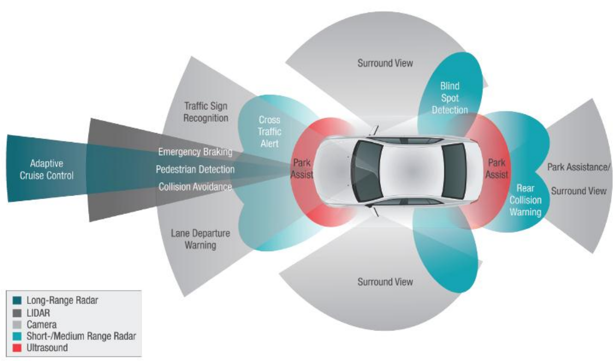
Figure 46. Comparison of cameras, radar and ultrasound sensors

	Cost ($)	Short range	Long range	Detection distance (m)	directivity	Weather	Outline
Cameras	Good	Good	5-20	Good	Poor	Good	Applications include AEB, ACC, LDW, and automated parking
Laser radar	Good	Bad	30-150	Poor	Bad	Good	Applications include AEB and ACC
Miliwave radar	Poor	Excellent	Excellent	Good	Good	Poor	Applications include AEB and ACC
Ultrasound sensor	Excellent	Poor	0.3-7	Good	Good	Excellent	Applications include automatic braking, parking assist, and theft protection

Source: Company data, TSR, Citi Research

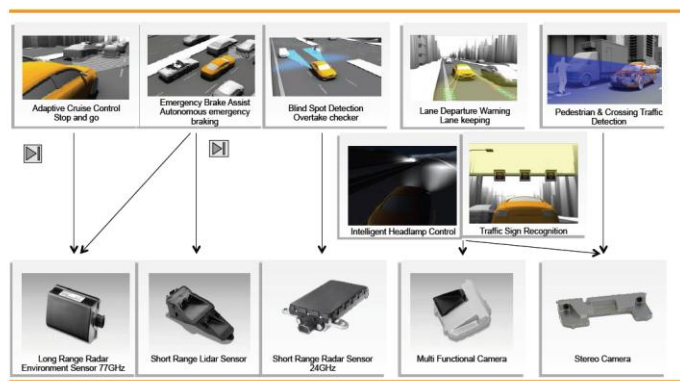
Much of the hardware required to form ADAS systems are available today, having originated from such industries as aerospace & defense (fighter jets, drones). But the “secret sauce” lies in the software algorithms required to provide collect, analyze and report the data, as well as to perform brake control and other semi-autonomous functions. These functions will only become more complex as traditional ADAS merges with the connectivity megatrend through V2V (vehicle-to-vehicle) communication, 4G LTE links and increased sophistication in automated features such as platooning or traffic jam assist. All of these features must then be communicated easily with the driver (HMI) through clusters and displays, which covered in the next chapter of this report.

Figure 47. ADAS Technology Overview



Source: Texas Instruments

Figure 48. ADAS Functions Overview



Source: Continental AG

ADAS & Connectivity Will Converge: Today, ADAS is sold and marketed as on-board systems that alert drivers to potential dangers and provide select driver assist capabilities. Meanwhile, the topic of Connectivity is mostly referenced in infotainment discussions. Clearly, a Connected Car also brings plenty of game-changing safety elements to the safety table. For example, vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2X) communication is winning early regulatory and consumer support. Using DSRC—or Dedicated Short Range Communication (similar to WiFi)—cars can quickly share critical safety information with each other before onboard ADAS systems can detect them. DSRC capabilities could also be enhanced by cellular connections such as GM’s upcoming OnStar 4G LTE rollout. According to the US Department of Transportation (DOT), connected vehicle technology address ~80% of crash scenarios involving non-impaired drivers. The application would be useful in many scenarios but particularly in intersections, traffic lights and school zones. In August 2012, DOT launched the Safety Pilot deployment of nearly 3,000 vehicles in Michigan. NHTSA has already noted that it will soon begin working on a regulatory proposal to require V2V devices in in future years. It should be noted that NHTSA’s work to date has apparently focused solely on light vehicles; we are not aware of similar test studies yet undertaken for commercial vehicles.

In the table below, we highlight the key products/technologies within ADAS currently

Figure 49. A Brief list and description of the types of ADAS

System	Detail
Adaptive Cruise Control	Follows the flow of traffic ahead of the vehicle and adapts the speed accordingly, even to stop and go
Advanced Parking Assistance(1)	Guides a driver into a parking space. At lower speeds, systems allow the car to manoeuvre itself into a space automatically. Currently systems require a driver to shift gears (e.g. reverse to first gear)
Blind Spot Detection	Monitors blind spots, alerting driver to obstacles if trying to change lane or turn a corner
Driver Drowsiness Detection(1)	Recognises inattentive driving (for example, in changes in steering) at high speeds and alerts driver to take a break
Distance Warning	Alerts the driver of the cars proximity to other cars/objects in the road
E-Call Telematics(1)	When needed, the car can send an automatic notification alert to emergency services
Emergency Brake Assist	Tracks cars in front and can brake automatically when driver is distracted
Head-Up Display	Displays most important driver information in the windshield of the vehicle
Intelligent Speed Adaption	Drawing on GPS speed sensors or traffic sign recognition, cars can automatically lower their speed to the speed limit
Lane Departure Warning	Keeps track of the lanes and warns a driver when drifting by accident, through acoustic or haptic (i.e. steering wheel vibrating) warnings
Lane Keeping System	Similar to Lane Departure Warning, this will automatically keep the driver in the correct lane if the car starts to drift
Night Vision(1)	Internal image of the road that helps driver see more clearly in the dark
Rear Cross Traffic Alert	Drivers are alerted to out-of-sight hazards when reversing out of a parking space
Traffic Sign Recognition	Recognises road signs and displays speed limits and other information on a panel in the cockpit

Source: Citi Research; (1) Not in Conti's ADAS division

ADAS Isn't Just About Safety: Clearly, ADAS is most often associated with its safety attributes. But there are other global megatrends that might play well into this. An increase in global urbanization will drive demand for safer, simpler and more sustainable mobility solutions. This will create demand for methods of managing/avoiding traffic, better coping with unavoidable traffic and limiting tailpipe emissions as much as possible in highly populous regions. Traffic jam assist, for example, will be a feature that's not only marketed for its safety attributes but also for its ability to greatly enhance driver productivity. According to the Texas Transportation Institute, American drivers spent nearly 5bn hours stuck in traffic in 2010. In some of the largest US cities, the average commuter spends ~60+ hours-per-year stuck in traffic. Today, responsible drivers must stay mentally alert and physically active (braking, accelerating) throughout a traffic jam. The Car of the Future will likely retire this nuisance. V2V technology and certain smartphone applications today can already avoid some traffic jams, but not all. A semi-autonomous car operating in a low-risk/high-mental workload environment like a traffic jam offers to add 2.5 days of productivity to our busiest commuters.

Figure 50. Company activities related to automated driving technology

Company	Outline
Toyota	Has set up an R&D base in Silicon Valley and is seeking alliances with research institutes and IT companies; conducting testing in Japan and the US
	Displayed a vehicle fitted with automated driving technologies at the CES 2013
	Has announced it wants to commercialize a highway driving assistance system around 2015
Honda	Has set up an R&D base in Silicon Valley and is seeking alliances with research institutes and IT companies
	Displayed a vehicle fitted with automated driving technologies at the 2013 ITS World Congress
Nissan	Has set up an R&D base in Silicon Valley and is seeking alliances with research institutes and IT companies
	Displayed a vehicle fitted with automated driving technologies at the CEATEC 2013
	Plans to launch several models fitted with automated driving technologies by 2020
GM	Conducting joint R&D with Continental and Carnegie Mellon University
	Has announced plans to commercialize automated highway driving assistance by 2017.
Ford	Conducting joint R&D with Stanford University, MIT, and Michigan Universities
Tesla	Has announced it will introduce an automated vehicle by 2016
VW	Conducting public road tests in the US, and joint research with Stanford University and Continental
	Developing semi-automated driving technology known as iCar. Group company Audi plans to commercialize traffic jam assistance in the next few years
BMW	Conducting joint research with Continental and public road tests
	Introduced a vehicle with traffic jam assistance in 2013.
Volvo	Plans to introduce a vehicle with traffic jam assistance for speeds of 50km or slower in 2013.
Daimler	Introduced a vehicle with traffic jam assistance (ACC, LKA, PD) in 2013
	Has announced plans to introduce an automated vehicle by 2020.
Bosch	Bosch plans to commercialize traffic jam assistance from 2014, automated parking systems from 2015, intelligent cruise assistance from 2016, and a fully-automated highway driving system from 2020
Continental	Conducting joint research with Carnegie Mellon University, VW, BMW, and GM, and has reached an agreement with Nokia to create regional database
	Aims to commercialize partially automated driving technology by 2016, high-level automated driving technology by 2020, and fully-automated driving technology by 2025
Google	Has employed university researchers and is a frontrunner in Automated driving technology R&D. Started public road tests in 2007.
	Initiated the Open Automotive Alliance (OAA), whose members include Honda, GM, VW, and Hyundai

Source: Company Data, Various Media Reports, Citi Research

Regulations Help, But ADAS Sells Itself

Regulation has had an obvious impact on the growth of ADAS type products, as safety ratings are often ranked amongst the top 3 consumer purchase considerations. For instance in Europe, Tire Pressure Monitoring Systems (TPMS) have been mandatory for all new cars (from 2014 in all cars) and in the US all new launches must have Lane Departure Warning Systems (LDWS) from 2014. Furthermore, back-up cameras are to be mandatory in all cars in the US by 2014 (40% in 2013). NHTSA estimates the US annual societal cost of traffic accidents at several hundred billion dollars. What is important to note, in our view, is that these changes to what is required show that ADAS are not simply restricted to the premium segment but have increasing importance to the mass market too. As an example in late 2013, Renault announced that it will include many ADAS technologies in cars in 2014, including adaptive cruise control and traffic sign recognition. We believe that any move to the mass market could ramp up quickly as adoption begins.

Figure 51. Vehicle safety regulation forecasts: Introduction of automatic braking and vehicle monitoring systems to advance

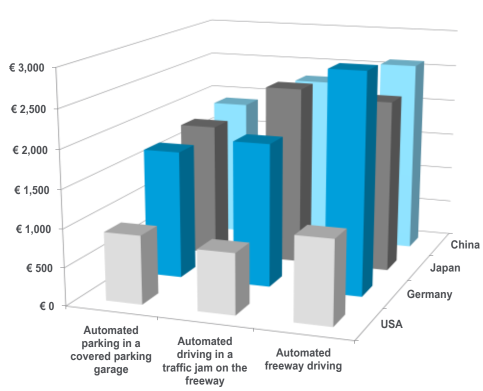
Year	Region	Outline
2013	North America	US NCAP adds points for LDW and FCW
2013	Europe	LDP and AEB made compulsory for large vehicles
2014	Europe	ECS made compulsory for all new vehicles
2014	Europe	Euro NCAP adds points for LDW and AEB
2014	Japan, Korea, Europe	ECS made compulsory for all new vehicles
2014	Japan	LDP and AEB made compulsory for large vehicles
2014	Japan	Regulations accelerate installation of LDW and AEB in commercial vehicles
2015	North America	Camera installation could be made compulsory under the Kids Transportation Act
2015	Europe	Europe modifies side camera ISO regulations
2016	Europe	Euro NCAP adds points for PD (Pedestrian Detection) and AEB
2016	Japan	Japan could approve side mirrors
2017	North America	North America approves side mirror cameras
2017	North America	US NCAP adds points for PD and AEB
2018	Japan	Japan could approve the use of autonomous parking assist
2018	Europe	Euro NCAP adds points for night-use PD and AEB
2018	EM countries	EM country NCAP considers adding points for PD and AEB

Source: Euro NCAP, company data, TSR, Media report, Citi Research

But ADAS isn't just a regulatory driven content story. Currently ADAS systems retail at $600-$900 for basic capabilities (blind-spot detection, cross-traffic alerts) and $1,000-$3,500 for additional forward-collision, adaptive cruise control, lane departure capabilities and advanced displays such as heads-up. In our view, the premiums are reasonable relative to other add-on features. Certain ADAS systems are also available in aftermarket applications.

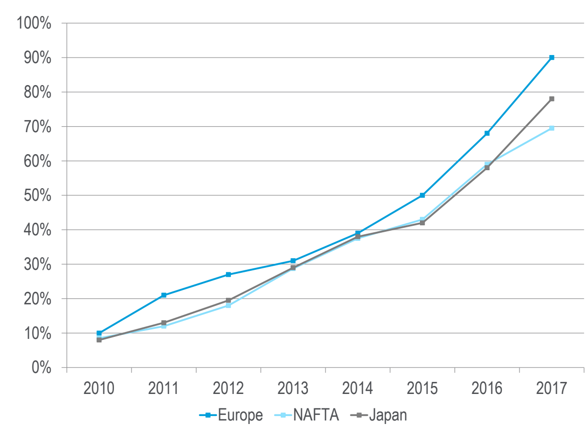
Indeed, consumer surveys conducted by Continental suggest a clear willingness to pay these premiums—notably the US ranks below Germany, Japan and China. For less than the price of average built-in navigation systems, ADAS offers consumers a safer, more confident experience. Importantly, we believe that once drivers experience the reduced stress of ADAS systems (or better, avoid an accident), we believe they would be far less likely to go back to non-ADAS equipped vehicles. We view ADAS as truly a technology "you didn't know you wanted until you used it, and now you can't see yourself going back".

Figure 52. Reasonable Price Survey on autonomous cars



Source: Continental, Citi Research

Figure 53. Increasing Installation Rates of ADAS[(1)]

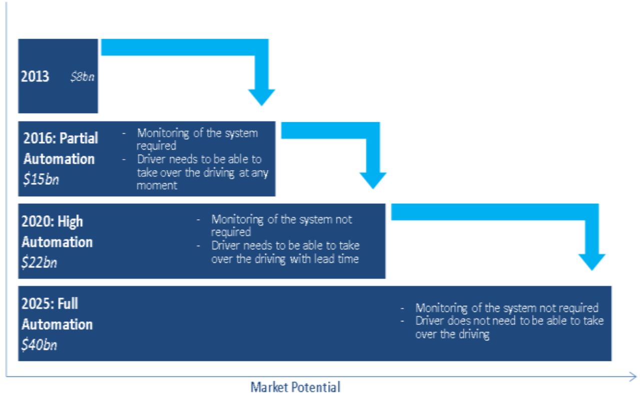


Source: Continental, Citi Research; (1) Adaptive Cruise Control, Collision Mitigation, Lane Departure Warning, Blind Spot Detection Intelligent Lighting, Night Vision, Traffic Sign Recognition,

Wider Impact on Mobility

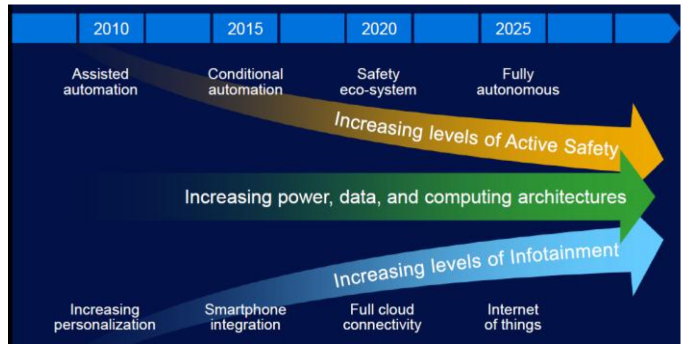
The trends toward partial and fully autonomous driving are likely to have a dramatic impact on many areas of the consumer experience. We list a number below:

Figure 54. Market potential of Autonomous driving



Source: Continental, Citi Research

Figure 55. ADAS & Connectivity Expected to Converge



Source: Delphi

Insurance: According to the US National Highway Traffic Safety Administration, more than 90% of accidents are caused by human error. ADAS could minimize this and in turn insurance costs. As an example, the University of Western Ontario has suggested that enhanced stability control could lower single-vehicle crashes up to 35%, even at lower levels of penetration, because this would increase safety for all.

Car weight & raw materials: Safer roads could enable OEMs to reduce the weight of their cars. Since car frames are generally made of steel, which is more secure in crashes than other metals, the shells of cars are heavier than they would be with other metals such as aluminum. Cars made of aluminum are up to 50% lighter than other cars. Despite its cost, aluminum could help the premium segment reach its CO_2 targets and save on fuel costs in general. For an automaker to be able to remove content to compensate for added content cost elsewhere is a key consideration of our Auto Technology Investing Framework.

Traffic congestion: Other impacts include likely reduced traffic congestion and the ability to manage traffic flow better. Furthermore, the fully autonomous car could probably enable higher speed limits for autonomous cars as well as freeing up driver time. In turn, beyond the potential for lower car insurance levels, there could also be a reduction in vehicle policing and physical road signage.

Fuel savings/ Car Parc: The reduction in wasted journey time, avoidance of congestion could also reduce fuel consumption; nevertheless, the convenience of autonomous driving could also mean more cars on the road as the attraction of public transportation diminishes.

How About Self-Driving? Yes, But Not So Fast…

While the technology of Advanced Driver Assistance System is the foundation for autonomous driving, the latter is unlikely to be a commercial reality before 2025, so it is important to make a distinction between ADAS and autonomous driving, in our view. The good news is that the technology for self-driving cars is already coming along (Google test vehicles recently exceeded 700,000 test miles) and likely only to improve in the coming years. Most automakers are expected to have some degree of offerings here in the 2020-2025 period. There are, however, a number of challenges that are worth considering:

- **If They Have to Monitor, Will They Pay?:** For the consumer, the incremental proposition of a self-driving (vs. a semi-autonomous) car centers on the ability to use time spent for working, playing or napping rather than driving. This would indeed be pleasant if regulators allow it, but will they? Let's consider modern aviation where planes are essentially autonomous through the majority of flight. Piloting an aircraft entails less workload today than decades ago, but pilots are still responsible for monitoring systems at all times. Now consider cars, where studies have shown that when a blindfolded driver is prompted to take over a self-driving car during highway conditions (say, because poor weather is compromising sensors), the driver needs some orientation time (perhaps a minute) to assess their surroundings. So if regulations and human limitations end up forcing drivers to continuously monitor systems like pilots do, would a consumer accept the premium of fully autonomous features vs. semi-autonomous? This is a challenge, but the answer is not necessarily a negative one. The equation is one that considers the cost premium of a self-driving vs. semi-autonomous car versus the incremental insurance savings to the driver and the potential to self-fund by reducing content in areas in powertrain (in theory less valued in a self-driving car), passive safety (airbags) and certain materials. As we monitor autonomous cars going forward, this is the equation we will likely go back to for assessing the penetration outlook.

- **Unintended Consequences:** There's also the issue of whether it's wise for society to lose the skill of driving. Again, let's go back to aviation where recent (though thankfully few) examples of incidents have been attributed to pilot error such as incorrect stall reactions. To be fair, this is an issue for basic ADAS as well—will drivers take unnecessary risks believing ADAS will bail them out? And if electric and turbocharged vehicles revive the joy of driving, will consumers value a driverless car whose systems must always be monitored?

- **Technology:** While much of the hardware for autonomous driving exists (mono cameras, stereo cameras, radars, lidars), these are in many cases currently quite bulky and may need to be scaled down as fully autonomous cars are likely to require a higher fitment of this hardware. Furthermore, technologies to process the vast quantity of information provided by hardware and then to connect this with driving functions that can be operated under all driving conditions (not just at a slow speed) also are not currently available in an efficient form and fully tested. And there's the issue of measuring incremental safety benefits of fully autonomous vs. semi-autonomous cars. Some industry contacts we've spoken with have questioned whether that incremental cost/benefit makes sense for consumers, though clearly it's too early to really know.

- **Reliability:** As with any new technology there are also skeptics around quality; for instance, will technology be able to operate in all weather conditions, e.g. could heavy fog complicate the processing of data. There are also concerns around the potential for hacking into a car taking control away from the owner.

- **Data Ownership/responsibility:** A fully autonomous car will generate and process huge amounts of data but there remain uncertainties about who actually owns this data. Furthermore who or what is likely to be responsible in the case of accidents (the driver, car owner, software provider?)

- **Dual technologies:** Once fully autonomous technologies are available it could still take another 10-15 years for the car parc to be completely converted to autonomous as this is a typical time frame for cars to be scrapped. This could suggest over 25 years before all cars have autonomous capabilities. In the meantime, some cars will be running with autonomous capacity and some without which could complicate the effective running of autonomous cars if most cars on the road do not have fully autonomous capacity.

- **Cost:** Autonomous driving technology is also currently expensive. Indeed the MIT Technology Review believes that technology used in Google's self-driving cars costs around $80,000 per car so there will have to be a reduction in costs here before it becomes commercially available.

Investing in ADAS

Figure 56. ADAS Investment Framework

	ADAS
Is There a Specific Regulatory Driver?	
Consumer Value (Perform, Safe, Connect)?	
Do OEMs Use This As a Selling Point?	
Is It Reasonably Affordable to Consumers?	
Is it Globally Scalable?	
How is the Competitive Landscape?	
Can It Be Funded By Content Reductions?	
Applicable to OEM Investing?	Yes

Source: Citi Research

As previously mentioned, the ADAS market is expected to grow at a 20-35% CAGR through the end of the decade, with a forecasted mid-decade acceleration due to regulation and consumer awareness. An eventual 80% global penetration level at $500/vehicle suggests of $40+bn market.

However, unlike say the turbocharger market that's been dominated by 2-3 players, ADAS already features a handful of prominent competitors and several more niche players including technology & defense companies providing critical capabilities. Consolidation appears likely. For these reasons, our working assumption is for ADAS operating margins to run in the high-single digit or low-double digit range for the Tier-1 auto supplier integrators. This would be higher than margins on commoditized products but lower than the mid-teens margin generated at more concentrated and mature end-markets like powertrain. That said, as our focus is on Tier-1 auto suppliers, we'd note that margins could vary across the supply chain.

Amongst the Tier-1 suppliers, we view winners as those who have proven technical capabilities (software mainly), those who can scale globally and integrate ADAS into connectivity platforms and human-machine interfaces as the worlds of connectivity and safety collide. ADAS remains a small component of most tier-1 suppliers' revenue base, but we believe market valuations will continue distinguish exposed players in the coming years considering the large and seemingly inevitable growth opportunity that exists in the coming decades.

Spotlight on Denso

Denso was the world's first auto parts firm to achieve success in the field of preventive automotive safety. When the Toyota Harrier was launched in February 2003, it featured the world's first pre-crash safety system (which uses millimeter-wave radar to detect obstacles ahead, and when a collision appears inevitable seeks to reduce damage via actions like brake activation), which Denso developed jointly with Toyota. Denso has subsequently fallen behind its rival Continental, however, with sales of preventive safety systems limited to Toyota's high-end models including under the Lexus brand, and mini vehicles manufactured by Daihatsu Motor. Denso is currently seeking to win orders via package solutions for preventive safety systems, with the aim of making up lost ground. Specifically, it is offering three packages combined with OEM target costing: 1) an entry package (low-speed collision avoidance assistance: forward vehicles + speed assistance + nighttime visual range assistance + lane departure warning); 2) a standard package (entry package + collision avoidance assistance (forward vehicles and pedestrians) + lane departure prevention + full-speed range adaptive cruise control); and 3) a premium package (standard package + head-on collision avoidance assistance + lane deviation prevention). Denso targets a 20% share of the global market for preventive safety systems in 2020 (2012 share of c10%).

Some automakers could be winners here too, particularly those who can establish an early mover advantage (Ford BLIS and 360 degree camera on the new F-150 come to mind) and by identifying their brands with ADAS. Because of strong consumer demand, we believe automakers currently enjoy high profit margins on ADAS systems. One leading supplier we spoke with noted that the dollar content of *all* of its ADAS offerings combined stood at just over $1,000. The retail price of an advanced ADAS system can run well north of $2,000. Even though these margins are likely to erode gradually over time, the potential for consumers to save on monthly insurance payments could support automaker profitability (either in ADAS or other content) and branding with quality and HMI driving differentiation.

Non-ADAS, ADAS Plays: Referring back to our Investment Framework, it's always important to step back and remember that automakers face limited variable cost budgets. Some auto suppliers enjoying tailwinds from ADAS could eventually (emphasize eventually!) lose content in other areas (passive safety, powertrain). Growth is nice, but there's value to products that face limited threats and even some small content gain opportunities. Seating comes to mind here. While often panned as a "commodity" product—which it is—automotive seats won't go away in any plausible Car of the Future scenario. In fact, the autonomous car may result in seating becoming more featured with new form factors and features like heating/cooled and other comfort functions. Other categories in this field include Climate systems to some extent (Visteon, Delphi) and tires.

Figure 57. Penetration outlook of major preventive safety applications

	2009	2010	2011	2012	2013E	2014E	2015E	2016E	2017E	2018E	2019E	2020E
Shipment units ('000 units)												
Stereocamera	5	28	42	102	211	308	468	711	1,016	1,280	1,545	1,806
AEB+FCW	0	9	65	720	2,580	5,842	8,368	11,124	12,995	14,509	15,974	17,301
PD+ACC	70	85	115	155	285	539	1,391	3,238	6,038	8,120	10,150	11,314
LDW/ AHB/ TSR	1,105	1,842	2,766	3,944	6,993	9,824	13,745	17,407	20,509	22,815	25,532	27,302
Traffic Jam Assistance	0	0	0	0	0	67	158	220	501	1,027	2,825	3,953
NVS/NSS/ADS	91	103	148	188	268	362	401	782	2,147	4,454	6,655	8,602
Parking Assist	10,590	14,091	15,914	18,537	20,053	22,588	25,010	27,266	28,845	30,466	32,201	34,046
Parking Assist (1-5m)	10,555	13,816	15,212	17,119	17,785	18,441	19,838	21,120	22,039	23,014	24,013	25,043
Semi-Autonomous Parking Assist	35	275	702	1,418	2,268	3,780	4,292	4,958	5,237	5,520	5,938	6,348
Autonomous Parking	0	0	0	0	0	367	880	1,188	1,569	1,932	2,250	2,655
Others	1,525	2,729	4,256	7,647	8,690	10,372	13,698	15,262	17,041	19,828	21,432	23,153
Total	**23,976**	**18,887**	**23,306**	**31,293**	**39,079**	**49,900**	**63,239**	**76,011**	**89,092**	**102,498**	**116,314**	**127,477**
Adoption rate (%)												
Stereocamera	0.0%	0.0%	0.1%	0.1%	0.3%	0.4%	0.5%	0.7%	1.0%	1.2%	1.4%	1.6%
AEB+FCW	0.0%	0.0%	0.1%	0.9%	3.1%	6.8%	9.2%	11.6%	13.1%	14.1%	14.9%	15.5%
PD+ACC	0.1%	0.1%	0.2%	0.2%	0.3%	0.6%	1.5%	3.4%	6.1%	7.9%	9.5%	10.2%
LDW/ AHB/ TSR	1.7%	2.5%	3.6%	4.9%	8.4%	11.5%	15.1%	18.1%	20.6%	22.1%	23.8%	24.5%
Traffic Jam Assistance	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.2%	0.5%	1.0%	2.6%	3.6%
NVS/NSS/ADS	0.1%	0.1%	0.2%	0.2%	0.3%	0.4%	0.4%	0.8%	2.2%	4.3%	6.2%	7.7%
Parking Assist	16.6%	19.2%	20.8%	22.9%	24.0%	26.5%	27.5%	28.4%	29.0%	29.5%	30.0%	30.6%
Parking Assist (1-5m)	16.5%	18.8%	19.8%	21.1%	21.3%	21.6%	21.8%	22.0%	22.2%	22.3%	22.4%	22.5%
Semi-Autonomous Parking Assist	0.1%	0.4%	0.9%	1.7%	2.7%	4.4%	4.7%	5.2%	5.3%	5.3%	5.5%	5.7%
Autonomous Parking	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	1.0%	1.2%	1.6%	1.9%	2.1%	2.4%
Others	2.4%	3.7%	5.6%	9.4%	10.4%	12.1%	15.1%	15.9%	17.1%	19.2%	20.0%	20.8%
Total	**37.5%**	**25.7%**	**30.4%**	**38.6%**	**46.8%**	**58.4%**	**69.5%**	**79.2%**	**89.5%**	**99.3%**	**108.5%**	**114.5%**

Source: company data, TSR, Citi Research

Connecting the Car of the Future

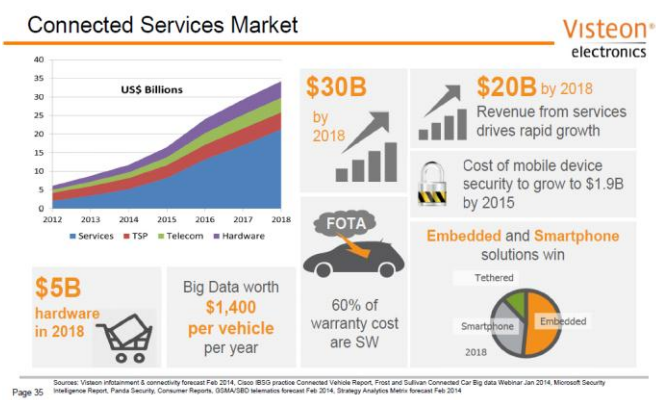
Figure 58. Investment Framework

	Embedded Infotainment	Clusters Displays	Embedded Telematics
Is There a Specific Regulatory Driver?			
Consumer Value (Perform, Safe, Connect)?			
Do OEMs Use This As a Selling Point?			
Is It Reasonably Affordable to Consumers?			
Is it Globally Scalable?			
How is the Competitive Landscape?			
Can It Be Funded By Content Reductions?			
Applicable to OEM Investing?	Yes	No	Yes

Source: Citi Research

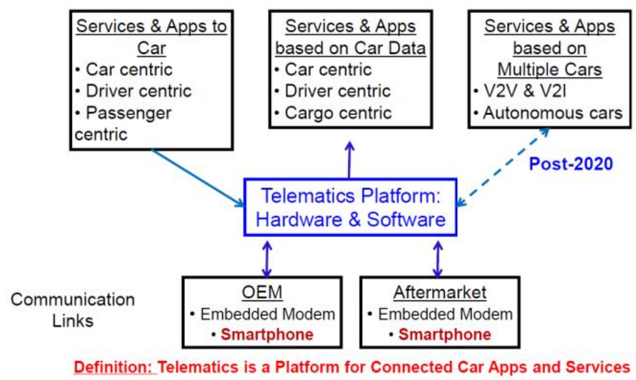
From a technological standpoint, the "Car of Today" is already outdated. We rely on mirrors to look behind us, contend with blind spots and generally don't have a great sense for assessing and anticipating our surroundings. As we first noted last year in our Rise of the Connected Car reports and December 2013 Connected Car Symposium, the convergence of active safety (covered in prior section) and embedded connectivity will change mobility as we know it—not only with a richer and safer driving experience, but also with new business models in the fields of telematics, big data and insurance. Rapid technological advancements and consumer demand will likely push the connected services market by end of decade towards $30bn from $10bn. Cockpit electronics will gain even more importance for differentiation and safety purposes, driving growth in areas like heads-up displays and personalized interfaces. A few suppliers involved in this trend include Continental, Delphi, Denso, Harman, Panasonic, Visteon and many more. Yet, this is also a trend that could differentiate and benefit certain OEMs—with GM's OnStar division a clear candidate.

Figure 59. Connectivity Basics



Source: Visteon

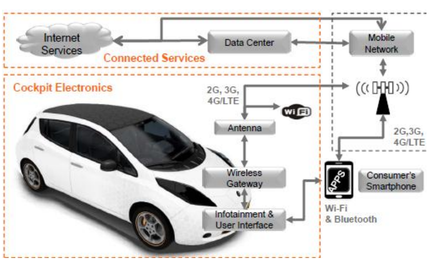
Figure 60. Connectivity Basics



Source: IHS

Ways to Connect, Lots of Players

Figure 61. Connected Car Architecture



Source: Visteon from Citi Connected Car Symposium

There are essentially two ways to "connect" a car — embedded and brought-in. The embedded approach means that the car is the all-capable connected device from a hardware and software standpoint. GM's OnStar is a good example of this. Brought-in uses a driver's smartphone as the connectivity gateway to utilize software/applications that are either already built-in to the car (Ford Sync system) or already on the phone. There's a healthy debate towards who will "win", but more than likely both will simply co-exist with mix varying by price-points and regions. If we had to choose a winner, we'd choose embedded. While more expensive, embedded allows for more advanced applications of the Connected Car (safety, FOTA, big data, car sharing, etc.) will likely require added reliability.

One of the complicating factors for assessing this theme is that, unlike more traditional automotive applications, the supply chain for connectivity appears more complex on the surface with players ranging from OS vendors to HMI providers. This is further complicated by regional and customer exposure considerations.

The following two charts provide a matrix for automakers and key suppliers to help investors better understand the supply chain dynamics for a Connected Car.

Figure 62. NA Supplier/OE Matrix

	Audi / Connect MMI	BMW / ConnectedDrive	Mini / Mini Connected	General Motors / OnStar	Nissan / CarWings	Ford / Sync & MyFord Touch	Toyota / Entune	Toyota / Safety Connect	Hyundai / BlueLink
Aeris (Sprint)									Cellular Provider
Agero								TSP	TSP
Airbiquity					TSP	Data over Voice Modem			
Alpine	Display (A8)	Display							
AT&T		Cellular Provider		4G LTE Provider	Cellular Provider				
Bosch				Navigation Component					
bSquare						Software & Hardware Proj. Integrator			
Chimei Innolux (CMI)				8" Capacitive Touch Display (Cadillac)					
Continental									TCU (U.S. Vehicles)
deCarta						Off-Board Routing			
Delphi				MyLink Head Unit** / 12.3" Disp Cluster			Head Unit (mid range)	TCU	
Denso							Head Unit (mid range)	TCU	
Flextronics						Hardware Mfg			
Ford						Hardware Design			
Freescale				Microprocessor					
Gentex									Mirror
Gracenote						On-Board Music Information			
Harman	Adv. Nav Head Unit / TCU	Head Unit / TCU	Head Unit				Head Unit (high end)		
Hitachi / Clarion					Head Unit				
Hyundai Mobis									Head Unit
IBM				Off-Board Voice Recognition					
Inrix						Live Traffic	Live Traffic		
LG				TCU / MyLink Head Unit*					TCU (Korea Vehicles)
Marvell	WiFi Chipset								
Microsoft						OS			
Microsoft Bing							Off-Board Local Search		
Microsoft TellMe						Off-Board Voice Recognition			
Nissan					CarWings Call Center				
Nuance		Voice Recognition	Voice Recognition			On-Board Voice Recognition	On-Board Voice Recognition		
nVidia	Processor								
NXP				Transceiver					
OnStar				Call Center					
Panasonic				MyLink Head Unit***					
Preh	MMI Controller / UI Interface	iDrive Controller							
QNX	OS	OS	OS				OS		
Qualcomm	Phone Module			CDMA Wireless Chipset					CDMA Wireless Chipset
Sharp						Center Stack Display			
TCS									Live Traffic
Telenav						Mapping Accumulator			
T-Mobile	Cellular Provider								
Tweedle Group							Online Portal		
Verizon				Cellular Provider				Cellular Provider	
Visteon						Radio Module			
Vlingo									Off-Board Voice Recognition
Voicebox							Voice Recognition		
Wavecom								Phone Module	
Wireless Car		TSP w/ ATX Call Center							

Source: IHS, Citi Research

Figure 63. EU Supplier/OE Matrix

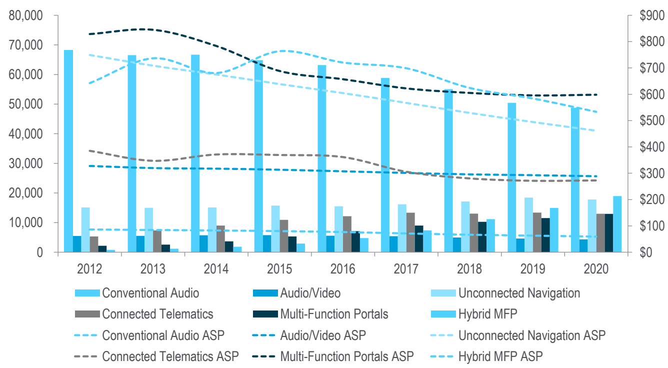
	Audi / Connect MMI	BMW / ConnectedDrive	Mini / Mini Connected	Mercedes / COMAND Online	Nissan / CarWings	Toyota / Touch Series	Renault / Carminat TomTom	Renault / R-Link	Volvo / OnCall	PSA / ATB box	PSA / Connected Apps
Actia									TCU		
Airbiquity					TSP						
Alpine	Display (A8) / Touchpad (A8)	Display									
Android								OS			
Bosch / Continental							Radio Head Units				
Boygues Telecom											Cellular Provder / USB Dongle
Ficosa								TCU			
Fujitsu-Ten						Display					
Harman	Adv. Nav Head Unit	Head Unit / TCU	Head Unit			Navigation & Connectivity Box / App Delivery					
Hitachi / Clarion					Head Unit						
Inter Mutuelles Assistance (IM										Call Center	
Magneti Marelli										TCU	Head Unit
Microsoft				OS							
Mitsubishi				Head Unit							
Nissan					CarWings Call Center						
NNG						Navigation Software					
Nuance		Voice Recognition						Voice Recognition			
nVidia	Processor										
O2 / Vodaphone		Cellular Provider									
Orange								Off-Board Voice Recognition			
P&T Luxembourg										Cellular Provider	
Panasonic						Head Unit for Touch Life / Display & Audio Head Unit					
Preh	MMI Controller / UI Interface			COMMAND Controller							
Preh		iDrive Controller									
PSA / Netsize										Servers	
QNX	OS	OS									
Qualcomm	Cellular Interface Module										
S1nn				iPhone Drive Kit							
Sierra Wireless							TCU			Cellular Module	
Telenor Connexion					Cellular Provider				Cellular Provider		
TomTom							Navigation Unit	Head Unit			
Vodaphone							Cellular Provider	Cellular Provider			
Voicebox								Voice Recognition			
Wavecom									Cellular Module		
Wireless Car		TSP w/ ATX Call Center							TSP		

Source: IHS, Citi Research

The Infotainment Environment and TAM

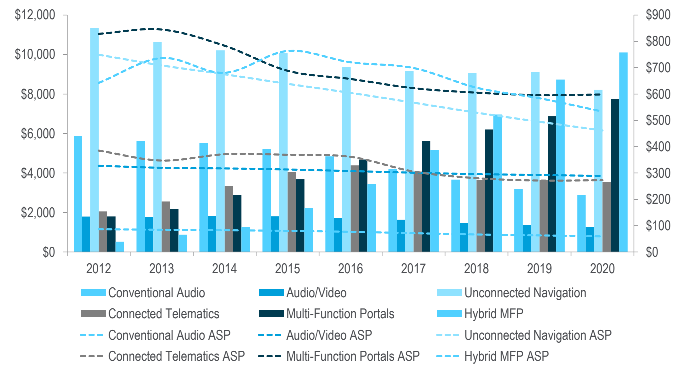
Infotainment sales are classified in two buckets: 1) OEM sales; 2) aftermarket sales. While some suppliers may choose to focus on one of the two, or both, we wanted to take the time to define the global market (OE and Aftermarket) in terms of units, revenue, and ASP potential. By 2020 the combined OE & Aftermarket total available market (TAM) is expected to be a $34bn revenue opportunity with an average ASP of $291; this compares to the 2012 TAM of $23bn and average ASP of $241.

Figure 64. Units (thousands) & ASP by Tech



Source: IHS, Citi Research

Figure 65. Revenue ($) & ASP by Tech



Source: IHS, Citi Research

In the Figure to the right, notice how Connected Telematics (tethering of smartphone) starts to teeter by 2020 while MFP (embedded TCU) and H-MFP (tethering and embedded TCU functionality) continue to grow at a 28% and 47% CAGR, respectively. Additionally, we highlight the increasing take rates of MFP and HMFP.

Figure 66. Global OE Front Unit Infotainment System Summary

(thousands)	2012	2013	2014	2015	2016	2017	2018	2019	2020
No Head Unit	8,139.9	8,357.2	8,690.7	8,998.0	9,191.6	9,229.4	9,149.2	9,080.4	8,126.1
Take Rate	10%	10%	10%	10%	10%	9%	9%	9%	8%
Conventional Audio	53,597.5	52,622.2	53,560.5	53,167.1	52,863.6	50,449.3	48,193.9	44,575.4	43,964.6
Take Rate	67%	64%	62%	58%	55%	51%	47%	42%	41%
Audio/Video	723.4	626.8	664.6	689.5	711.7	785.8	786.3	792.0	791.1
Take Rate	1%	1%	1%	1%	1%	1%	1%	1%	1%
Unconnected Navigation	9,450.0	9,842.3	10,565.6	11,763.8	12,128.1	13,300.9	14,646.9	16,077.7	15,576.4
Take Rate	12%	12%	12%	13%	13%	13%	14%	15%	14%
Connected Telematics	5,044.5	6,824.4	8,128.6	9,617.5	10,132.3	10,544.0	9,539.9	9,358.8	8,510.1
Take Rate	6%	8%	9%	10%	11%	11%	9%	9%	8%
Multi-Funcion Portals	1,893.0	2,224.2	3,204.2	4,618.1	6,355.4	8,305.6	9,622.8	11,007.4	12,526.0
Take Rate	2%	3%	4%	5%	7%	8%	9%	10%	12%
Hybrid MFP	807.8	1,191.9	1,827.2	2,836.6	4,622.5	7,102.7	10,672.8	14,202.0	17,964.4
Take Rate	1%	1%	2%	3%	5%	7%	10%	14%	17%
Total	**79,656.1**	**81,689.0**	**86,641.4**	**91,690.6**	**96,005.2**	**99,717.7**	**102,611.8**	**105,093.7**	**107,458.7**

Source: IHS, Citi Research Note: 2013-2020 are estimates.

Figure 67. Global Aftermarket Front Unit Infotainment System Summary

(thousands)	2012	2013	2014	2015	2016	2017	2018	2019	2020
Conventional Audio	14,649.5	13,910.1	13,116.6	11,668.6	10,297.7	8,387.8	6,874.9	5,848.5	4,825.6
Audio/Video	2,406.4	2,412.1	2,399.7	2,344.3	2,114.0	1,854.6	1,513.7	1,271.2	1,171.5
Unconnected Navigation	5,674.9	5,163.1	4,567.5	3,997.3	3,382.9	2,871.0	2,496.5	2,355.2	2,228.8
Connected Telematics	286.8	533.3	878.2	1,333.8	2,009.7	2,792.9	3,480.0	4,040.9	4,462.1
Multi-Funcion Portals	277.2	340.3	477.0	734.9	773.4	717.1	632.6	526.0	427.6
Hybrid MFP	0.0	0.0	25.0	76.5	163.8	291.4	483.0	751.2	978.4
Total	**23,294.8**	**22,358.9**	**21,464.0**	**20,155.4**	**18,741.5**	**16,914.8**	**15,480.7**	**14,793.0**	**14,094.0**

Source: IHS, Citi Research Note: 2013-2020 are estimates

Conventional Audio

Conventional audio is defined as a head unit that produces audio, but cannot process video or provide navigation. Your standard AM/FM tuner, cassette player, CD player, Mini Disc, flash memory storage, HDD, or aux port technology are included in this segment.

As of 2013, roughly 68% of total front infotainment units sold (OE and aftermarket) were conventional audio; by 2020 it is forecast to be 42%. Conventional audio also carries the lowest ASP of all technology, thus as volume declines outsized profit potential for this segment faces headwinds.

Figure 68. Conventional Audio Head Units (OE Front)

	2012	2013	2014	2015	2016	2017	2018	2019	2020
North America									
Vehicle Sales (K)	17,170.2	17,791.5	18,514.6	19,136.8	19,538.8	19,664.3	19,489.4	19,652.4	19,847.7
x Take Rate	64.9%	59.7%	54.7%	49.6%	47.9%	43.0%	37.5%	31.4%	24.9%
= Units Sold	11,149.5	10,620.7	10,122.7	9,495.7	9,358.2	8,450.3	7,307.0	6,167.7	4,947.5
x ASP ($)	90.0	88.2	85.6	83.0	80.5	78.1	75.7	72.0	68.4
= Revenue ($, mlns)	1,003.5	936.7	866.0	788.0	753.3	659.8	553.4	443.8	338.2
South America									
Vehicle Sales (K)	5,843.0	5,849.5	6,212.6	6,612.7	6,990.0	7,372.2	7,752.5	8,128.0	8,467.0
x Take Rate	75.0%	73.7%	73.1%	68.0%	64.8%	61.6%	56.6%	49.8%	47.3%
= Units Sold	4,384.8	4,309.2	4,541.1	4,495.7	4,529.0	4,541.4	4,387.1	4,048.4	4,009.0
x ASP ($)	60.0	63.0	69.3	76.2	76.2	72.4	68.8	65.4	62.1
= Revenue ($, mlns)	263.1	271.5	314.7	342.7	345.2	328.9	301.8	264.6	248.9
W. Europe									
Vehicle Sales (K)	13,153.0	12,820.4	13,301.3	14,052.1	14,484.0	14,958.2	15,335.4	15,579.7	15,614.9
x Take Rate	68.8%	63.4%	58.3%	51.0%	44.4%	35.0%	27.7%	23.2%	23.4%
= Units Sold	9,047.9	8,128.1	7,753.7	7,172.4	6,427.9	5,239.5	4,253.1	3,610.5	3,652.1
x ASP ($)	88.0	86.2	84.5	82.0	77.9	74.0	70.3	66.8	63.4
= Revenue ($, mlns)	796.2	701.0	655.3	588.0	500.6	387.7	298.9	241.1	231.7
Central Europe									
Vehicle Sales (K)	928.2	931.2	979.7	1,093.1	1,229.7	1,338.1	1,426.2	1,477.1	1,605.4
x Take Rate	73.3%	71.4%	69.9%	65.4%	61.9%	51.0%	45.9%	42.2%	41.1%
= Units Sold	680.7	665.0	684.6	715.2	760.7	682.5	654.2	623.8	660.1
x ASP ($)	75.0	78.8	79.5	78.7	77.2	73.3	69.6	66.2	62.9
= Revenue ($, mlns)	51.1	52.4	54.5	56.3	58.7	50.0	45.6	41.3	41.5
China									
Vehicle Sales (K)	19,193.3	20,872.6	23,112.0	25,171.1	26,943.4	28,457.6	29,541.3	30,284.1	31,007.0
x Take Rate	73.2%	72.5%	70.8%	68.3%	65.4%	60.9%	56.8%	52.0%	48.2%
= Units Sold	14,057.3	15,136.8	16,354.1	17,195.0	17,630.1	17,317.8	16,769.1	15,754.5	14,958.6
x ASP ($)	62.0	65.1	66.4	65.7	63.8	57.4	51.7	49.1	46.6
= Revenue ($, mlns)	871.6	985.4	1,085.9	1,130.4	1,124.2	993.9	866.1	773.0	697.3
Japan									
Vehicle Sales (K)	5,217.1	4,597.9	4,666.8	4,664.5	4,550.0	4,542.8	4,494.2	4,472.4	4,407.1
x Take Rate	38.7%	33.5%	33.6%	30.2%	24.8%	22.4%	20.3%	19.3%	16.5%
= Units Sold	2,018.1	1,542.0	1,567.1	1,410.2	1,126.6	1,016.3	913.3	861.6	725.6
x ASP ($)	92.0	90.2	88.4	86.6	82.3	78.1	74.2	70.5	67.0
= Revenue ($, mlns)	185.7	139.0	138.5	122.1	92.7	79.4	67.8	60.8	48.6
South Korea									
Vehicle Sales (K)	1,501.3	1,517.8	1,554.2	1,577.5	1,598.0	1,616.4	1,631.7	1,640.7	1,640.0
x Take Rate	69.2%	68.5%	64.0%	58.2%	52.4%	46.5%	42.4%	38.0%	37.6%
= Units Sold	1,038.9	1,039.4	994.8	917.6	836.8	751.8	692.3	624.2	617.4
x ASP ($)	89.0	87.2	85.5	83.8	81.3	77.2	73.3	69.7	66.2
= Revenue ($, mlns)	92.5	90.7	85.0	76.9	68.0	58.0	50.8	43.5	40.9
Rest of World									
Vehicle Sales (K)	16,649.6	17,308.1	18,300.7	19,382.6	20,671.4	21,768.4	22,941.1	23,859.3	24,869.8
x Take Rate	67.4%	64.6%	63.0%	60.7%	59.0%	57.1%	57.6%	54.0%	53.9%
= Units Sold	11,218.1	11,180.8	11,538.3	11,758.2	12,188.8	12,437.0	13,210.2	12,886.3	13,412.1
x ASP ($)	71.0	70.3	69.6	68.2	66.8	65.5	63.5	61.6	58.5
= Revenue ($, mlns)	796.5	785.9	802.9	801.9	814.6	814.6	839.2	794.1	785.2

Source: IHS, Citi Research Note: 2013-2020 are estimates

Audio/Video

Audio/Video is defined as a head unit that produces audio and video signals, but is not a navigation system or multi-function portal. These systems may serve as a vehicles sound system, but they are not included (double counted) in conventional audio. Looking at the growth and opportunity for this segment (OE & Aftermarket), this product has the lowest 2020 units and revenue opportunity.

The take rates of this technology by region and highlight the limited adoption, which makes sense if you consider the alternatives of MFP and HMFP.

As of 2013 roughly 6% of total front infotainment units sold (OE and aftermarket) were Audio/Video; by 2020 it is forecast to be 4%. ASPs for Audio/Video are significantly better than conventional audio, but are still on the lower end of the infotainment system scale.

Figure 69. Audio/Video Head Units (OE)

	2012	2013	2014	2015	2016	2017	2018	2019	2020
North America									
Front Seat Units Sold	37.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rear Seat Units Sold	1,028.0	1,002.3	933.7	850.6	766.6	702.6	633.5	571.5	514.3
x ASP ($)	410.0	405.9	401.8	397.8	393.8	386.0	378.2	370.7	363.3
= Revenue ($, mlns)	437.0	406.8	375.2	338.4	301.9	271.2	239.6	211.8	186.8
South America									
Front Seat Units Sold	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rear Seat Units Sold	60.6	61.9	60.6	57.6	54.7	50.3	46.3	44.0	43.5
x ASP ($)	445.0	440.6	436.1	431.8	427.5	418.9	410.5	402.3	394.3
= Revenue ($, mlns)	27.0	27.2	26.4	24.9	23.4	21.1	19.0	17.7	17.2
W. Europe									
Front Seat Units Sold	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rear Seat Units Sold	272.9	266.6	269.4	275.1	265.1	258.5	249.8	235.4	221.3
x ASP ($)	415.0	410.9	406.7	398.6	394.6	386.7	375.1	367.6	363.9
= Revenue ($, mlns)	113.3	109.5	109.6	109.7	104.6	100.0	93.7	86.5	80.5
Central Europe									
Front Seat Units Sold	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rear Seat Units Sold	14.3	15.0	15.1	14.8	14.1	13.2	12.4	11.4	10.4
x ASP ($)	450.0	445.5	441.0	432.2	427.9	419.3	406.8	398.6	394.6
= Revenue ($, mlns)	6.4	6.7	6.7	6.4	6.0	5.5	5.1	4.6	4.1
China									
Front Seat Units Sold	253.3	243.2	296.4	354.4	418.4	485.8	487.4	484.5	480.6
Rear Seat Units Sold	196.3	238.1	292.1	346.8	382.5	418.7	443.2	450.5	441.5
x ASP ($)	390.0	386.1	382.2	374.6	370.8	363.4	352.5	345.5	342.0
= Revenue ($, mlns)	175.3	185.8	225.0	262.6	297.0	328.7	328.1	323.0	315.4
Japan									
Front Seat Units Sold	104.3	92.0	65.3	56.0	54.6	50.0	44.9	44.3	43.2
Rear Seat Units Sold	54.5	49.5	49.4	48.6	45.6	45.1	45.2	44.4	43.0
x ASP ($)	484.0	474.3	469.6	467.2	462.6	448.7	430.7	417.8	409.5
= Revenue ($, mlns)	76.9	67.1	53.9	48.9	46.4	42.7	38.8	37.0	35.3
South Korea									
Front Seat Units Sold	61.6	49.3	46.6	46.5	32.0	32.3	24.5	24.6	23.8
Rear Seat Units Sold	29.7	29.1	28.5	27.9	27.4	26.8	26.3	25.8	25.3
x ASP ($)	465.0	460.4	455.7	451.2	446.7	442.2	428.9	424.7	416.2
= Revenue ($, mlns)	42.4	36.1	34.2	33.6	26.5	26.2	21.8	21.4	20.4
Rest of World									
Front Seat Units Sold	266.4	242.3	256.2	232.6	206.7	217.7	229.4	238.6	243.7
Rear Seat Units Sold	161.2	290.2	464.4	557.3	613.0	643.6	630.8	599.2	539.3
x ASP ($)	415.0	410.9	415.0	410.8	406.7	394.5	378.7	367.4	360.0
= Revenue ($, mlns)	177.5	218.8	299.0	324.5	333.4	339.8	325.8	307.8	281.9

Unconnected Navigation

Unconnected Navigation is defined as a head unit that utilizes GPS to provide route information and points of interest. Only systems with onboard maps are included here, meaning that there is no off-board data connection required; connected navigation head units are split across connected telematics, hybrid multi-function portals and multi-function portals, as these all require an off-board data connection.

Figure 70. Unconnected Navigation OE Head Units Take Rates by Region

Unconnected Navigation Take Rate (%)	2012	2013	2014	2015	2016	2017	2018	2019	2020
N. America	14.4%	15.4%	15.2%	16.8%	16.2%	19.4%	23.6%	29.1%	29.6%
S. America	1.4%	1.9%	2.2%	1.9%	2.2%	3.4%	5.4%	8.7%	9.8%
W. Europe	17.3%	17.5%	19.2%	20.0%	21.3%	25.9%	27.5%	26.7%	24.9%
C. Europe	6.5%	8.2%	8.7%	8.3%	9.6%	9.6%	10.4%	10.9%	10.4%
China	5.2%	4.8%	4.4%	4.0%	3.7%	3.5%	3.4%	3.3%	3.3%
Japan	14.3%	11.3%	9.3%	9.4%	10.4%	10.6%	9.3%	7.1%	5.5%
S. Korea	15.6%	13.9%	14.8%	16.3%	17.6%	17.8%	18.6%	19.1%	14.9%
RoW	15.4%	17.0%	18.1%	19.7%	18.6%	15.9%	15.4%	15.4%	13.4%

Source: IHS, Citi Research Note: 2013-2020 are estimates

As of 2013, roughly 15% of total front infotainment units sold (OE and aftermarket) were unconnected navigation; by 2020 it is forecast to also be 15%. ASPs for unconnected navigation are in the upper echelon of all infotainment systems.

Figure 71. Unconnected Navigation Head Units (OE)

	2012	2013	2014	2015	2016	2017	2018	2019	2020
North America									
Units Sold	2,472.1	2,735.3	2,808.3	3,207.5	3,159.8	3,820.6	4,606.5	5,718.9	5,869.3
x ASP ($)	780.0	702.0	631.8	600.2	558.2	519.1	482.8	458.6	435.7
= Revenue ($, mlns)	1,928.2	1,920.2	1,774.3	1,925.2	1,763.8	1,983.3	2,223.9	2,623.0	2,557.3
South America									
Units Sold	82.9	113.2	139.1	128.5	155.9	247.2	415.6	709.7	825.6
x ASP ($)	850.0	765.0	711.5	640.3	589.1	542.0	498.6	458.7	422.0
= Revenue ($, mlns)	70.5	86.6	99.0	82.3	91.9	134.0	207.2	325.5	348.4
W. Europe									
Units Sold	2,279.5	2,238.6	2,554.2	2,807.8	3,088.8	3,871.0	4,219.6	4,166.0	3,881.0
x ASP ($)	680.0	714.0	678.3	644.4	612.2	581.6	535.0	492.2	452.9
= Revenue ($, mlns)	1,550.1	1,598.4	1,732.5	1,809.3	1,890.9	2,251.2	2,257.6	2,050.6	1,757.5
Central Europe									
Units Sold	60.7	76.7	85.6	91.0	117.6	128.6	148.8	160.3	166.7
x ASP ($)	794.6	754.8	717.1	681.2	647.2	595.4	547.8	503.9	478.8
= Revenue ($, mlns)	48.2	57.9	61.4	62.0	76.1	76.6	81.5	80.8	79.8
China									
Units Sold	1,004.5	1,005.5	1,006.5	1,007.5	1,008.5	1,009.5	1,010.5	1,011.5	1,012.5
x ASP ($)	660.0	627.0	595.7	536.1	493.2	453.7	431.1	409.5	389.0
= Revenue ($, mlns)	663.0	630.4	599.5	540.1	497.4	458.1	435.6	414.2	393.9
Japan									
Units Sold	745.4	518.3	432.1	438.2	475.0	480.6	416.3	316.3	242.6
x ASP ($)	870.0	852.6	835.5	793.8	754.1	716.4	680.6	646.5	614.2
= Revenue ($, mlns)	648.5	441.9	361.0	347.9	358.2	344.3	283.3	204.5	149.0
South Korea									
Units Sold	233.7	210.8	230.4	256.6	281.8	287.2	302.9	314.1	245.1
x ASP ($)	891.0	846.5	804.1	763.9	725.7	689.4	655.0	622.2	591.1
= Revenue ($, mlns)	208.2	178.4	185.3	196.0	204.5	198.0	198.4	195.5	144.9
Rest of World									
Units Sold	2,571.1	2,943.9	3,309.3	3,826.6	3,840.7	3,456.1	3,526.7	3,680.8	3,333.7
x ASP ($)	875.0	787.5	779.6	740.6	703.6	668.4	635.0	603.3	573.1
= Revenue ($, mlns)	2,249.7	2,318.3	2,580.1	2,834.2	2,702.4	2,310.2	2,239.5	2,220.5	1,910.5

Source: IHS, Citi Research Note: 2013-2020 are estimates

Connected Telematics

Connected Telematics is defined as a head unit that has a positioning module embedded within but does not feature a wireless communication module; rather, this head unit makes use of a driver's cellular device to establish wireless communication (Ford Sync).

Figure 72. Connected Telematics OE Head Units Take Rates by Region

Connected Telematics Take Rate (%)	2012	2013	2014	2015	2016	2017	2018	2019	2020
N. America	13.8%	17.0%	18.9%	17.0%	14.2%	9.9%	9.8%	9.2%	9.2%
S. America	2.5%	3.1%	4.6%	9.2%	9.2%	9.3%	9.3%	8.2%	7.5%
W. Europe	2.1%	6.8%	9.7%	10.2%	6.1%	3.0%	2.5%	1.5%	0.0%
C. Europe	2.0%	2.6%	4.2%	8.8%	6.3%	4.2%	3.2%	2.5%	1.5%
China	0.1%	0.1%	0.3%	0.9%	1.3%	2.3%	2.0%	1.6%	1.3%
Japan	40.7%	47.8%	49.1%	50.8%	53.3%	53.3%	53.7%	53.6%	53.5%
S. Korea	6.8%	9.4%	12.3%	15.3%	18.2%	20.0%	20.7%	21.4%	23.0%
RoW	2.0%	3.8%	4.7%	5.6%	7.5%	8.7%	4.2%	4.3%	2.7%

Source: IHS, Citi Research Note: 2013-2020 are estimates

As of 2013 roughly 7% of total front infotainment units sold (OE and aftermarket) were connected telematics; by 2020 it is forecast to be 11%. ASPs for connected telematics are currently at a modest premium to that of Audio/ Video, this premium is forecast to abate over time, reaching parity around 2017 at which the ASP will then be at a modest discount to Audio/Video.

Additionally, the % of connected telematics head units with navigation are increasing healthily for all regions; this just further reinforces the point made in the unconnected navigation section that connected navigation growth is growing at a faster clip than it's unconnected counterpart. Globally connected navigation unit growth is 23.6% CAGR ('12-'20) vs. unconnected at a 6.4% CAGR ('12-'20)

Figure 73. Connected Telematics Head Units (OE)

	2012	2013	2014	2015	2016	2017	2018	2019	2020
North America									
Units Sold	2,369.0	3,024.8	3,493.1	3,253.5	2,765.4	1,947.9	1,912.8	1,817.7	1,821.5
% w/ navigation	15.0%	16.0%	20.0%	20.0%	30.0%	35.0%	40.0%	35.0%	35.0%
x ASP ($)	118.0	153.4	207.1	289.9	347.9	278.3	194.8	192.9	187.1
= Revenue ($, mlns)	279.5	464.0	723.4	943.3	962.1	542.2	372.7	350.6	340.8
South America									
Units Sold	145.5	182.2	284.2	605.6	646.2	684.1	724.4	669.1	636.5
% w/ navigation	5.0%	8.0%	15.0%	20.0%	25.0%	30.0%	35.0%	35.0%	30.0%
x ASP ($)	118.0	160.0	216.0	302.4	362.9	290.3	203.2	201.2	195.1
= Revenue ($, mlns)	17.2	29.1	61.4	183.1	234.5	198.6	147.2	134.6	124.2
W. Europe									
Units Sold	274.9	867.5	1,288.2	1,432.0	886.4	454.0	381.0	235.2	0.0
% w/ navigation	60.0%	35.0%	40.0%	45.0%	50.0%	52.0%	52.0%	48.0%	0.0%
x ASP ($)	320.0	230.0	225.4	220.9	216.5	212.1	207.9	166.3	0.0
= Revenue ($, mlns)	88.0	199.5	290.4	316.3	191.9	96.3	79.2	39.1	0.0
Central Europe									
Units Sold	18.7	23.8	41.2	96.1	77.7	55.9	46.2	37.2	23.8
% w/ navigation	60.0%	35.0%	40.0%	45.0%	50.0%	55.0%	60.0%	60.0%	65.0%
x ASP ($)	320.0	240.0	235.2	230.5	225.9	221.4	216.9	212.6	208.4
= Revenue ($, mlns)	6.0	5.7	9.7	22.2	17.6	12.4	10.0	7.9	5.0
China									
Units Sold	13.0	22.9	80.7	233.2	344.2	644.4	599.2	489.7	393.8
% w/ navigation	100.0%	80.0%	60.0%	60.0%	40.0%	35.0%	35.0%	40.0%	40.0%
x ASP ($)	195.0	214.5	225.2	214.0	203.3	193.1	183.4	174.3	165.6
= Revenue ($, mlns)	2.5	4.9	18.2	49.9	70.0	124.4	109.9	85.3	65.2
Japan									
Units Sold	2,125.0	2,198.4	2,291.5	2,367.7	2,426.1	2,421.6	2,413.2	2,396.4	2,358.9
% w/ navigation	35.0%	38.5%	42.4%	44.5%	46.7%	49.0%	51.5%	54.1%	56.8%
x ASP ($)	600.0	540.0	550.8	539.8	523.6	507.9	487.6	463.2	440.0
= Revenue ($, mlns)	1,275.0	1,187.1	1,262.2	1,278.1	1,270.3	1,229.9	1,176.6	1,110.0	1,038.0
South Korea									
Units Sold	102.3	142.7	190.7	241.1	290.4	322.8	337.4	350.8	376.5
% w/ navigation	100.0%	95.0%	85.0%	80.0%	80.0%	85.0%	85.0%	85.0%	85.0%
x ASP ($)	380.0	361.0	343.0	325.8	309.5	294.0	279.3	265.4	252.1
= Revenue ($, mlns)	38.9	51.5	65.4	78.5	89.9	94.9	94.3	93.1	94.9
Rest of World									
Units Sold	327.4	663.3	862.6	1,083.4	1,553.8	1,892.6	963.4	1,026.0	665.7
% w/ navigation	15.0%	15.0%	18.0%	25.0%	40.0%	50.0%	55.0%	40.0%	45.0%
x ASP ($)	220.0	210.0	203.7	197.6	191.7	184.0	180.3	162.3	160.7
= Revenue ($, mlns)	72.0	139.3	175.7	214.1	297.8	348.2	173.7	166.5	107.0

Source: IHS, Citi Research Note: 2013-2020 are estimates

Multi-Function Portals

Multi-Function Portals are defined as head units that have an embedded telematics control unit with advanced connective features such as email, weather and live POI search. This head unit does not have to include navigation. The embedded transmission control unit (TCU) allows for data connectivity with the primary difference between the MFP and the hybrid MFP being that the HMFP can also be tethered or make use of your cellular phones connection.

Figure 74. MFP OE Head Units Take Rates by Region

MFP Take Rate (%)	2012	2013	2014	2015	2016	2017	2018	2019	2020
N. America	2.9%	3.5%	5.4%	6.2%	7.0%	7.7%	8.4%	8.7%	12.2%
S. America	0.1%	0.3%	1.0%	2.4%	5.0%	6.7%	7.9%	9.0%	9.1%
W. Europe	5.1%	5.3%	5.2%	8.2%	11.1%	14.2%	16.4%	19.0%	20.4%
C. Europe	1.3%	1.4%	1.7%	2.6%	5.5%	11.5%	13.9%	16.3%	18.0%
China	2.4%	3.1%	4.8%	6.6%	8.7%	10.8%	11.5%	12.6%	13.3%
Japan	3.5%	3.9%	4.8%	5.6%	6.0%	5.4%	5.3%	5.0%	5.0%
S. Korea	3.2%	3.7%	4.3%	5.3%	6.7%	8.2%	7.3%	6.1%	5.6%
RoW	0.1%	0.1%	0.2%	0.5%	1.1%	2.6%	4.0%	5.1%	5.7%

Source: IHS, Citi Research Note: 2013-2020 are estimates

As of 2013 roughly 3% of total front infotainment units sold (OE and aftermarket) were MFPs; by 2020 it is forecast to be 11%. ASPs for MFPs are currently at the peak of all infotainment systems; this coveted top ASP spot is forecast to swap throughout 2020 with similar technology, HMFPs.

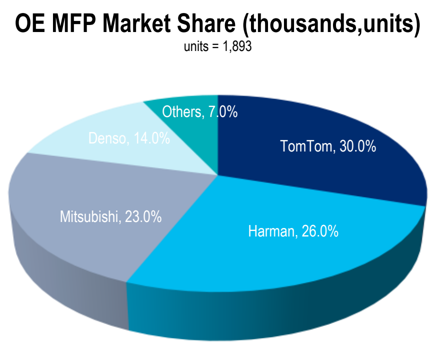
Again, note the % of units for all regions with navigation. All in, connected navigation is expected to total 20.8mln units vs. 3.8mln units in 2012; connected navigation units are embedded within connected telematics, MFP, and HMFP forecasts in this section.

Figure 75. Multi-Function Portal Head Units (OE)

	2012	2013	2014	2015	2016	2017	2018	2019	2020
North America									
Units Sold	500.0	615.6	995.0	1,187.6	1,364.7	1,505.3	1,636.9	1,717.6	2,414.9
% w/ navigation	100.0%	100.0%	85.0%	70.0%	70.0%	70.0%	75.0%	80.0%	80.0%
x ASP ($)	1007.8	977.6	865.4	760.3	732.2	704.1	692.5	680.0	646.7
= Revenue ($, mlns)	503.9	601.8	861.1	903.0	999.3	1,059.9	1,133.6	1,168.0	1,561.8
South America									
Units Sold	8.4	14.9	59.5	161.7	351.4	497.3	609.9	732.7	771.3
% w/ navigation	100.0%	100.0%	85.0%	70.0%	70.0%	70.0%	70.0%	60.0%	60.0%
x ASP ($)	1045.7	1014.3	881.3	756.2	727.8	699.5	665.4	579.3	551.4
= Revenue ($, mlns)	8.8	15.1	52.4	122.3	255.8	347.9	405.8	424.4	425.3
W. Europe									
Units Sold	670.0	674.6	698.3	1,147.5	1,612.5	2,129.1	2,518.3	2,954.7	3,184.9
% w/ navigation	100.0%	100.0%	80.0%	65.0%	60.0%	50.0%	50.0%	60.0%	70.0%
x ASP ($)	610.0	720.0	634.5	569.5	532.8	480.1	457.8	471.5	483.4
= Revenue ($, mlns)	408.7	485.7	443.0	653.5	859.1	1,022.2	1,152.9	1,393.1	1,539.6
Central Europe									
Units Sold	12.5	12.8	17.1	28.5	67.8	153.3	198.5	241.1	288.2
% w/ navigation	100.0%	100.0%	80.0%	65.0%	40.0%	40.0%	40.0%	45.0%	45.0%
x ASP ($)	1011.0	1000.9	854.7	744.9	568.5	547.5	521.9	528.7	507.6
= Revenue ($, mlns)	12.7	12.8	14.6	21.2	38.5	83.9	103.6	127.5	146.3
China									
Units Sold	458.5	655.4	1,101.7	1,651.2	2,339.5	3,072.7	3,393.0	3,822.8	4,133.8
% w/ navigation	100.0%	100.0%	100.0%	80.0%	80.0%	80.0%	85.0%	85.0%	90.0%
x ASP ($)	748.0	725.6	703.8	596.2	578.8	561.9	564.9	564.3	584.3
= Revenue ($, mlns)	342.9	475.6	775.4	984.4	1,354.0	1,726.5	1,916.7	2,157.4	2,415.2
Japan									
Units Sold	182.5	177.6	222.1	262.8	274.4	247.5	236.0	224.3	220.8
% w/ navigation	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
x ASP ($)	963.7	933.4	890.2	863.5	843.0	817.2	792.3	793.3	794.3
= Revenue ($, mlns)	175.9	165.8	197.8	226.9	231.4	202.2	187.0	178.0	175.4
South Korea									
Units Sold	47.6	55.8	67.4	83.0	107.7	132.3	119.3	100.4	91.7
% w/ navigation	100.0%	100.0%	95.0%	95.0%	90.0%	90.0%	95.0%	100.0%	100.0%
x ASP ($)	986.2	943.1	897.0	870.5	819.9	788.2	779.6	769.4	738.6
= Revenue ($, mlns)	46.9	52.6	60.5	72.2	88.3	104.3	93.0	77.3	67.8
Rest of World									
Units Sold	13.5	17.5	43.1	95.8	237.3	568.1	910.9	1,213.9	1,420.3
% w/ navigation	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
x ASP ($)	988.9	959.6	903.0	888.8	858.7	824.9	758.3	759.3	760.3
= Revenue ($, mlns)	13.4	16.8	38.9	85.2	203.8	468.6	690.7	921.7	1,079.8

Source: IHS, Citi Research Note: 2013-2020 are estimates

Figure 76. Supplier Market Share OE MFP Head Units (2012)



Source: IHS, Citi Research

Hybrid Multi-Function Portals

Similar to MFPs, HFMPs are defined as head units that must have an embedded telematics control unit AND must also be able to make use of the consumer's smart phone or other device to offer additional services through a separate data plan (GM OnStar plus MyLink, BMW ConnectedDrive plus ConnectedApps).

As of 2013 roughly 1% of total front infotainment units sold (OE and aftermarket) were MFPs; by 2020 it is forecast to be 16%. ASPs for HMFPs are currently just below MFPs, which is the top ASP infotainment system; the coveted top ASP spot is forecast to swap throughout 2020 with similar technology, MFPs.

Figure 77. HMFP OE Head Units Take Rates by Region

HMFP Take Rate (%)	2012	2013	2014	2015	2016	2017	2018	2019	2020
N. America	1.0%	1.8%	3.2%	7.8%	12.9%	18.5%	19.5%	20.6%	23.4%
S. America	0.0%	0.1%	0.5%	1.8%	3.7%	6.2%	9.9%	14.8%	18.2%
W. Europe	2.2%	2.8%	3.5%	6.8%	13.4%	18.4%	22.7%	26.7%	29.6%
C. Europe	0.7%	0.7%	1.3%	2.8%	7.1%	15.8%	19.8%	22.9%	25.2%
China	0.0%	0.7%	1.0%	1.5%	2.1%	3.8%	8.0%	12.5%	17.3%
Japan	0.0%	0.7%	1.1%	2.0%	3.4%	6.4%	9.7%	13.3%	17.7%
S. Korea	0.4%	0.5%	0.8%	1.3%	2.3%	4.8%	8.7%	13.0%	16.6%
RoW	0.0%	0.1%	0.1%	0.3%	1.0%	3.3%	6.9%	9.2%	10.3%

Source: IHS, Citi Research Note: 2013-2020 are estimates

Figure 78. Hybrid Multi-Function Portal Head Units (OE)

	2012	2013	2014	2015	2016	2017	2018	2019	2020
North America									
Units Sold	170.9	314.7	595.6	1,499.5	2,512.3	3,638.7	3,806.8	4,052.5	4,635.8
% w/ navigation	100.0%	95.0%	85.0%	70.0%	70.0%	60.0%	50.0%	40.0%	40.0%
x ASP ($)	1048.0	943.2	848.9	679.1	611.2	589.0	580.3	569.3	535.2
= Revenue ($, mlns)	179.1	296.8	505.6	1,018.3	1,535.5	2,143.3	2,209.1	2,307.3	2,481.0
South America									
Units Sold	0.0	8.7	28.5	118.8	260.1	459.6	767.2	1,204.8	1,537.5
% w/ navigation	0.0%	100.0%	85.0%	70.0%	70.0%	70.0%	70.0%	60.0%	60.0%
x ASP ($)	0.0	1150.0	1035.0	931.5	745.2	596.2	476.9	453.1	444.0
= Revenue ($, mlns)	0.0	10.0	29.5	110.7	193.9	274.0	365.9	545.9	682.7
W. Europe									
Units Sold	290.5	364.4	467.3	951.9	1,943.7	2,754.4	3,483.9	4,160.9	4,615.9
% w/ navigation	100.0%	95.0%	80.0%	50.0%	40.0%	30.0%	30.0%	30.0%	30.0%
x ASP ($)	1127.0	1014.3	912.9	730.3	584.2	549.2	538.2	527.4	495.8
= Revenue ($, mlns)	327.4	369.6	426.6	695.1	1,135.6	1,512.7	1,875.0	2,194.6	2,288.5
Central Europe									
Units Sold	6.6	6.9	12.4	30.6	87.2	211.0	282.4	337.8	405.2
% w/ navigation	100.0%	95.0%	70.0%	50.0%	40.0%	30.0%	25.0%	25.0%	25.0%
x ASP ($)	1140.0	1026.0	923.4	738.7	591.0	555.5	538.9	522.7	491.3
= Revenue ($, mlns)	7.5	7.1	11.4	22.6	51.5	117.2	152.1	176.6	199.1
China									
Units Sold	0.0	145.7	239.5	375.3	568.4	1,089.7	2,348.6	3,784.7	5,376.6
% w/ navigation	0.0%	100.0%	80.0%	70.0%	60.0%	50.0%	40.0%	40.0%	40.0%
x ASP ($)	0.0	998.0	898.2	718.6	574.8	517.4	507.0	496.9	467.1
= Revenue ($, mlns)	0.0	145.4	215.1	269.7	326.7	563.8	1,190.8	1,880.5	2,511.2
Japan									
Units Sold	0.0	32.9	51.3	92.2	156.9	290.5	434.5	593.6	780.7
% w/ navigation	0.0%	80.0%	80.0%	85.0%	85.0%	90.0%	90.0%	95.0%	95.0%
x ASP ($)	0.0	1450.0	1305.0	1174.5	939.6	845.6	820.3	795.7	779.7
= Revenue ($, mlns)	0.0	47.7	66.9	108.3	147.4	245.7	356.4	472.3	608.7
South Korea									
Units Sold	5.3	7.6	11.9	20.1	36.6	76.9	142.3	213.4	272.3
% w/ navigation	100.0%	100.0%	95.0%	95.0%	90.0%	90.0%	85.0%	85.0%	90.0%
x ASP ($)	1145.0	1087.8	979.0	783.2	626.5	563.9	552.6	541.6	530.7
= Revenue ($, mlns)	6.1	8.3	11.6	15.7	22.9	43.4	78.6	115.6	144.5
Rest of World									
Units Sold	5.4	10.2	21.9	60.0	204.8	715.3	1,576.9	2,189.2	2,561.3
% w/ navigation	100.0%	100.0%	100.0%	80.0%	70.0%	40.0%	35.0%	35.0%	35.0%
x ASP ($)	1145.0	1030.5	927.5	742.0	593.6	534.2	518.2	502.6	492.6
= Revenue ($, mlns)	6.2	10.5	20.3	44.6	121.6	382.1	817.1	1,100.4	1,261.6

Source: IHS, Citi Research Note: 2013-2020 are estimates

The Rise of the Touch Screen

As technology, electrification and infotainment continue to advance in the automobile, new human machine interfaces (HMI) become more prevalent. If we look at the cell phone (consumer electronics) for example, it has evolved from physical keys with a screen to now an entire touch screen display. The trends in consumer electronics are starting to migrate to that of the automobile. We are evolving from the day of knob and tuners to a more sophisticated, technologically advanced piece of equipment. As mentioned in the above section, the more advanced technological infotainment options make use of touch screen HMIs, including but not limited to: Audio/Video, Unconnected Navigation, Connected Telematics, MFPs and HMFPs. With the continued evolution of infotainment systems, we believe that touch screens will remain a mission critical piece of the puzzle as more and more information is required by the end user.

Auto Specific Touch Screens

The market for auto specific touch screens is growing rapidly. The combined global unit volume (capacitive and resistive) is expected to grow at a 23% CAGR ('13-'19). The addressable revenue for this market is also expected to grow significantly, from roughly $428 million in 2013 to $1.3bn in 2019 (21% CAGR).

From a volume perspective both NA & APAC appear to be the best two regions for OEMs/suppliers to position themselves.

NA is forecast to grow at an 11% unit CAGR ('13-'19); APAC is forecast to grow at a 49% unit CAGR over the same time period, quite impressive given the volume. Western Europe should also help adoption of touch screens in the near-term, but their volume is not forecast to reach levels commensurate with NA or APAC.

Figure 79. Total Auto Specific Touch Screens and ASP

Unit Sales in 1000's	2011	2012	2013	2014	2015	2016	2017	2018	2019
North America									
ASP ($)	46.0	44.6	43.7	41.7	41.0	40.3	39.0	37.8	36.8
Units (1000's)	3,356	4,465	5,559	6,829	7,810	8,891	9,592	10,049	10,348
Revenue (mln)	**154**	**199**	**243**	**285**	**320**	**358**	**374**	**379**	**381**
South America									
ASP ($)	44.9	44.0	43.3	43.5	43.3	43.2	42.6	41.3	40.5
Units (1000's)	171	214	282	421	544	689	836	1,007	1,189
Revenue (mln)	**8**	**9**	**12**	**18**	**24**	**30**	**36**	**42**	**48**
West Europe									
ASP ($)	42.7	41.7	41.7	41.5	41.1	40.5	39.6	38.4	37.4
Units (1000's)	1,417	1,833	2,360	2,776	3,221	3,689	4,116	4,624	4,939
Revenue (mln)	**60**	**77**	**98**	**115**	**132**	**149**	**163**	**177**	**185**
East Europe									
ASP ($)	36.1	35.5	36.8	35.8	35.0	35.0	34.7	34.8	34.2
Units (1000's)	105	188	218	384	593	671	792	933	1,193
Revenue (mln)	**4**	**7**	**8**	**14**	**21**	**23**	**28**	**32**	**41**
Asia Pacific									
ASP ($)	37.1	38.3	40.0	42.3	41.1	39.9	38.1	37.6	36.6
Units (1000's)	795	1,347	1,653	2,196	3,017	5,112	7,988	12,409	17,858
Revenue (mln)	**29**	**52**	**66**	**93**	**124**	**204**	**305**	**467**	**654**
Rest of World									
ASP ($)	35.0	34.4	33.2	35.1	36.9	36.2	34.8	33.8	33.0
Units (1000's)	4	5	9	19	33	59	90	123	153
Revenue (mln)	**0.1**	**0.2**	**0.3**	**0.7**	**1.2**	**2.1**	**3.1**	**4.2**	**5.1**
ASP	0.00	42.67	42.42	41.61	40.87	40.12	38.80	37.80	36.81
Units	5,848	8,052	10,081	12,625	15,218	19,111	23,414	29,145	35,680
Revenue	**256**	**344**	**428**	**525**	**622**	**767**	**908**	**1,102**	**1,314**

Source: IHS, Citi Research Note: 2013-2019 are estimates

Capacitive vs. Resistive: The Battle of Tech has Begun

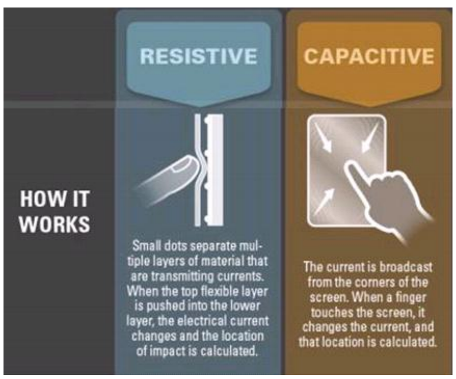
Resistive Screens

A resistive touch screen is a flexible material layered on top of other layers of material. The lower layers of materials have currents running through them, so when a user presses on the top layer, the material presses against the lower layers and changes the flow of the current; this change in current allows for the calculation of the location of impact. A resistive touch screen generally costs less than its capacitive counterpart (polyester film) and allows for more external activation options (finger, gloved finger, and stylus). Globally, resistive touch screens units are expected to grow at a ~7% CAGR from 2013-2019; revenue for the same period is expected to grow at a ~1.5% according to IHG.

Capacitive Screens

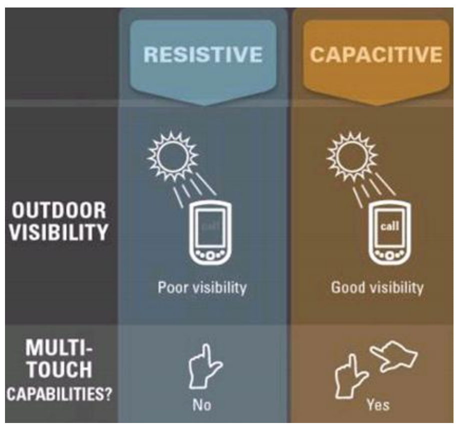
A capacitive touch screen has currents running from the four corners of the screen and when a finger touches it the current is changed and a location is then calculated. Additionally, a capacitive touch screen is more expense than a resistive touch screen, but offers benefits that its counterpart does not, including: (1) increased sharpness; (2) increased brightness and more easily viewable in outdoor lighting; (3) better sensitivity to finger activation; and (4) offers multi-touch capability. Globally, capacitive touch screen units are expected to grow at a ~51% CAGR from 2013-2019; revenue for the same period is expected to grow at a ~45% CAGR.

Figure 80. How a Touch Screen Works (Cell Phone) – Cricket Wireless Infographic



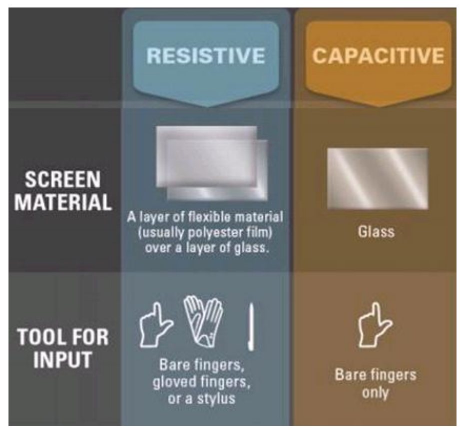
Source: Cricket Wireless, http://www.mycricket.com/community/cell-phone-info/how-does-touch-screen-phone-work

Figure 81. How a Touch Screen Works (Cell Phone) – Cricket Wireless Infographic



Source: Cricket Wireless, http://www.mycricket.com/community/cell-phone-info/how-does-touch-screen-phone-work

Figure 82. How a Touch Screen Works (Cell Phone) – Cricket Wireless Infographic



Source: Cricket Wireless, http://www.mycricket.com/community/cell-phone-info/how-does-touch-screen-phone-work

Figure 83. Capacitive Touch Screen by Geo (units, ASP, revenue)

Unit Sales in 1000's	2011	2012	2013	2014	2015	2016	2017	2018	2019
North America									
ASP ($)	0.0	60.6	53.4	45.5	43.2	45.0	43.3	41.5	39.8
Units (1000's)	0	223	834	1,502	2,733	4,001	5,276	6,130	7,244
Revenue (mln)	**0**	**14**	**45**	**68**	**118**	**180**	**229**	**254**	**289**
South America									
ASP ($)	0.0	50.0	48.0	50.6	50.4	49.2	47.3	45.1	43.5
Units (1000's)	0	11	37	84	174	310	460	615	833
Revenue (mln)	**0**	**1**	**2**	**4**	**9**	**15**	**22**	**28**	**36**
West Europe									
ASP ($)	0.0	55.5	52.1	49.3	46.6	44.0	42.9	41.2	39.5
Units (1000's)	0	92	354	611	1,128	1,660	2,264	2,821	3,458
Revenue (mln)	**0**	**5**	**18**	**30**	**53**	**73**	**97**	**116**	**137**
East Europe									
ASP ($)	0.0	42.0	47.2	46.9	41.5	39.4	37.5	38.0	36.5
Units (1000's)	0	9	26	69	166	242	333	476	716
Revenue (mln)	**0**	**0**	**1**	**3**	**7**	**10**	**12**	**18**	**26**
Asia Pacific									
ASP ($)	0.0	42.0	48.4	54.8	50.7	47.4	44.9	43.3	41.6
Units (1000's)	0	391	744	1,273	2,172	3,425	4,873	7,569	11,250
Revenue (mln)	**0**	**16**	**36**	**70**	**110**	**162**	**219**	**327**	**468**
Rest of World									
ASP ($)	0.0	42.1	40.7	44.5	43.6	43.6	39.7	39.2	37.4
Units (1000's)	0	0	1	4	11	26	50	75	107
Revenue (mln)	**0.0**	**0.0**	**0.0**	**0.2**	**0.5**	**1.2**	**2.0**	**2.9**	**4.0**
ASP	0.00	49.55	51.13	49.60	46.52	45.65	43.79	42.21	40.64
Units	0	726	1,996	3,544	6,384	9,664	13,254	17,686	23,608
Revenue	**0**	**36**	**102**	**176**	**297**	**441**	**580**	**747**	**959**

Source: IHS, Citi Research

Figure 84. Resistive Touch Screen by Geo (units, ASP, revenue)

Unit Sales in 1000's	2011	2012	2013	2014	2015	2016	2017	2018	2019
North America									
ASP ($)	46.0	43.8	41.9	40.6	39.8	36.4	33.8	32.0	29.9
Units (1000's)	3,356	4,242	4,725	5,327	5,076	4,890	4,317	3,919	3,105
Revenue (mln)	**154**	**186**	**198**	**216**	**202**	**178**	**146**	**125**	**93**
South America									
ASP ($)	45	44	43	42	40	38	37	35	34
Units (1000's)	171	204	245	337	370	379	376	393	357
Revenue (mln)	**8**	**9**	**10**	**14**	**15**	**14**	**14**	**14**	**12**
West Europe									
ASP ($)	43	41	40	39	38	38	36	34	32
Units (1000's)	1,417	1,741	2,006	2,165	2,094	2,029	1,852	1,804	1,482
Revenue (mln)	**60**	**71**	**80**	**85**	**80**	**76**	**66**	**61**	**48**
East Europe									
ASP ($)	36	35	35	33	33	33	33	32	31
Units (1000's)	105	179	192	315	427	430	459	457	477
Revenue (mln)	**4**	**6**	**7**	**11**	**14**	**14**	**15**	**14**	**15**
Asia Pacific									
ASP ($)	37	37	33	25	16	25	28	29	28
Units (1000's)	795	956	909	922	845	1,687	3,115	4,839	6,607
Revenue (mln)	**29**	**35**	**30**	**23**	**14**	**42**	**86**	**139**	**186**
Rest of World									
ASP ($)	35	34	32	33	34	30	29	25	23
Units (1000's)	4	5	8	15	22	32	41	48	46
Revenue (mln)	**0.1**	**0.2**	**0.3**	**0.5**	**0.7**	**1.0**	**1.2**	**1.2**	**1.0**
ASP	43.77	41.99	40.27	38.48	36.78	34.47	32.28	30.99	29.34
Units	5,848	7,327	8,085	9,081	8,834	9,447	10,160	11,460	12,074
Revenue	**256**	**308**	**326**	**349**	**325**	**326**	**328**	**355**	**354**

Source: IHS, Citi Research

Does Size Matter?

Touch screens come in various different sizes, with the larger sizes typically carrying a heftier price tag. The larger screen sizes do come with advantages though, including accuracy of screen touch and less need to squint to read the screen. From a unit perspective, the large volume touch screens remain range bound between 6" and 8", a statistic that isn't forecast to change by 2019. Within this range band, the most rapid growing screen size is the 8" screen, growing at a 27% CAGR ('13-'19). This particular screen size represented just 39% of the market in 2013 and is expected to increase to 46% of the market by 2019. While other screen sizes have impressive CAGRs (4", 5", 10", 12"), their 2019 volume is forecast to represent a combined 10% of the market by 2019, up from 6% in 2013.

As you can see from the table to the right, that highlights global screen size forecasts, the largest volumes are 6" and 8" screens. Relatively speaking, the 12" and higher screen sizes appear to be more of a niche play, but we believe that as technology continues to advance and consumers get used to the larger screens it should gain popularity.

Figure 85. Global Touch Screen Unit Sales & Forecast by Screen Size (units, thousands)

	2011	2012	2013	2014	2015	2016	2017	2018	2019
4"	0	0	2	45	189	302	371	481	634
5"	216	368	550	902	1,191	1,522	1,969	2,347	2,831
6"	1,203	2,264	2,778	3,630	4,523	5,547	6,834	8,134	9,656
7"	1,838	2,170	2,776	3,105	3,734	4,294	4,799	5,355	5,837
8"	2,574	3,215	3,933	4,866	5,474	7,316	9,294	12,654	16,532
10"	1	2	2	10	23	24	23	22	23
12"	17	31	38	58	76	99	118	147	161
17"	0	2	3	7	6	6	6	7	8
Total	**5,849**	**8,052**	**10,082**	**12,623**	**15,216**	**19,110**	**23,414**	**29,147**	**35,682**

Source: IHS, Citi Research

Connectors and Vehicle Electrification

We forecast annual average volume growth of 4%-6% per vehicle in addition to annual auto production growth of 2-3% less average price declines of 0-2% resulting in organic connector growth of 6-8% without aggressive assumptions.

Connectors are another product that will benefit from vehicle electrification. As the installation of electronic systems advances, the number of electronic circuits that exchange information and hence the number of connectors will increase. Because the increase in electronic circuits will be exponential to system installation, we forecast annual average volume growth of 4%-6% versus just over 2% for ECUs. We forecast auto volume growth and an increase in the number of connectors per vehicle will result in the connector market expanding from $2.9bn in 2013 (our estimate), to $4bn in 2014, $5.1bn in 2015, and $12bn in 2020.

Major auto-use connector makers include Yazaki, Sumitomo Wiring Systems, Japan Aviation Electronics, Hirose Electric, Iriso Electronics, and JST (Japan), TE Connectivity, Delphi, Molex, and Amphenol (US), and FCI (Europe). The number of suppliers is large because the type of connector used differs by application. Even so, we estimate TE Connectivity has a market share of 30%-40% and is the dominant player.

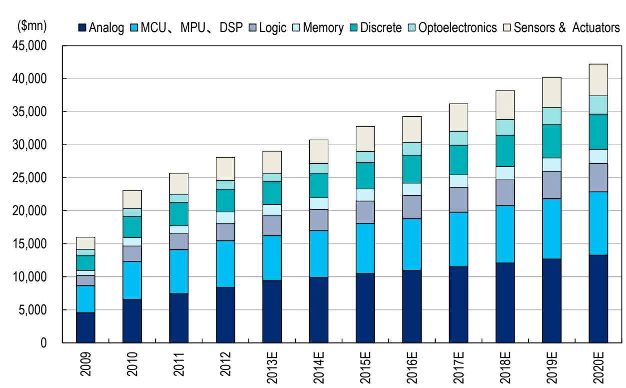
Volume growth expected for MLCC and other passive components

We forecast demand for multilayer ceramic capacitors (MLCCs), aluminum electrolytic capacitors, resistors, crystal devices and other passive components will expand as electronic control unit (ECU) installation advances. Demand for MLCCs, in particular, should increase strongly as each ECU uses 100–300 of them. We estimate average annual MLCC growth of 7%-9% assuming auto market volume growth of 3%-5%, ECU volume growth of just over 2%, and a c3% increase in the number of ECUs per vehicle driven by the substitution of large capacity capacitors (tantalum and aluminum electrolytic capacitors) and increasing circuit sophistication. On this basis, we forecast the auto-use connector market will expand from $2.9bn in 2013 (our estimate) to $4bn in 2014, $5.1bn in 2015, and $12bn in 2020.

Major auto-use passive component makers

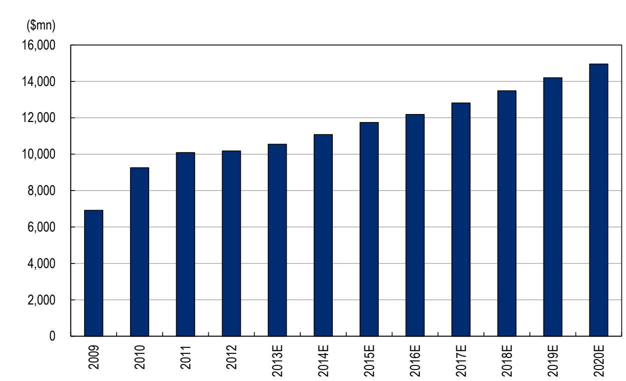
Big-name Japanese electronic component makers, including Panasonic (electronic component business), TDK, Murata, Nichicon, and Nippon Chemicon are major suppliers of auto-use passive components. Relatively new entrants like Samsung Electro Mechanics (SEMCO) are establishing a presence in the IT-use MLCC market, but Japanese companies remain highly competitive in the auto-use MLCC market, which is almost a duopoly between TDK and Murata.

Figure 86. We forecast continued auto-use semiconductor market growth driven by xEV, ECU, and LED-related demand



Source: WSTS, Citi Research estimate

Figure 87. We forecast connectors will be one of the biggest beneficiaries of vehicle electrification



Source: Bishop, Citi Research estimate

Figure 88. Top 10 Connector Manufacturers 2009-2012

Top 10 Connector Manufacturers

$ Millions

Rank	Manufacturer	2009	2010	2011	2012	2009 Y/Y Change	2010 Y/Y Change	2011 Y/Y Change	2012 Y/Y Change	2009 Market Share	2010 Market Share	2011 Market Share	2012 Market Share
1	TE Connectivity	$6,005	$7,865	$8,476	$8,482	-26%	31%	8%	0%	17.5%	17.3%	17.5%	17.8%
2	Amphenol Corporation	$2,820	$3,293	$3,676	$4,015	-13%	17%	12%	9%	8.2%	7.3%	7.6%	8.4%
3	Molex Incorporated	$2,480	$3,403	$3,582	$3,580	-23%	37%	5%	0%	7.2%	7.5%	7.4%	7.5%
4	Foxconn (Hon Hai)	$1,146	$1,547	$2,718	$2,683	-22%	35%	76%	-1%	3.3%	3.4%	5.6%	5.6%
5	Delphi Connection Systems	$726	$1,228	$2,522	$2,589	-27%	69%	105%	3%	2.1%	2.7%	5.2%	5.4%
6	Yazaki	$1,260	$1,777	$2,176	$2,278	-16%	41%	22%	5%	3.7%	3.9%	4.5%	4.8%
7	JST	$1,364	$1,602	$1,509	$1,451	-12%	17%	-6%	-4%	4.0%	3.5%	3.1%	3.0%
8	JAE	$786	$976	$1,083	$1,311	-25%	24%	11%	21%	2.3%	2.2%	2.2%	2.8%
9	Hirose	$939	$1,155	$1,160	$1,185	-10%	23%	0%	2%	2.7%	2.5%	2.4%	2.5%
10	Sumitomo Wiring Systems			$859	$904				5%				1.9%
	Total Top 10	$17,526	$24,543	$27,761	$28,477	-21%	40%	13%	3%	51%	54%	57%	60%
	All Others	$16,864	$20,799	$20,594	$19,133	-23%	23%	-1%	-7%	49%	46%	43%	40%
	Total Market	$34,390	$45,341	$48,355	$47,610	-22%	32%	7%	-2%	100%	100%	100%	100%

Notes: Molex and Amphenol both had acquisition that impacted 2006 growth. MOLX organic growth was 18% and APH was 16%.

Source: Bishop and Citi Research. Note 2013 data not yet available.

Figure 89. Top 10 Connector Manufacturers Segment Rankings (2012)

World Rank	Computers and Peripherals	Business Retail Education	Instruments	Medical Equipment	Industrial Equipment	Automotive Equipment	Transportation Equipment	Military Aerospace	Telecom Datacom Equipment	Consumer Electronics	Other
1	Foxconn	Foxconn	Samtec	TE Connectivity	TE Connectivity	TE Connectivity	Delphi	Amphenol	TE Connectivity	Molex	TE Connectivity
2	Molex	TE Connectivity	TE Connectivity	Amphenol	Amphenol	Yazaki	TE Connectivity	TE Connectivity	Amphenol	TE Connectiity	Hirose
3	Amphenol	JST	LEMO SA	Molex	HARTING	Delphi	Molex	Glenair	Molex	JST	Delphi
4	Foxlink	Smiths	Rosenberger	LEMO SA	Molex	Sumitomo	Amphenol	ITT	JAE	PPC	Multi-Contact
5	LOTES	AVX/Elco	Foxconn	WAGO	JST	JAE	Sumitomo	China Aviation	Hirose	Yeonho	Sumitomo
6	FCI	Hirose	AVX/Elco	3M	I-PEX	JST	Yazaki	Souriau	Rosenberger	AVX/Elco	Foxconn
7	TE Connectivity	IRISO	WAGO	Delphi	Belden, Inc.	Molex	Carlisle	Radiall	Foxconn	Hirose	JST
8	Hosiden	3M	Multi-Contact	Sauriau	3M	Rosenberger	Korea Electric	Carlisle	DDK	JAE	3M
9	JAE	Sumitomo	JST	Samtec	Weidmuller	Hirose	JAE	AMETEK	Delphi	Delphi	JAE
10	IRISO	Rosenberger	3M	ITT	Phoenix	Amphenol	Souriau	Delphi	FCI	FCI	China Aviation

Source: Bishop and Citi Research. Note 2013 data not yet available.

Companies to Benefit from Electrification

Companies that will benefit from electrification

We believe the companies that will benefit from vehicle electrification can be divided into two groups. First, electronic device makers that are focusing on the auto market as a growth field. Second, Tier 1 auto parts makers that have established positions as suppliers not only of standalone products but also electronic systems. The first group includes electronic component makers Murata and TE Connectivity and semiconductor makers Infineon and Freescale Semiconductor. The second group includes companies such as Denso and Continental.

Some technology companies already have a presence as Tier 1 auto parts makers. Hitachi, Mitsubishi Electric, and Panasonic supply auto products as Tier 1 makers. Also, machinery manufacturer NSK is a Tier 1 maker of power steering and has the second largest share of the global market. Nidec mainly makes Tier 2 products and its business is not large (we forecast FY3/14 sales of ¥115bn), but it aims to become a Tier 1 maker through new product development and acquisitions.

Based on the global auto parts maker sales ranking compiled by Automotive News, Panasonic and Hitachi feature in the top 20 and Mitsubishi Electric and NSK in the top 40. Panasonic is sixth on the Japanese auto parts maker sales ranking (FY3/13 sales of around ¥1trn) behind Toyota Boshoku.

Figure 90. Automotive News global auto parts sales ranking (2012) and automotive sales of major technology companies

Company name	Country	Sales
1 Robert Bosch	Germany	36,787
2 Denso	Japan	34,200
3 Continental	Germany	32,800
4 Magna	Canada	30,428
5 Aisin Seiki	Japan	30,080
6 Johnson Controls Inc	US	22,515
7 Faurecia	France	22,500
8 Hyundai Mobis	Korea	21,351
9 ZF Friedrichshafen	Germany	18,614
10 Yazaki	Japan	15,801
11 Lear Corp	US	14,567
12 Delphi Automotive	US	14,432
13 TRW Automotive Holdings	US	14,141
14 BASF SE	Germany	13,168
15 Valeo	France	12,816
16 Sumitomo Electric Industries	Japan	11,232
17 Toyota Boshoku	Japan	10,484
18 JTEKT	Japan	9,793
19 Hitachi Automotive Systems	*Japan*	*9,613*
20 Cummins	US	9,025
21 Schaeffler	Germany	8,700
22 Autoliv	Sweden	8,263
23 Calsonic Kansei	Japan	7,801
24 Benteler Automobiltechnik	Germany	7,643
25 Gestamp Automocion	Spain	7,599
26 Dana Holding	US	7,224
27 JATCO	Japan	7,223
28 Toyoda Gosei	Japan	7,200
29 BorgWarner	US	7,183
30 Mahle	Germany	7,081
31 Magneti Marelli	Italy	7,073
32 Visteon	US	6,860
33 HELLA KGaA Hueck	Germany	6,505

Company name	Country	Sales
34 GKN PLC	UK	6,438
35 NTN Corp	Japan	6,250
36 Tenneco Inc	US	6,100
37 Mitsubishi Electric	*Japan*	*6,000*
38 Hyundai-WIA	Korea	5,885
39 Brose Fahrzeugteile	Germany	5,778
40 Plastic Omnium	France	5,585
41 NHK Spring	Japan	5,463
42 Koito Manufacturing	Japan	5,243
43 Behr GmbH	Germany	5,000
44 Takata Corp.	Japan	4,861
45 IAC Group	Lexembourg	4,700
46 Mando	Korea	4,689
47 NSK	*Japan*	*4,689*
48 Tokai Rika	Japan	4,537
49 Flex-N-Gate	US	4,340
50 Federal-Mogul	US	4,300
51 Goodyear Tire & Rubber	US	4,300
52 Nemak	Mexico	4,300
53 TS Tech	Japan	3,717
54 Leoni	Germany	3,600
55 Eberspaecher Holding	Germany	3,581
56 Grupo Antolin	Spain	3,465
57 Harman International Industries	US	3,230
58 Alcoa	US	3,200
59 DuPont	US	3,100
60 Honeywell	US	3,083
61 Webasto SE	Germany	3,077
62 Bayer MaterialScience	Germany	3,053
63 TI Automotive	US	3,000
64 Draexlmaier	Germany	2,990
65 Showa	Japan	2,964
66 American Axle & Mfg. Holdings	US	2,931

Company name	Country	Sales
67 Iochpe-Maxion	Brazil	2,921
68 Martinrea International	Canada	2,901
69 Cooper-Standard Automotive	US	2,881
70 Hyundai Powertech	Korea	2,858
71 Inteva Products	US	2,800
72 Keihin	Japan	2,650
73 Alpine Electronics	*Japan*	*2,600*
74 Asahi Glass	Japan	2,543
75 SKF Automotive	Sweden	2,529
76 WABCO Holdings	Belgium	2,477
77 Mitsuba Corp	Japan	2,470
78 Infineon Technologies	*Germany*	*2,400*
79 KSPG AG	Germany	2,392
80 Linamar Corp	Canada	2,339
81 Leopold Kostal	Germany	2,273
82 Nexteer Automotive	US	2,200
83 CIE Automotive	Spain	2,190
84 Stanley Electric	Japan	2,105
85 Tower International	US	2,051
86 Autoneum Management	Switzerland	2,047
87 TrelleborgVibracoustic	Germany	2,000
88 Ryobi	Japan	1,995
89 Tokai Rubber Industries	Japan	1,941
90 Hyundai Dymos	Korea	1,935
91 Royal Philips Electronics	*Netherlands*	*1,886*
92 CITIC Dicastal	China	1,881
93 Kautex Textron	Germany	1,845
94 PPG Industries	US	1,780
95 F-Tech	Japan	1,724
96 Akebono Brake Industry	Japan	1,694
97 Pioneer Corp	*Japan*	*1,693*
98 HBPO	Germany	1,670
99 Eaton	US	1,600

Company name	Country	Sales
16 Panasonic	Japan	12,041
19 Hitachi	Japan	9,715
35 MELCO	Japan	6,256
37 NSK	Japan	5,906
43 TE Connectivity	US	5,180
49 Alps Elec	Japan	4,333
83 Infineon	Germany	2,134
90 STMicroelectronics	Switzerland	1,997
94 GS Yuasa	Japan	1,808
<100 TDK	Japan	1,682
<100 Texas Instruments	US	1,411
<100 Murata	Japan	1,229
<100 Sensata Technologies	US	1,225
<100 Omron	Japan	1,175
<100 Nidec	Japan	1,044
<100 Freescale	US	986
<100 Rohm	Japan	863
<100 Mabuchi	Japan	591
<100 Amphenol	US	466
<100 Vishay	US	446
<100 Hirose	Japan	173

Note: Japanese companies are highlighted in dark blue, US companies in light blue, and European companies in grey. Technology companies are italicized. Sales units are $mn. Sales for some companies are estimates and there could be some discrepancy with actual sales due to exchange rates. Sales for some companies are based on fiscal years rather than calendar years.

Source: Automotive News, Company data, Citi Research

Figure 91. Major products by companies which will benefit from electrification

Company	Outline
Hitachi	HEV related products 30% (motors, inverter modules batteries etc), powertrain related products 20% (timing bulb systems, DI etc)、safety related products 20% (electronic breaking, suspension, cameras etc), informatics 20% (car navigation etc), others 10%
MELCO	HEV related products (motors, inverter modules, ECU etc)、powertrain related products (starters, alternators, EPS motors, EMSs, EGR bulbs etc), safety related products (milli-wave radars etc) Informatics (car navigation, key less systems etc)
Panasonic	xEVs related products 31% (Lithium ion batteries, lead batteries, capacitors, compressors, charging systems etc), safety related products 19%(cameras, switches, sensors, key less systems etc), informatics 51% (car navigation, PND, car audio, head up displays etc)
GS Yuasa	Lead batteries, lithium ion batteries
Mabuchi Motor	Automotive motors (DC small motors with brush, motors for power wind and power sheets etc)
Nidec	Automotive motors (EPS motors, cooling fan motors for engines, motors for electronic breaking, stepping motors, DC small motors with brush etc), ECU(old Honda Elesys), CVT bulbs (old Nidec Tosoku)
TDK	MLCC 30%, inductors 40%, magnet 20%, DC-DC converter 5%, others (capacitors, filters for CAN, current sensors, jairo sensors, temperature sensors, pressure sensors etc)
Alps Elec	Switches, door sheets, steering systems, ky less entry systems, instrumental panels, encoders, car navigation (Alpine)
Hirose Elec	Automotive connectors (antennas, HID, wires LAN etc)
Rohm	Automotive semiconductors (LSI for car navigation and audio systems, LED driver ICs, regulator ICs, Discrete ICs, acceleration sensors etc)
Murata	MLCC 40%, resonators 10%, acceleration sensors 10%, power modules 5%、WiFi 5%, others (ultrasound sensors, air pressure sensors for TPMS)
NSK	Auto bearings, EPS
Omron	ECU (EPS, body controls etc), laser radars, switches, DC-DC converters etc
Infineon	Automotive semiconductors (MCU, power semiconductors etc), sensors (magnet sensors, pressure sensor for TPMS etc)
STMicroelectronics	Automotive semiconductors (MCU, power semiconductors, driver ICs, LSI for car navigations etc)
Freescale	Automotive semiconductors (MCU, power semiconductors, analog ICs etc)
Texas Instruments	Automotive semiconductors (analog ICs, embedded ICs, wireless semiconductors etc)
TE Connectivity	Automotive connectors
Amphenol	Automotive connectors
Vishay	ECU, air bag systems, sensors (temperature sensors etc)
Sensata Technologies	Auto motive sensors
Toyota Industries	HEV related products (DC-DC converters, electronic air conditioner compressors etc)
Denso	HEV related products (motors, inverter modules, ECU, DC-DC converters etc), powertrain related products (starters, alternators, EPS motors, ECU, EGR bulbs etc), safety related products (ECU, electronic breaking systems, preventive safety products, air bags etc), informatics (car navigation, ETC related products etc)
Stanley Elec	LED lamp
Koito	LED lamp
Continental	Powertrain related products (fuel injection related products, transmission related products etc), safety related products (electronic breaking systems, preventive safety products, air bags etc), informatics (telematics, head-up displays etc)
Valeo	HEV related products, powertrain related products (electronic products, transmission related products etc), safety related products (preventive safety products etc), LED lamps
Autoliv	Safety related products (preventive safety products, air bags etc)
Delphi	Powertrain related products (starters, alternators , transmission related products etc), safety related products (ECU, electronic breaking systems, preventive safety products etc)
Johnson Control	Interior products, sheet products, informatics (interior instruments etc)
Lear	Sheet products, wire harness
Visteon	Powertrain related products

Source: Company data, Citi Research

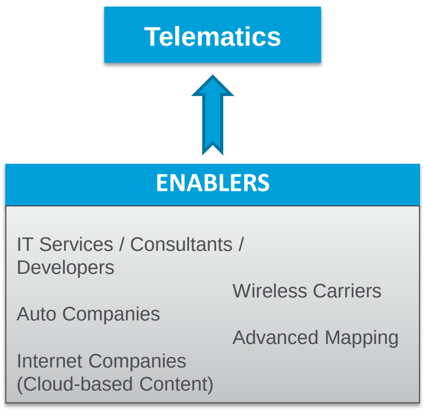
Telematics

The word "Telematics" is the combination of "Telecommunications" and "Informatics" and was originally coined to reflect the blending of computers and phone networks. The Oxford Dictionary defines Telematics as "the branch of information technology that deals with the long-distance transmission of computerized information".

This generic definition embraces a wide range of applications, although the term has become more narrowly aligned with automotive or vehicle telematics because so many recent developments revolve around the "Connected Car" concept. This section devotes a lot of attention to the Connected Car concept but we also highlight other Telematics applications in Fleet Management, Rail Transportation, Insurance and Aerospace.

How Does Telematics Work?

Figure 92. Telematics Enablers

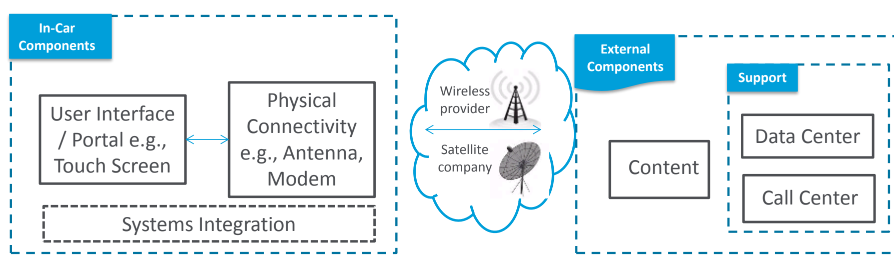


Source: Citi Research

The three components of a basic Telematics solution are Platform, Connectivity and Content/Support. This is illustrated in the Figure below and the providers of these components are the enablers shown in the Figure on the left.

- **Platform –** The user interface or portal – typically a touch screen nowadays – helps the user (driver or passenger) communicate with the system, accepting inputs as well as displaying outputs / responses to requests.
- **Connectivity –** The connection to the external components.
  - The physical connection device, e.g., antenna, modem, etc.
  - The wireless provider or the satellite company.
- **Content / Support -** The external components – this can include OEM-specific and other content, the back-office support and call center support functions.

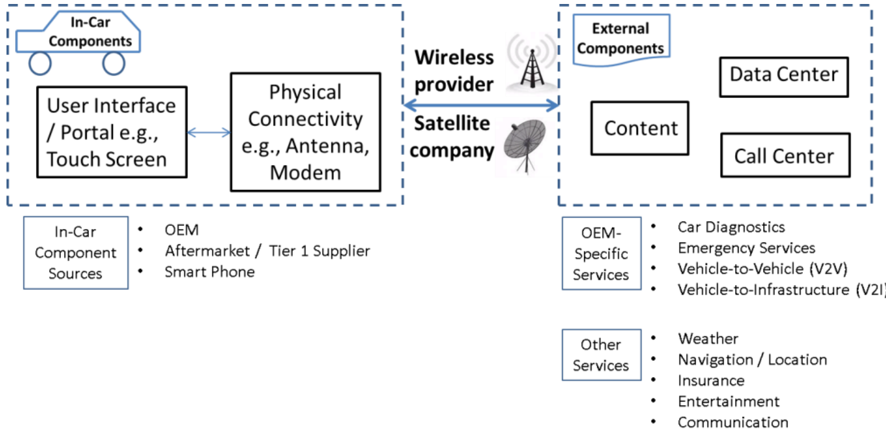
Figure 93. Telematics Components – Platform, Connectivity and Content/Support



Source: Citi Research

Vehicle Telematics brings Mobility and its benefits to the automotive environment. Given Auto companies fashion that environment and the users' experience; they are obviously key enablers of the trend. Figure 94 below shows the various Telematics building blocks and services.

Figure 94. Automotive Telematics Building Blocks and Services

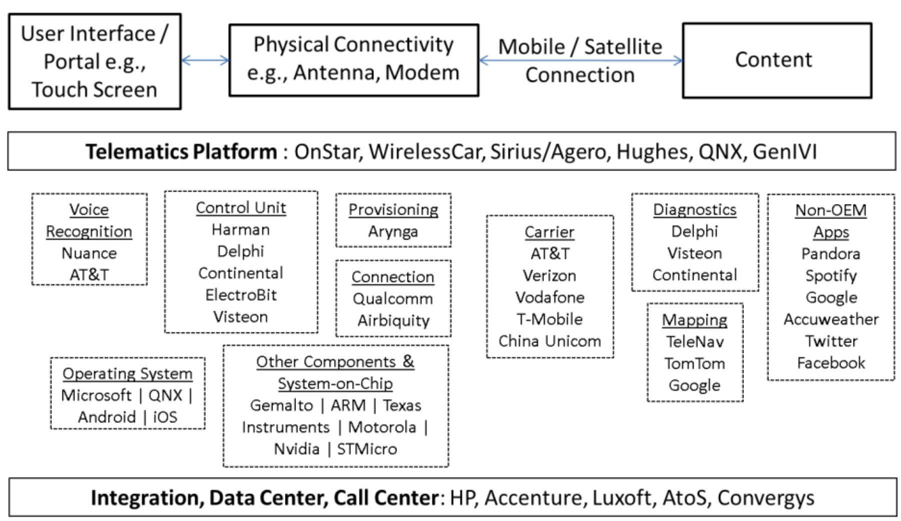


Source: Citi Research

The lower left of the Figure 94 above illustrates that the in-car components can be installed directly by the OEM or the user can have them installed using an aftermarket product or in some cases, the user's smartphone could serve as the portal. The lower right makes the point that certain services like car diagnostics, seem to be best provided by the OEM. At the same time, we believe that the OEM has no particular advantage providing services like weather, entertainment or navigation since commonly-available mobile apps can serve the purpose quite well in those cases.

The Figure below shows the Connected Car Value Chain, including some representative players. The list of companies is not comprehensive.

Figure 95. Automotive Telematics Value Chain and Representative Players



Source: Citi Research

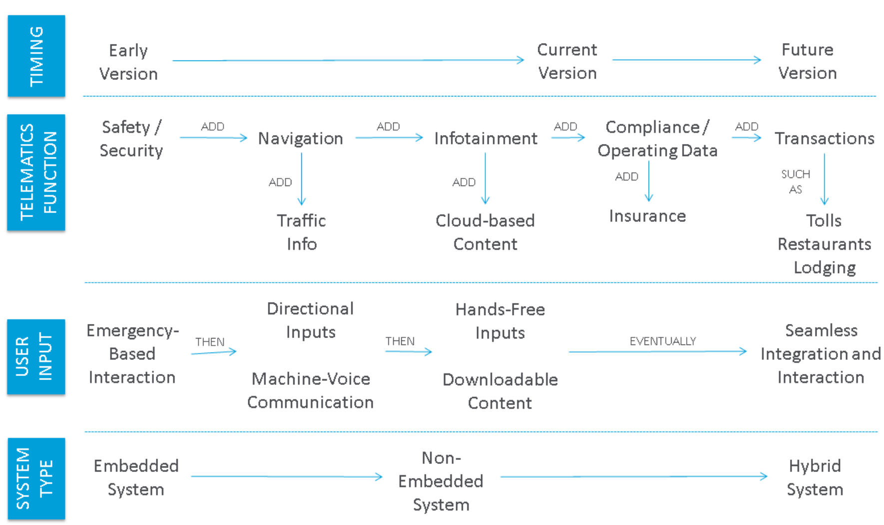
Evolution of Connected Car / Vehicle Telematics

Early Telematics had limited appeal but technology and market advances have moved it from a niche market to mainstream

Vehicle Telematics has been around for a while, but the early versions had limited functionality and consequently, also had limited appeal among consumers. General Motors' initial 1996 implementation of OnStar provided accident notification and emergency use. BMW was the next market entrant, in 2001. Over the last decade several technological and market advances have taken this from a niche offering to the verge of becoming mainstream. The primary change was the proliferation of mobile phones, which led to an increased desire among consumers to be always connected. The rise of smart phones further fueled this trend – the Telematics system no longer had to be embedded, i.e., built into the car and non-embedded systems with access to Internet-based applications became a possibility. The growth of non-embedded systems also opened up the market to aftermarket players in addition to Auto companies. The increasing functionality and consumer demand led to a larger number of Auto companies launching their own Telematics offering.

- *BMW and GM modified their existing offerings in 2007 to include embedded Infotainment. Mercedes and Lexus followed suit. Also, that same year, Honda / Acura introduced non-embedded (mobile) Infotainment.*
- *In 2008-09, Ford introduced their non-embedded "Sync" system. GM standardized its OnStar offering on a wider range of cars in 2009.*
- *In 2010, BMW started offering a non-embedded option for Infotainment. The same year, Infiniti started offering an embedded Telematics option. Toyota brought the Lexus telematics functionality down-market.*
- *2011-13 saw widespread Telematics adoption as well as increased use of the non-embedded option as Hyundai, Subaru, Kia, Chrysler, Volvo all jumped in. So, the last few years have seen near-universal adoption by global auto companies, partly driven by several governments – the EU with its eCall directive and Russia with its Automated Crash Notification (ACN) push – raising the possibility of mandated Telematics in the future, at least for the safety / security function.*

Figure 96. Evolution of Connected Car Feature / Functionality



Source: Citi Research

Telematics Use Cases

The basics of Automotive Telematics are discussed above. Here we discuss some of the pros and cons before we dive into non-automotive Use Cases. Automotive Telematics has shown a steady growth trajectory which should continue. We attribute this to the following reasons.

1. Improves the customer relationship by engaging more frequently with the customer, based on usage data;

2. Tracks customer usage of car features to determine use frequency, which can eliminate wasted features or highlight less-used features that should be modified;

3. Potential for new revenue streams – premium features like streaming audio, video (to back seat) and usage-based insurance;

4. Lowers maintenance cost as some updates and changes can become software-based rather than hardware-based, which would imply they can be done over-the-air (OTA);

5. Legal requirements; and

6. In the case of electric vehicles, promotes peace of mind by providing a current map of charging locations.

Risks - Could Telematics Momentum Stall?

The skepticism around Telematics largely stems from the fact that users have so far been resistant to subscriber-based payment models – in other words, it is not clear how the investment could be effectively recouped.

Competition from non-embedded systems (smartphones) is also a concern but we do not buy this because fully functional Telematics systems should have access to car operations data and that can arguably be better accessed via embedded systems. We do believe, however, that a lot can be done to improve the current user experience associated with a Telematics system by making the look and feel similar to popular smartphone interfaces.

Lastly, privacy concerns are also a potential mitigating factor to the trend.

China Telematics Focus

The market in China is truly unique with ~60% of the passenger vehicle market dominated by foreign and JV brands. Each of these foreign and JV brands have unique positioning and offerings in telematics and connectivity, which includes but is not limited to: (1) BMW ConnectedDrive; (2) Hyundai blueLink; (3) Nissan Carwings; (4) Toyota G-Book; (5) HondaLink; (6) Audi Connect; (7) Ford Sync; and (8) GM's OnStar.

Now, aside from the fact that China market share is dominated by foreign and JV brands, that is not stopping the domestic OEs from rolling out telematics and connectivity products on their own. Below we list key China telematics players and the echo system that currently exists.

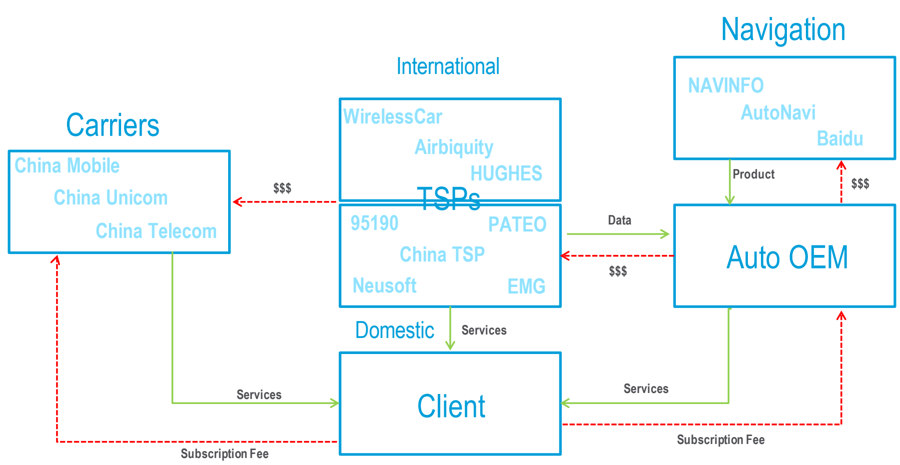
Figure 97. Trajectory Group – China Domestic Telematics Players

OEM	System		China Launch
SAIC/Roewe	inkaNet		2010
Hawtai	Intelligent Decision System TIVI		2010
Geely	G-Netlink		2011
FAW	D-Partner		2011
Dongfeng/Yulon	Think+		2011
Changan	In Call		2011
BYD	i-System		2011
Chery	NetCar, Mobile in Vehicle (MIV)		2011
SGM	eMotion		Planned
GAIG's Trumpchi			Planned
Qoros			Planned

Source: Trajectory Group

The telematics ecosystem for China is very unique. Multiple players exist with each offering value added services ultimately for the end consumer

Figure 98. China Telematics Ecosystem



Source: Trajectory Group, Citi Research

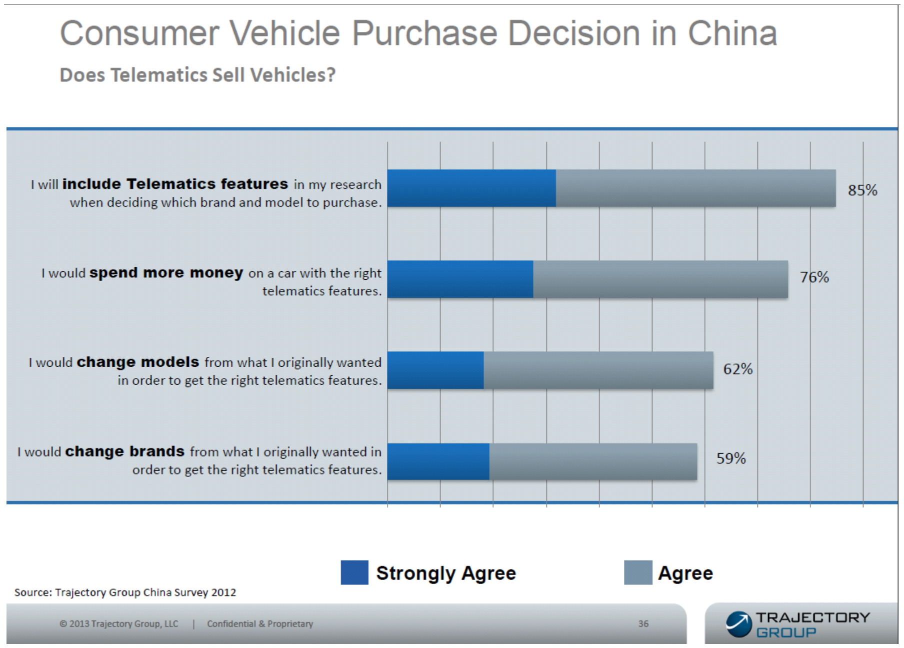
The Sale: The Trajectory Group's unique survey helps to isolate certain key points regarding the stickiness, revenue opportunity, and consumer elasticity of telematics services.

Telematics is truly becoming an integral part of the consumers purchasing decision

85% of those surveyed agreed in some fashion that they will include telematics features in their purchase decision

76% say they would spend more money on the car with the right telematics features

Figure 99. Purchase Decision

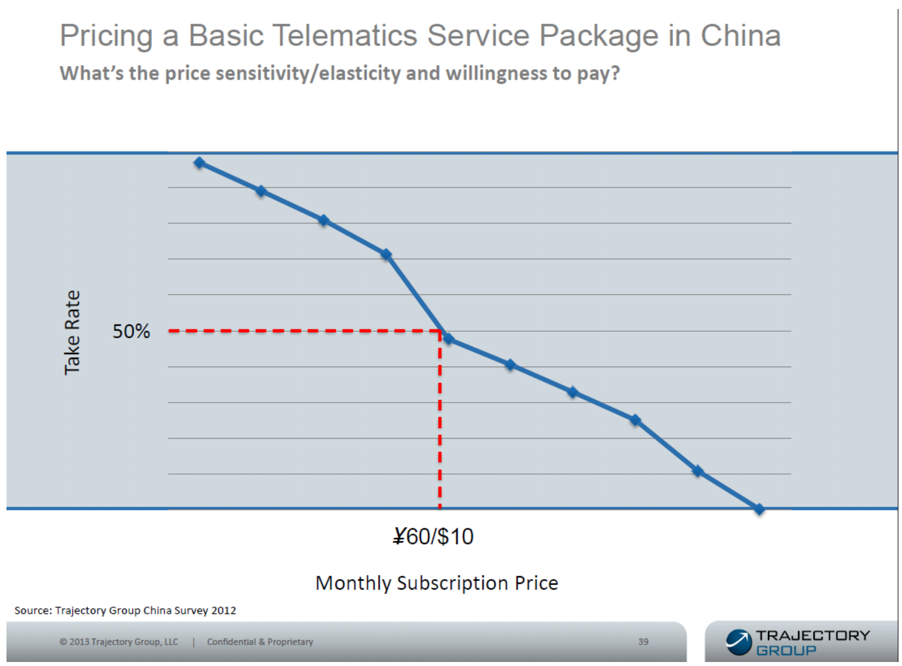


Source: Trajectory Group, Citi Research

The Subscription Pricing: The 76% willing to spend more money on the right telematics features brings up quite the interesting point…how can one monetize the telematics trend? Again, we turn to the Trajectory Group's survey for answers.

The chart at the right highlights customers' elasticity for telematics pricing packages. In order to achieve a 50% take rate, the monthly subscription price would need to be ~$10/month.

Figure 100. Telematics Product Pricing



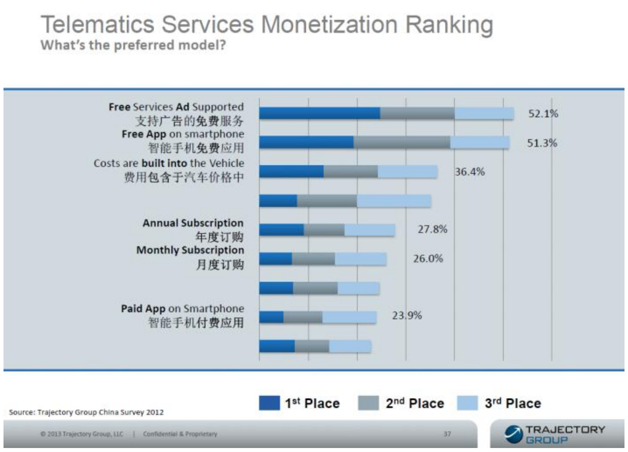
Source: Trajectory Group

Other Service Uptake Alternatives: Now that we've had a look at a hypothetical subscription model price per month, we need to evaluate how consumers view this option relative to other potential options.

According to the Trajectory Group the most preferred method of telematics uptake would be via free services with ads supported; 52.1% of those surveyed ranked this as a top 3 choice. Other options include: (1) Free Smartphone App – 51.3% had as a top 3 choice; (2) costs built into the vehicle – 36.4% had as a top 3 choice; and (3) annual/monthly subscriptions – 28% and 26% had as a top 3 choice, respectively.

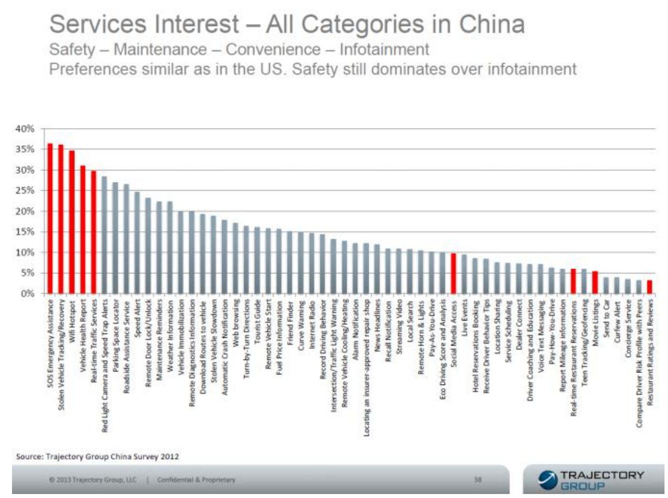
The Conclusion: The wants and use cases for telematics in China is not that different from what we are seeing in the US. Both regions have a strong preference to use telematics to increase vehicle safety, ease of maintenance, convenience, and for infotainment; of those top preferences, safety takes the pole position. The figure below highlights telematics use cases from the Trajectory Group's China survey.

Figure 101. Services Monetization Preferences



Source: Trajectory Group

Figure 102. Telematics Use Cases



Source: Trajectory Group

How OEMs Can Leverage Connected Cars

At the core, a connected car introduces a greater opportunity for automakers to profit throughout a vehicle's life. In previously mapping this, we've identified three buckets: 1) Auto margin enhancement from lower warranty, streamlined advertising and greater loyalty; 2) Enhanced telematics & infotainment services; and 3) Leveraging big data through numerous schemes.

Auto Margins: The Connected Car could provide a modest but permanent boost to automaker profit margins to the tune of 20-50bp, through lower warranty costs & streamlined advertising. The collection of read-time data, remote software updates will allow for early detection of quality/design issues. We believe that over time this will reduce the need to over-engineer and allow for a better understanding of a vehicle's lifetime performance. Industry expert Roland Berger estimates that OEM warranty/claim costs could be reduced by 30-50%. Additionally, Cisco has estimated 10% lower costs to service vehicles, including warranty savings. Warranty benefits would come in the way of remote diagnostics & fixes, which 3rd party estimates.

Figure 103. Warranty Cost Savings Potential

Warranty Cost Savings Potential

		2011	2012					
Ford	Global Revenue	128,168	126,567	% Warranty Saved	5%	15%	30%	40%
	Global Warranty Expense	2,215	1,885	Margin Benefit	0.07%	0.22%	0.45%	0.60%
	% of Revenue	**1.7%**	**1.5%**	**EPS Benefit**	**$0.02**	**$0.05**	**$0.10**	**$0.13**

		2011	2012					
GM	Global Revenue	148,866	150,295	% Warranty Saved	5%	15%	30%	40%
	Global Warranty Expense	3,062	3,394	Margin Benefit	0.11%	0.34%	0.68%	0.90%
	% of Revenue	**2.1%**	**2.3%**	**EPS Benefit**	**$0.07**	**$0.21**	**$0.43**	**$0.57**

Source: Citi Research

Streamline Customer Communication: In today's current environment OEMs spend roughly 3-4% of revenue on advertising; a reduction in costs by 5% translates to roughly 20bps of margin opportunity. 3-4% of revenue on advertising represents a good portion of revenue, but when we think customer interaction outside of that initial push, OEMs aren't that actively or directly engaged with customers throughout the vehicle's lifecycle. Connected cars allow for the opportunity to offer unique services such as: 1) near real-time trade-in value estimates & new vehicle "trade ideas"; 2) special offers; 3) service reminders; 4) test drive offers; and 5) feedback. These opportunities should get OEMs in front of customers allowing them to gain valuable brand loyalty; OEM loyalty runs in the 40-50% range and a 1% point improvement is roughly $200 million or more of profit potential. A recent 3rd party survey shows that >80% of consumers will base an opinion of an OEM on their connected services.

Ads & Big Data: There are a lot of unknowns surrounding this theme, and one of them revolves around consumers' willingness to pay. Surveys suggest some willingness to pay but with clearer willingness to forfeit data in exchange for a lower price. To that, in-vehicle advertising and 3rd party data monetization could allow automakers to partially subsidize costs and/or earn an extra margin. 3rd party surveys have shown that >70% of consumers would be willing to accept in-vehicle advertising to reduce the costs. Additionally, >70% of consumers would be willing to share connected car data with OEMs and dealers to reduce costs. If we assume

that ads are displayed upon a vehicle turning on & off while in Park and further assume that a car is used 6 days per week for 1 round trip per day, then that is 24 opportunities per week for ad penetration. If we further assume that 2 ads trigger per opportunity and that there is an average of 2 occupants per car then that yields ~400 impressions per month. In a 3rd part survey >50% of consumers expressed willingness to share personal data with OEMs & dealers. A Cisco survey concluded that 74% would allow their driving habits to be monitored in order to save money.

Enhanced Telematics/Infotainment: Improved connectivity can meaningfully enhance existing telematics services and create a push for new services; next-gen safety and security, remote car sharing, UBI, diagnostics, and concierge services are just a few of the opportunities. In addition, going back to the issue of vehicle propulsion, a connected car could allow automakers to offer consumer guaranteed payback on fuel saving technologies, presumably if a driver's behavior met certain predetermined bandwidths (aggressive driving increases fuel consumption. Since consumers often distrust fuel economy labels, such a mechanism could allow automakers to more confidently invest in technologies where the payback could be assured to the end user.

There's Money Here: Back in May 2013, IHS estimated that OnStar's 4G LTE could add $400 million to estimated gross profit by mid-decade. A more recent data point came from Sirius XM's (covered by Jason Bazinet) recent earnings call where the company provided an outlook for Connected Car services. Siri expects Connected Car services to deliver close to $100 million in revenue this year with expected "strong double-digit rates over the next many years". The business is expected to be at or near EBITDA breakeven in 2014, but over time should see a similar "financial profile of connected vehicle services as satellite radio". Note that SIRI's 2014 EBITDA margin guidance is implied at >30%. We viewed this outlook as a positive read in terms of the potential for GM to continue growing OnStar and generate margins/returns that are far higher than that of a traditional automaker's profile. By way of background, Siri is a growing player in vehicle telematics services having become an estimated #2 player after the August 2013 acquisition of Agero. GM's wholly-owned OnStar division remains the market leader (including in China), though a key difference of course is that OnStar exclusively serves GM while Sir serves a handful of automakers including Nissan. Based on our prior OnStar revenue estimate (north of $1bn), a 30-35% margin and the potential for growth from the 4G LTE rollout, we continue to value OnStar standalone at $7-10bn using market multiple comparisons (Sirius multiple and Verizon/Hughes deal).

Figure 104. IHS OnStar Profit Forecast

IHS OnStar Profit Forecast (May 2013)

GM

OnStar IHS Estimates	2011	2012	2013E	2014E	2015E	2016E	2017E	2018E
OnStar Gross Profit - Pre LTE	$654	$729	$791	$854	$912	$963	$997	$1,014
OnStar Gross Profit- Post LTE	$654	$729	$791	$977	$1,107	$1,370	$1,482	$1,567
LTE Add:	**$0**	**$0**	**$0**	**$123**	**$195**	**$407**	**$485**	**$553**
@ 10x (Citi Estimate, Not HIS)	$0	$0	$0	$1,230	$1,950	$4,070	$4,850	$5,530
/ per GM Share	$0.0	$0.0	$0.0	$0.7	$1.2	$2.5	$2.9	$3.3
Source: IHS Estimates in Citi Call Presentation, May 2013								

IHS Assumptions: (1) LTE Data Subs Penetration: 10% (CY14), 40% (CY18); (2) AT&T/GM Revenue Split: 60/40; (3) Monthly sub price (w/data): $30-50; (4) GM Internal Data Cost: 5%; (5) Extrapolation from GM CEO comments regarding $20 revenue opportunity per car.

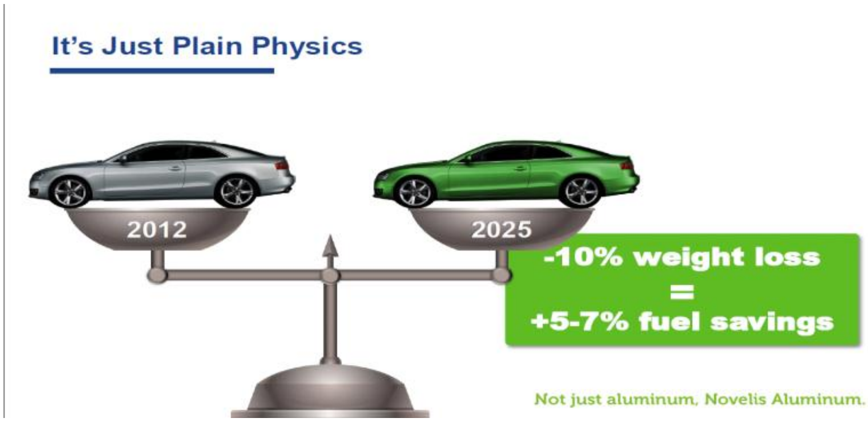
Source: Citi Research

Building the Car of the Future

Lightweighting

Vehicle lightweighting is the process of using lighter materials such as aluminum and composites to drive a reduction in overall vehicle weight. In doing so, manufacturers will be more apt to reach CO_2 emissions standards as well as targeted mile per gallon (MPG) standards for their fleets. While lightweighting will play a pivotal role in the evolution of the automobile, it is not without its challenges. For one, the costs for these materials are typically higher than their heavier counterparts; also, the mechanical properties differ (key being energy absorption; modulus of toughness), thus requiring extensive testing for which components can be created using the new lighter materials without impacting the structural integrity of the vehicle. Bonding and corrosion of these lighter weight materials also pose challenges. When taking into account regional CO_2 emission standards, a general rule is that for every 10kg of reduction in weight, a car emits 1g/km less of CO_2.With current regulation in Europe requiring OEMs to reduce CO_2 emissions to 95g/km by 2020, lightweight materials such as aluminum, high-strength steel, and other metals/composites are key to meeting standards. On top of the reduced emissions, lightweighting also offers the benefit of increased fuel savings; it is estimated that every -10% of weight loss equates to +5-7% in fuel savings.

Figure 105. Weight Loss Equates to Fuel Savings



Source: Novellis

Lightweight Materials

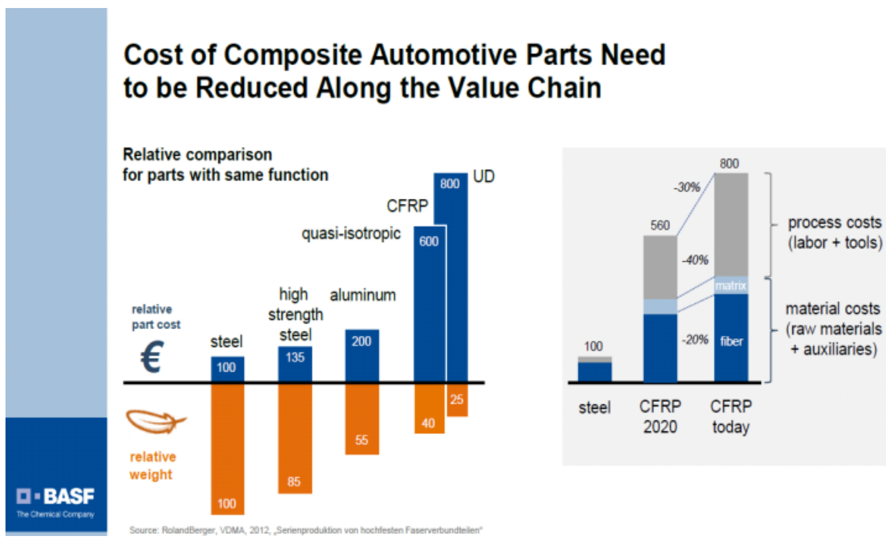
When one thinks about using lightweight materials it is important to consider how they will fit into the Car of the Future and exactly what will be the use cases. We know that steel is universal and used in vehicle frames, bumpers, and intrusion beams etc., but what roles can these new lightweight materials fill?

Aluminum and other lightweight materials have fundamentally different mechanical properties, relative to steel. Parts that are created using these new lightweight materials need to be extensively tested to make sure that structural integrity is maintained, and this is ultimately a measure of energy absorption.

The most obvious place to reduce weight is from the car frame, which is the heaviest single component of the car. Steel is cheap, has high energy absorption (Modulus of Toughness), is easily obtainable and can be molded relatively easily; this is why it is currently used for most car frames. However, it is increasingly being substituted by other materials, principally aluminum and high strength steel (lighter weight).

- **High Strength Steel (HSS):** HSS is 10-20% lighter than steel and the least costly replacement option to traditional steel. While it can fill roles of structural parts that require higher strength, the HSS is actually more difficult to form given its higher strength. Vehicle pillars (A-,B-, Hinge-pillars), arches connecting pillars, and rocker panels are some components of a vehicle that will utilize HSS.
- **Aluminum:** Aluminum has been used in cars for almost 100 years and is 40-45% lighter than steel and costs ~2x more than steel; it also requires a significant investment in production lines processes for vehicle integration. It can fill roles that span from structural parts to functional parts given its structural stiffness. Currently aluminum is used in trim, body structure, body skin sheets, wheels, suspension components, wiring, powertrain castings, and bumper beams, just to name a few instances.
- **Carbon-fiber-reinforced Polymer (CFRP):** CFRP is ~60% lighter than traditional steel with costs ~6x that of steel. It is a high-strength material, resilient, could reduce fuel consumption by ~30% and increases passenger safety. A key obstacle to its usage, however, has been the high cost and the longer processing cycle time required. CFRP can be used in frames, hoods, tailgates, and in higher performance vehicles such as the monocoque chassis ("safety cell") fitted to an aluminum drive module (BMW i3).

Figure 106. Relative Weight & Part Cost Comparison



Source: BASF

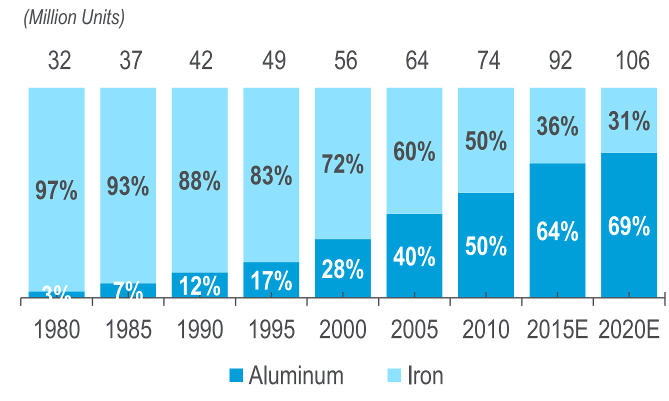
Lighter Engine Blocks

As noted above, aluminum is being increasingly adapted into the vehicle powertrain. Figure 107 and Figure 108 illustrate the ongoing evolution of aluminum use in cylinder heads and engine blocks for light vehicles; the use of aluminum in cylinder heads is mature, yet growth within engine blocks continues to accelerate.

However, there remain constraints to the use of aluminum in engine blocks, aside from costs. Aluminum is a less resistant metal vs. cast iron, which creates limitations in the use in high-performance / high-torque engines (typically diesel engines), where the explosion of the fuel-air mixture generates extreme pressure.

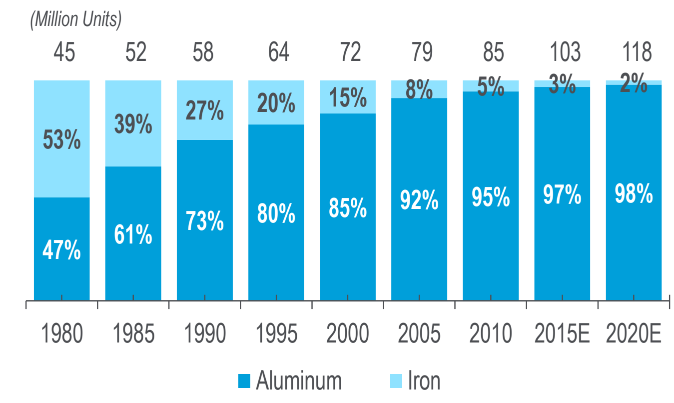
Nevertheless, aluminum engine block producers like Nemak, a subsidiary of Alfa and a leading supplier to US and European OEMs, remain optimistic on the pace of penetration of aluminum in engine blocks and the adaptation into diesel engines. Nemak expects aluminum engine blocks to represent 67% of total global production of light vehicle engines over the next five years (vs. ~60% today)

Figure 107. Global Engine Blocks for Light Vehicles (Aluminum vs. Iron)



Source: Nemak

Figure 108. Global Cylinder Heads for LV (Aluminum vs. Cast Iron)



Source: Nemak

Citi's NA Metals and Mining Commodity Pricing Model

In order to provide more detail on the pricing trends of commodities that have potential use in the automobile industry, we highlight the pricing model of Citi's North American Metals & Mining team. For the remainder of this section, we incorporate this pricing model into some of our analysis to calculate potential incremental costs per vehicle using select lightweight materials. Our analysis assumes the following: 1) CRC pricing serves as a proxy for regular steel; 2) Hot Dipped Galvanized pricing serves as a proxy for high strength steel; 3) 1 Tonne = 2,204.62 pounds; and 4) 1 Ton = 2,000 pounds.

Figure 109. Citi's Commodity Pricing Model

Citi Commodity Forecasts	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Copper (USc/lb)	241	342	400	360	333	308	323	349	363	372
Nickel ($/lb)	7	10	10	8	7	8	10	11	12	11
Aluminum (USc/lb	78	99	110	93	85	80	85	88	95	100
HRC ($/ton)	$492	$604	$743	$656	$627	$627	$595	$590	$600	$605
CRC ($/ton)	$592	$743	$868	$763	$734	$733	$695	$690	$700	$705
Hot Dipped Galvanized ($/ton)	$692	$843	$968	$863	$834	$833	$795	$790	$800	$805
CR Stainless 304 Sheet ($/ton)	$2,373	$3,296	$3,531	$2,849	$2,509	$2,719	$3,519	$4,010	$4,256	$4,092
Conversion to Pounds										
Copper	$2.41	$3.42	$4.00	$3.60	$3.33	$3.08	$3.23	$3.49	$3.63	$3.72
Nickel	$6.74	$9.89	$10.38	$7.98	$6.85	$7.53	$9.75	$11.11	$11.79	$11.34
Aluminum	$0.78	$0.99	$1.10	$0.93	$0.85	$0.80	$0.85	$0.88	$0.95	$1.00
HRC	$0.25	$0.30	$0.37	$0.33	$0.31	$0.31	$0.30	$0.30	$0.30	$0.30
CRC	$0.30	$0.37	$0.43	$0.38	$0.37	$0.37	$0.35	$0.35	$0.35	$0.35
Hot Dipped Galvanized	$0.35	$0.42	$0.48	$0.43	$0.42	$0.42	$0.40	$0.40	$0.40	$0.40
CR Stainless 304 Sheet	$1.19	$1.65	$1.77	$1.42	$1.25	$1.36	$1.76	$2.01	$2.13	$2.05

Source: Citi Research NA Metals and Mining Team

Lightweighting Potential Incremental Costs

With the framework in place for vehicle weight savings, emission savings and increased passenger safety, we attempt to calculate the incremental potential costs of lightweighting at the raw material level for OEMs. It is important to note that for all the analysis below, we use certain material pricing from our NA Metals and Mining team's Commodity Pricing model; using their forecasts for these materials acts purely as a proxy for raw materials that OEMs **MAY** use in production. As there are varying degrees of steel, aluminum, and other metals, the analyses below are just meant to provide a high level view on potential incremental costs of lightweighting.

In order to run this analysis, we must first take note of all figures and forecasts being used to help drive the end results. Therefore, we make use of the following:

(1) Citi's NA Metals pricing model – this will help us assess current commodity prices as well as future forecasted prices. We use this forecast in accordance with a weight (in pounds) of a certain material per vehicle (historical and forecasted). **Price** multiplied by the weight will yield cost of a material "x" per car.

(2) The American Chemistry Council's analysis on vehicle composition by materials – this provides us with the average percentage of materials in a vehicle as well as the approximate weight of the average vehicle in North America. We use this as the base value when running CAGRs and comparisons for forward-looking material contribution per vehicle. Price multiplied by the **Weight** will yield cost of a material "x" per vehicle.

(3) 2025 Forecast of Lightweight Materials by Ducker Worldwide – Ducker Worldwide forecasts the average 2025 material content for North American light vehicles as follows: 1) Regular Steel – 950 pounds/vehicle; 2) High & Medium Strength Steel – 858 pounds/ vehicle; 3) Aluminum – 550 pounds / vehicle; 4) Plastics/ Composites – 400 pounds/ vehicle; and 5) Magnesium – 100 pounds / vehicle. We then take Ducker Worldwide's forecast for an average vehicle to be 400 pounds lighter by 2025 and run a 2013 to 2025 CAGR. We utilize these CAGRs in conjunction with the base 2012 American Chemistry Council percent material composition per vehicle and the average vehicle weight; we grow these materials and vehicle weight at their respective CAGR to figure out potential percentages per material and average vehicle weight by year. This serves as our weight variable of the equation.

The figure below is a combination of the three points above. Regular steel, High- & Medium-Strength Steel, Aluminum, Magnesium, Plastics/Composites, and vehicle weight were all grown at their respective 2013 to 2025 CAGRs. The values in the table are representative of weight in pounds. We then run a quick analysis on percentage of total vehicle weight per material.

Figure 110. Average NA LV Material Composition

Legend:	ACC = American Chemistry Council																							
	DW = Ducker Worldwide																							
	DW CAGR = Ducker Worldwide CAGR Applied Annually																							
Source:	ACC	ACC	ACC	ACC	ACC	ACC	ACC	ACC	ACC	ACC	ACC	DW CAGR	DW CAGR	DW CAGR	DW CAGR	DW CAGR	DW CAGR	DW CAGR	DW CAGR	DW CAGR	DW CAGR	DW CAGR	DW CAGR	DW
	2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013E**	**2014E**	**2015E**	**2016E**	**2017E**	**2018E**	**2019E**	**2020E**	**2021E**	**2022E**	**2023E**	**2024E**	**2025E**
Regular Steel	1,649	1,646	1,650	1,634	1,622	1,644	1,627	1,501	1,458	1,439	1,346	1,310	1,276	1,242	1,209	1,177	1,146	1,116	1,086	1,058	1,030	1,002	976	950
High- & Medium-Strength Steel	443	460	479	491	502	518	523	524	555	608	606	622	639	657	674	693	711	731	751	771	792	813	835	858
Stainless Steel	64	65	70	71	73	75	75	69	72	73	68													
Other Steels	30	32	34	35	34	34	33	31	32	32	30													
Iron Castings	355	336	331	328	331	322	253	206	240	265	280													
Aluminum	289	299	311	316	323	319	316	324	338	356	364	376	388	400	413	427	440	455	469	484	500	516	533	550
Magnesium	9	10	10	10	10	10	11	11	11	12	11	13	15	18	22	26	30	36	43	51	60	71	84	100
Copper & Brass	69	70	71	71	67	66	71	71	74	73	72													
Lead	35	35	37	38	39	41	44	42	41	40	37													
Zinc Castings	10	10	10	10	10	9	9	9	9	9	8													
Poweder Metals	39	41	43	42	42	43	43	41	41	42	44													
Other Metals	4	4	5	4	5	5	5	5	5	5	5													
Plastics/ Composites	307	319	338	334	341	338	347	382	363	362	355	358	362	365	368	372	375	379	382	386	389	393	396	400
Rubber	168	169	172	179	187	188	200	236	230	223	210													
Coatings	26	25	28	27	29	29	30	34	34	34	33													
Textiles	45	46	51	49	47	46	48	58	56	50	49													
Fluid and Lubricants	209	210	210	210	211	215	214	217	219	221	217													
Glass	104	105	105	104	105	103	99	88	92	98	95													
Other	79	83	86	87	89	92	91	90	92	93	90													
	3,934	**3,965**	**4,041**	**4,040**	**4,067**	**4,097**	**4,039**	**3,939**	**3,962**	**4,035**	**3,920**	**3,888**	**3,856**	**3,824**	**3,792**	**3,761**	**3,730**	**3,699**	**3,669**	**3,639**	**3,609**	**3,579**	**3,549**	**3,520**
Regular Steel	41.9%	41.5%	40.8%	40.4%	39.9%	40.1%	40.3%	38.1%	36.8%	35.7%	34.3%	33.7%	33.1%	32.5%	31.9%	31.3%	30.7%	30.2%	29.6%	29.1%	28.5%	28.0%	27.5%	27.0%
High- & Medium-Strength Steel	11.3%	11.6%	11.9%	12.2%	12.3%	12.6%	12.9%	13.3%	14.0%	15.1%	15.5%	16.0%	16.6%	17.2%	17.8%	18.4%	19.1%	19.8%	20.5%	21.2%	21.9%	22.7%	23.5%	24.4%
Stainless Steel	1.6%	1.6%	1.7%	1.8%	1.8%	1.8%	1.9%	1.8%	1.8%	1.8%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Other Steels	0.8%	0.8%	0.8%	0.9%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iron Castings	9.0%	8.5%	8.2%	8.1%	8.1%	7.9%	6.3%	5.2%	6.1%	6.6%	7.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Aluminum	7.3%	7.5%	7.7%	7.8%	7.9%	7.8%	7.8%	8.2%	8.5%	8.8%	9.3%	9.7%	10.1%	10.5%	10.9%	11.4%	11.8%	12.3%	12.8%	13.3%	13.9%	14.4%	15.0%	15.6%
Magnesium	0.2%	0.3%	0.2%	0.2%	0.2%	0.2%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.4%	0.5%	0.6%	0.7%	0.8%	1.0%	1.2%	1.4%	1.7%	2.0%	2.4%	2.8%
Copper & Brass	1.8%	1.8%	1.8%	1.8%	1.6%	1.6%	1.8%	1.8%	1.9%	1.8%	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Lead	0.9%	0.9%	0.9%	0.9%	1.0%	1.0%	1.1%	1.1%	1.0%	1.0%	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Zinc Castings	0.3%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Poweder Metals	1.0%	1.0%	1.1%	1.0%	1.0%	1.0%	1.1%	1.0%	1.0%	1.0%	1.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Other Metals	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Plastics/ Composites	7.8%	8.0%	8.4%	8.3%	8.4%	8.2%	8.6%	9.7%	9.2%	9.0%	9.1%	9.2%	9.4%	9.5%	9.7%	9.9%	10.1%	10.2%	10.4%	10.6%	10.8%	11.0%	11.2%	11.4%
Rubber	4.3%	4.3%	4.3%	4.4%	4.6%	4.6%	5.0%	6.0%	5.8%	5.5%	5.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Coatings	0.7%	0.6%	0.7%	0.7%	0.7%	0.7%	0.7%	0.9%	0.9%	0.8%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Textiles	1.1%	1.2%	1.3%	1.2%	1.2%	1.1%	1.2%	1.5%	1.4%	1.2%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fluid and Lubricants	5.3%	5.3%	5.2%	5.2%	5.2%	5.2%	5.3%	5.5%	5.5%	5.5%	5.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Glass	2.6%	2.6%	2.6%	2.6%	2.6%	2.5%	2.5%	2.2%	2.3%	2.4%	2.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Other	2.0%	2.1%	2.1%	2.2%	2.2%	2.2%	2.3%	2.3%	2.3%	2.3%	2.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Source: American Chemistry Council, Ducker Worldwide, Citi Research Estimates

To start the analysis, we take the material weights from the American Chemistry Council analysis from 2012 and multiply those weights by the cost per pound from Citi's NA Metals pricing model. We run this analysis for each material and find that in 2012, these select materials cost roughly $1,113 total. We apply the same type of analysis to 2018 estimates, using the Ducker Worldwide CAGR, and see the cost of these three materials in 2018E is approximately $1,119 – a $6 increase in cost. The reason why the increased in cost is minimal is because the overall weight per vehicle has been reduced. The lower weight allows for less to be spent on steel, and ultimately the pounds of steel coming out of the vehicle, relative to the aluminum addition, mitigate the impact of total cost. In this example, 2.6 pounds of steel is removed for every 1 pound of aluminum added.

Figure 111. Steel Cost Analysis

	2012E	2018E	'12-'18 Delta
Average Vehicle Weight (lbs)	**3,920**	**3,730**	(190)
Regular Steel (lbs)	1,346	1,146	(200)
High- & Medium- Strength Steel (lbs)	606	711	105
Aluminum (lbs)	364	440	76
// CRC proxy as cost for Regular Steel; Galvanized CRC proxy as cost for High-/Medium- Strength Steel			
Regular Steel ($/lb)	$0.38	$0.35	($0.03)
High- & Medium- Strength Steel ($/lb)	$0.43	$0.40	($0.03)
Aluminum ($/lb)	$0.93	$1.00	$0.07
Regular Steel	$513.43	$393.30	($120)
High- & Medium- Strength Steel	$261.46	286.38	25
Aluminum	$338.28	439.47	101
	$1,113.16	**$1,119.14**	**$6**

Source: American Chemistry Council, Ducker Worldwide, Citi Research Estimates

Ford's 2015 F-150 Aluminum Analysis

We now attempt to estimate the incremental potential cost of certain lightweight raw materials for the 2015 Ford F-150. First, we establish a base estimate for the cost of those certain lightweight materials in the 2014 F-150. We use the American Chemistry Council's 2012 percentage contribution of materials and apply this to the 2014 F-150 curb weight. We believe that this is a fair assumption given that the weight of the 2012 and 2014 F-150 is quite similar.

Figure 112. Step 1: Pounds of Material 2014 F-150

F-150 Analysis	**2014**	
Curb Weight (lbs)	5,043	
	% of LV (ACC)	***lb of Material***
Regular Steel	34.3%	*1732*
High- & Medium- Strength Stee	15.5%	*780*
Stainless Steel	1.7%	*87*
Other Steels	0.8%	*39*
Iron Castings	7.1%	*360*
Aluminum	9.3%	*468*
Magnesium	0.3%	*14*
Copper & Brass	1.8%	*93*
Lead	0.9%	*48*
Zinc Castings	0.2%	*10*
Powder Metals	1.1%	*57*
Other Metals	0.1%	*6*
Plastics/Composites	9.1%	*457*
Rubber	5.4%	*270*
Coatings	0.8%	*42*
Textiles	1.3%	*63*
Fluid and Lubricants	5.5%	*279*
Glass	2.4%	*122*
Other	2.3%	*116*

Source: American Chemistry Council, Citi Research

Step 1: We utilize the most recent American Chemistry Council figures for 2012; this serves as a base for the percentages of materials in a light vehicle in NA. We apply this to the 2014 Ford F-150 weight (Supercab/Supercrew V6 variant). The 2014 weight is comparable to 2012 curb weight, so we assume material composition relatively flat in order to determine the approximate weight of materials in the 2014 F-150.

Now that we have approximate weight in pounds for the material composition, we can quickly apply the pricing from Citi's 2014 NA Metals Pricing Model to figure out the cost per select lightweight materials.

Figure 113. Step 2: Proxy for F-150 Cost of Metals in 2014

2014			
F-150 Approximate Vehicle Weight (lbs)	5,043		
	lbs	**cost/pound**	**cost**
Aluminum	468	$0.80	$375.55
High-Strength Steel (Dipped Galv as Proxy)	780	$0.42	$324.61
Steel (CRC as Proxy)	1,732	$0.37	$634.42
Copper & Brass (Copper as proxy)	93	$3.08	$285.52
Stainless Steel (CR Stainless 304 as proxy)	87	$1.36	$118.92
Total	**3,159.59**		**$1,739.01**
% of total weight	62.7%		

Source: American Chemistry Council, Citi Research Estimates

Step 2: We run the major steel components' weight in the 2014 F-150 through our Commodity Pricing Model (Citi's NA Metals and Mining team) to figure out approximate costs per material.

We now hone the analysis to focus on aluminum. We use estimates from Ford's press releases, certain periodicals and conversations with industry contacts. As the estimate on aluminum content per vehicle runs the gamut, we run a scenario analysis based on the anticipated weight of the 2015 F-150 and the percentage of aluminum per vehicle. We cap our analysis at ~1,000 pounds of aluminum content which equates to approximately 23% of total vehicle weight. We then go and compare the cost of aluminum using 2015 estimates from Citi's Commodity Pricing Model versus the approximate costs of the 2014 F-150.

Step 3: We run a scenario analysis on aluminum content and respective cost per F-150, given numbers from press releases as well as periodicals.

Figure 114. Step 3: 2015 F-150 Aluminum Analysis

2015 F-150		
F-150 Ap	4,343	*// Ford says vehicle will be up to 700lbs lighter (1/13/14 press release)*
2015E C	$0.85	*// Citi's NA Metals and Mining Aluminum cost/lb estimate*
Weight Sa	450	*// 1/10/2014 NYT Article "The F-150's Aluminum Diet"*
Weight Sa	250	*// 1/10/2014 NYT Article "The F-150's Aluminum Diet"*
Estimated	~ 1000	*// 1/10/2014 NYT Article "The F-150's Aluminum Diet"*

Aluminum Content in Vehicle

f vehicle	lbs	Cost of Aluminum	Delta vs. 2014 Cost
10%	434	$368.38	($7.16)
12.50%	543	$460.48	$84.93
15.00%	651	$552.57	$177.03
17.50%	760	$644.67	$269.12
20.00%	869	$736.76	$361.22
22.50%	977	$828.86	$453.31

Source: Citi Research

In order to keep the analysis flowing smoothly, we largely assume that an increase in aluminum will likely result in the consumption of less regular steel. We utilize Ducker Worldwide's forecast CAGR for lightweight materials in 2025 to come up with a 2015 estimate. For the other materials (ex. iron castings and other), we look at the 3- and 5-year historical CAGR for pounds of material of all materials and utilize that CAGR as our target 3YR forward CAGR for 2012-2015. For iron castings, we believe in the 2015 F-150 there is potential for aluminum powertrain castings to further reduce weight, so we reduce the weight for this material more aggressively.

Step 4: We hold materials, excluding Regular Steel, High-/Medium- Strength Steel, Aluminum, Magnesium, and Plastics/Composites, at the pound per LV 2012 level; we make some minor tweaks to adjust the weight per material to levels in line with the historical 3 & 5YR CAGR (we further reduce "other" and "iron casting").We then use Ducker Worldwide's implied '12-'25 CAGRs to achieve an expected 2015E level.

Figure 115. Step 4: 2015 F-150 Approximate Material Composition

		AL = 10%	AL = 12.5%	AL = 15%	AL = 17.5%	AL = 20%	AL = 22.5%
F-150 Analysis	**2012**	**2015E**	**2015E**	**2015E**	**2015E**	**2015E**	**2015E**
Curb Weight (lbs)	5,043	4,343	4,343	4,343	4,343	4,343	4,343
Regular Steel	34.3%	**25.7%**	**23.2%**	**20.7%**	**18.2%**	**15.7%**	**13.2%**
High- & Medium- Strength Steel	15.5%	**19.5%**	**19.5%**	**19.5%**	**19.5%**	**19.5%**	**19.5%**
Stainless Steel	1.7%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
Other Steels	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%
Iron Castings	7.1%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Aluminum	9.3%	**10.0%**	**12.5%**	**15.0%**	**17.5%**	**20.0%**	**22.5%**
Magnesium	0.3%	**0.5%**	**0.5%**	**0.5%**	**0.5%**	**0.5%**	**0.5%**
Copper & Brass	1.8%	2.3%	2.3%	2.3%	2.3%	2.3%	2.3%
Lead	0.9%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
Zinc Castings	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Powder Metals	1.1%	1.3%	1.3%	1.3%	1.3%	1.3%	1.3%
Other Metals	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Plastics/Composites	9.1%	**10.8%**	**10.8%**	**10.8%**	**10.8%**	**10.8%**	**10.8%**
Rubber	5.4%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%
Coatings	0.8%	1.1%	1.1%	1.1%	1.1%	1.1%	1.1%
Textiles	1.3%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%
Fluid and Lubricants	5.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%
Glass	2.4%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%
Other	2.3%	2.1%	2.1%	2.1%	2.1%	2.1%	2.1%
Regular Steel	1,732	**1,117**	**1,008**	**900**	**791**	**682**	**574**
High- & Medium- Strength Steel	780	**845**	**845**	**845**	**845**	**845**	**845**
Stainless Steel	87	87	87	87	87	87	87
Other Steels	39	36	36	36	36	36	36
Iron Castings	360	217	217	217	217	217	217
Aluminum	468	**434**	**543**	**651**	**760**	**869**	**977**
Magnesium	14	**24**	**24**	**24**	**24**	**24**	**24**
Copper & Brass	93	98	98	98	98	98	98
Lead	48	45	45	45	45	45	45
Zinc Castings	10	10	10	10	10	10	10
Powder Metals	57	57	57	57	57	57	57
Other Metals	6	6	6	6	6	6	6
Plastics/Composites	457	**469**	**469**	**469**	**469**	**469**	**469**
Rubber	270	300	300	300	300	300	300
Coatings	42	46	46	46	46	46	46
Textiles	63	65	65	65	65	65	65
Fluid and Lubricants	279	282	282	282	282	282	282
Glass	122	116	116	116	116	116	116
Other	116	91	91	91	91	91	91

Source: American Chemistry Council, Ducker Worldwide, Citi Research

For the final step in this 2015 F-150 potential aluminum content analysis, we run the above materials on a per pound basis through Citi's NA Metals Pricing Model and compare the potential 2015 costs to the estimated 2014 costs. This helps us to determine just how much an increase there is in raw material costs from using lightweight material.

Step 5: We now build out a model that highlights the approximate costs per metal in 2015E and run a comparison to costs for the same material in 2014.

Figure 116. Step 5: F-150 Incremental Aluminum Cost Analysis

2015								
F-150 Approximate Vehicle Weight (lbs)	5,043	4,343						
	2014 Costs	**2015 cost/pound**	**AL=10% cost**	**AL = 12.5% cost**	**AL = 15% cost**	**AL = 17.5% cost**	**AL = 20% cost**	**AL = 22.5% cost**
Aluminum	$375.55	$0.85	$368.38	$460.48	$552.57	$644.67	$736.76	$828.86
High-Strength Steel (Dipped Galv as Proxy)	$324.61	$0.40	$335.77	$335.77	$335.77	$335.77	$335.77	$335.77
Steel (CRC as Proxy)	$634.42	$0.35	$388.05	$350.32	$312.59	$274.86	$237.13	$199.40
Copper & Brass (Copper as proxy)	$285.52	$3.23	$315.81	$315.81	$315.81	$315.81	$315.81	$315.81
Stainless Steel (CR Stainless 304 as proxy)	$118.92	$1.76	$152.83	$152.83	$152.83	$152.83	$152.83	$152.83
Total	**$1,739.01**		**$1,560.85**	**$1,615.21**	**$1,669.58**	**$1,723.94**	**$1,778.31**	**$1,832.67**
D '15 - '14 Aluminum			*($7)*	*$85*	*$177*	*$269*	*$361*	*$453*
D '15 - '14 High-Strength Steel			*$11*	*$11*	*$11*	*$11*	*$11*	*$11*
D '15 - '14 Steel			*($246)*	*($284)*	*($322)*	*($360)*	*($397)*	*($435)*
D '15 - '14 Copper & Brass			*$30*	*$30*	*$30*	*$30*	*$30*	*$30*
D '15 - '14 Stainless Steel			*$34*	*$34*	*$34*	*$34*	*$34*	*$34*

Source: American Chemistry Council, Ducker Worldwide, Citi Research Estimates

The Takeaway: While we note that aluminum is right around 2x the cost of traditional steel, we believe that the 2015 F-150 could face only modest ***net*** incremental costs as it pertains to cost per pound of materials. Perhaps the more meaningful cost increase will come from higher fixed investments made for re-tooling, new manufacturing processes and R&D, etc. Our best estimate at this time suggests a net price increase of $800-$1,000, though this is admittedly rough at this stage. Such a price range would likely amount to less than a 2-year payback for consumers (powertrain configurations held constant).

Next 12 Months Key to Dictating The Car of the Future: The next 12 months will reveal a few important data points that could shape the Car of the Future. First, we'll learn Ford's actual price strategy with respect to the 2015 F-150. Second, we'll learn whether consumers will be willing to accept the payback period, which again we forecast at under 2 years. We'll also learn how dealers are coping with the change. We're optimistic and curious at the same time. Competitors are watching. At the Fiat-Chrysler Investor Day, CEO Sergio Marchionne noted that aluminum was not in the current plans for the 2017 light-duty RAM redesign. However, Mr. Marchionne noted that the company will closely watch the F-150 and could pursue aluminum if it were deemed appropriate.

Figure 117. Fuel Cost per Year, 2014 F-150 (static CPG and Fuel Capacity)

MPG	Miles per Year: 10,000	11,000	12,000	13,000	14,000
19	$1,779	$1,957	$2,135	$2,313	$2,491
20	$1,690	$1,859	$2,028	$2,197	$2,366
21	$1,610	$1,770	$1,931	$2,092	$2,253
22	$1,536	$1,690	$1,844	$1,997	$2,151
23	$1,470	$1,617	$1,763	$1,910	$2,057

Source: Citi Research

Figure 118. Fuel Cost per Year, 2015 F-150 (static CPG and Fuel Capacity)

MPG	Miles per Year: 10,000	11,000	12,000	13,000	14,000
26	$1,300	$1,430	$1,560	$1,690	$1,820
27	$1,252	$1,377	$1,502	$1,627	$1,753
28	$1,207	$1,328	$1,449	$1,569	$1,690
29	$1,166	$1,282	$1,399	$1,515	$1,632
30	$1,127	$1,239	$1,352	$1,465	$1,577

Source: Citi Research

Figure 119. Cost Savings Per Year

MPG	Cost Savings Per Year: 10,000	11,000	12,000	13,000	14,000
19/26	$479	$527	$575	$623	$671
20/27	$438	$482	$526	$570	$613
21/28	$402	$443	$483	$523	$563
22/29	$371	$408	$445	$482	$519
23/30	$343	$377	$411	$446	$480

Source: Citi Research

Car Frames: Carbon Fiber

Carbon fiber, an-oil based compound, is up to 50% lighter than steel, but can cost significantly more. BMW uses the material in i3, and intends to roll it out to other models include the next 7-series.

Another key weight reduction initiative around the car frame includes the roll out of carbon fiber. Carbon fiber is made of thin strands of acrylonitrile, an oil-based compound that is carbonized at a high temperature and molded into strands that are woven together and coated with resin or plastic to give it a permanent shape. This is also known as a composite because it is made up of more than one element – in this case plastic/resin and carbon fiber.

The key advantage of carbon fiber is that it is up to 50% lighter than steel, and 15% lighter than aluminum, but also more resilient and, as such, could reduce fuel consumption by c. 30% and increase passenger safety. A key obstacle to its usage, however, has been the high cost of this material and the longer processing cycle time required.

Nevertheless, it is likely that by 2020, both the cost and processing time will have fallen significantly. In fact, BMW, the first large OEM to have introduced a car with a carbon fiber frame, aims to lower the price to the same as an aluminum frame by 2020. BMW has introduced a carbon fiber frame in its i3 electric car, the first mass produced car to be manufactured with carbon fiber. To source its material, BMW has formed a JV with supplier SGL Automotive Carbon Fibers and has built a $100mn carbon fiber factory in the US. BMW intends to use carbon fiber in more vehicles going forward including the next 7-series.

Other parts: Seating, Roofs etc.

All parts of the car can have their weight reduced and there are a number of different materials that can help reduce weight.

All parts of the car can have their weight reduced and there are a number of different materials that can help reduce weight. High strength steel weighs 20% less than conventional steel and can be used in all structural parts. Plastics also weigh 20% less and cost the same amount as steel and are used for parts which require no structural strength, such as fascias or covers. There have also been considerable innovations in recent years in glass manufacturing creating newer, lighter, stronger and flexible glass. These new forms of glass have quickly gained adoption in portable consumer electronics including mobile phones, tablets and notebooks due to their light weight, durability, and low cost achieved from mass production. Examples include Gorilla Glass by Corning and Dragontrail by Asahi weigh less than 50% traditional automotive glass thereby creating the potential to reduce the weight of the vehicle and improve mileage.

- **BMW:** Currently, BMW is looking at manufacturing other components from carbon fiber apart from just the frame, including wheels. The new BMW i8 launching in 2014 will use Gorilla glass (unknown at this time if it will be used all or only some of its windows).
- **Faurecia:** Faurecia has developed magnesium alloy seat frames, which it believes could reduce the weight of a seat by 35% compared with the latest steel frames. Faurecia is also looking at using carbon-based composites for seats, as well as chassis, the roof, the battery, doors and, in general, substituting steel for composites.

Spotlight on Suzuki's new lightweight platform

Suzuki is to debut a new platform in 2014 that cuts both weight and costs. Increased use of high-tensile materials, hot pressed materials, carbon fiber and the like is a good option in terms of reducing vehicle weight, but then rising costs becomes an issue. In that sense, the new lightweight platform that Suzuki will introduce in models from 2014 is of interest. With its new platform, we understand Suzuki aims with its new platform to cut the total vehicle weight of its mini vehicles and small cars by up to 15%. It plans to achieve this by revising the framework structure and so we think the changes are likely to also lead to cost savings. To achieve its goal, we believe Suzuki is rethinking the shape of the frame and the make-up of joint parts. Suzuki has built a name for itself in fuel-efficient technologies, with models like the Alto Eco delivering 35km/L. However, we believe the adoption of lithium-ion batteries for the Ene-charge regenerative braking system and the like has inflated costs. The new framework is expected to be adopted for the new Alto, which is due out in the latter half of this year and we think the debut of a new model that combines fuel efficiency and cost-savings offers promise. For more, see our April 16 note Suzuki Motor (7269) - Auto tech briefing raises hopes for future technologies.

Global Platform Commonality

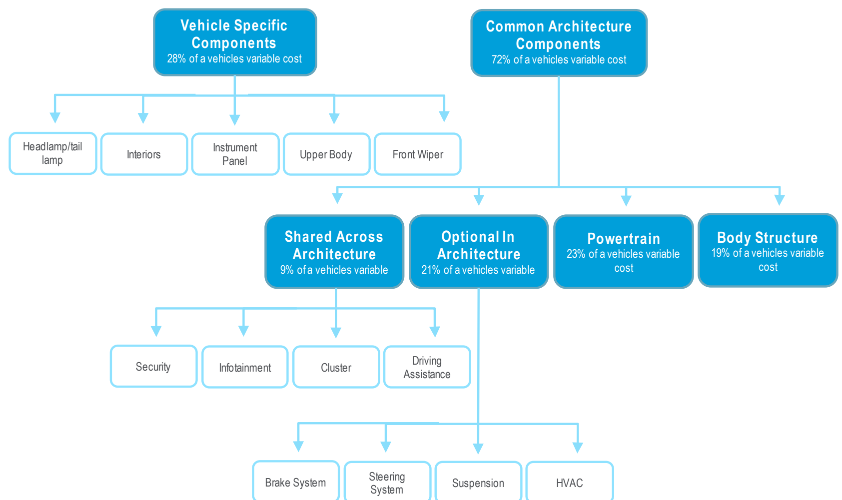
In addition to lightweighting, the Car of the Future will be built on a more common vehicle architecture or platform. This trend usually refers to a vehicle built on a common chassis that shares as many components/processes as feasible. The sizes of a vehicle built on a global platform are generally similar though automakers have been increasingly able to find ways to build unique variations. A recent example is the Ford C-platform that builds vehicles like the Focus, C-Max and Escape, and more recently the Lincoln MKC crossover. This isn't as easy as it sounds; a global platform is only as good as the amount of commonality and flexibility it creates —

not going far enough risks missing cost savings targets and going too far risks making a volume automaker's cars look the same. It's as much an art as science.

If done right, global platforms can lower unit variable costs thereby allowing automakers to either flow savings to the bottom line (rare) or invest in new technologies. Consider that a car's variable expenses typically account for 65-75% of revenue. According to FCA (Fiat Chrysler Automobiles), ~70% of a car's variable costs can be leveraged across other models and multiple vehicle platforms. The other ~30% is more car specific such as instrument panels, body design, and headlamp/tail lamp.

According to prior estimates from A.T. Kearney, a ~1 million unit global platform can generate $700/car of cost savings versus a ~0.5 million unit platform and under. A ~2 million unit platform can generate about $1,000/car in savings. So going from 1 to 2 million = $300/car of savings to spend on new content to enhance pricing and/or market share. Best-in-class global automakers in this regard include Toyota, Volkswagen, Ford and Hyundai. Notably, General Motors still trails on commonality metrics but is making gradual progress.

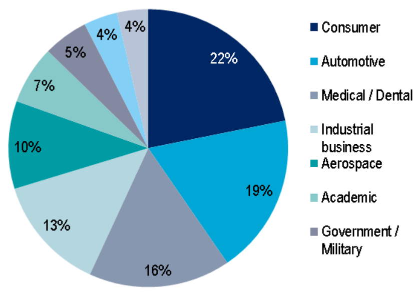
Figure 120. Building the Car of the Future—Variable Cost Breakdown



Source: FCA & Citi Research Estimates

Additive Manufacturing

Figure 121. Additive Mfg – End Markets



Source: Wohler Report

Additive manufacturing (more commonly known as 3D printing) is the process of repeatedly applying thin layers of materials to build objects generated from 3D computer animated design (CAD) files. The technique is most commonly used by engineers during the prototyping stage of the design process and interest around manufacturing end use parts has started to pick up momentum as the build quality and speed of the technology improves. The automotive sector along with aerospace and healthcare have led the way in terms of incorporating 3D printing into the design and production process.

Car manufacturers and parts suppliers account for nearly 20% of the 3D printing market and we believe it will continue to represent a disproportionate share of the market in future years. Today, auto manufacturers are mainly using 3D printers to speed up the iterative design process. We are also seeing companies such as Ford apply the technology to create unique jigs and fixtures that are used during the manufacturing and assembly process. We are also seeing the likes of Ford, Mercedes, Porsche and other utilize 3D printers from Voxeljet in an indirect fashion to create sand casts and molds of key components such as engine blocks and transmission cases during the forging process. We are already seeing specialty vehicles (limited quantities) such as race cars and high-end sports cars build end-use components from the scoop hood to the entire body printed on 3D printers.

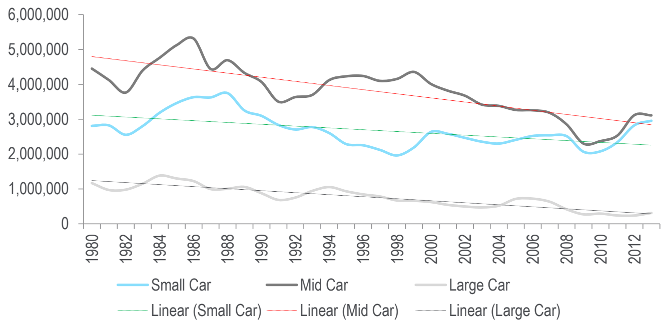
While we believe the technology is still years away from a world of mass customization, we think the ability to design without constraint provides customers with significant competitive advantages. Nearly every auto manufacturer that we have spoken to has some elements of 3D printing in their production workflow and we expect this trend to continue materials and processes improve.

Vehicle Types & Sizes

Trends in the US

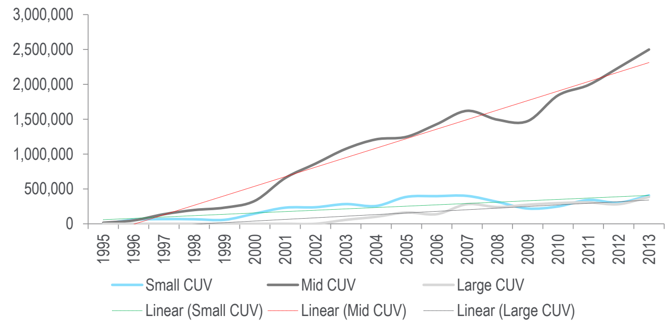
If we look at trends since 1980 we see that the consumer is actually shifting away from cars and sports utility vehicles (SUVs) and leaning much more heavily on crossover utility vehicles (CUVs). The reason is relatively simple. A CUV for one provides the consumer with more room (vs. moving into a large car with a heftier price tag), allows for similar driving style to that of a car and tends to be more fuel efficient vs. an SUV). In fact, in 2013, CUVs accounted for ~21% of total light vehicle sales (vs. 16% 5 years ago) while cars accounted for 41% of total light vehicle sales (vs. 44% 5 years ago).

Figure 122. Small-/Mid-/Large-Sized CAR Trends (1980-2013)



Source: Wards, Citi Research

Figure 123. Small-/Mid-/Large-Sized CUV Trends (1980-2013)



Source: Wards, Citi Research

Quick Download on U.S. Trends

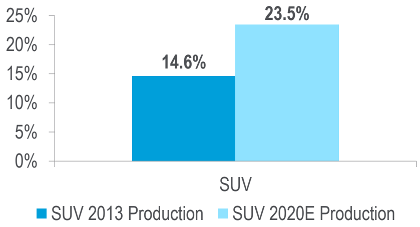
Cars

- Segment is in a pretty steady decline.
- Appears that small-sized variant (while still in a declining trend) is actually holding up the best and potentially keeping consumers in the vehicle type, as opposed to migrating to the increasingly popular CUV segment.
- Appears that the consumer is increasingly migrating from that of a mid-sized variant to that of a small-sized variant. This could be indicative of the baby boomer trend of downsizing to fit their needs or justified by the travel habits and automobile perception of Generation Y.

CUVs

- Segment has continued to perform very well.
- Initially this appeared to mainly be at the cost of the SUV, but more recently CUVs appear to be taking volume from the car segment.
- The most prevalent size variant in this segment is the mid-sized CUV, growing at a healthy 33% CAGR since 1995.
- It appears that the trend will remain in favor of the mid-sized CUV, at least in the near future, but we wouldn't be surprised if small-sized (or mid-sized) variants continued to eat into the SUV market or mid-sized car market.

Figure 124. LMC China Production Forecast – SUV as % of Total Production



Source: : LMC, Citi Research

Trends in China

China vehicle size trends are also interesting to analyze, particularly as it relates to assessing future global platform and commonality decisions. According to LMC Automotive, China is expected to grow from ~25% of global auto production and ~26% of global auto sales (FY 2013) to ~29% of global production and ~30% of global sales in 2020. With impressive global growth in both production and sales, it is imperative to know trends in the Chinese market and understand how consumers are thinking about vehicle purchases.

In a McKinsey & Company study, two important growth catalysts are highlighted in China: "Going Bigger" and "Trading Up".

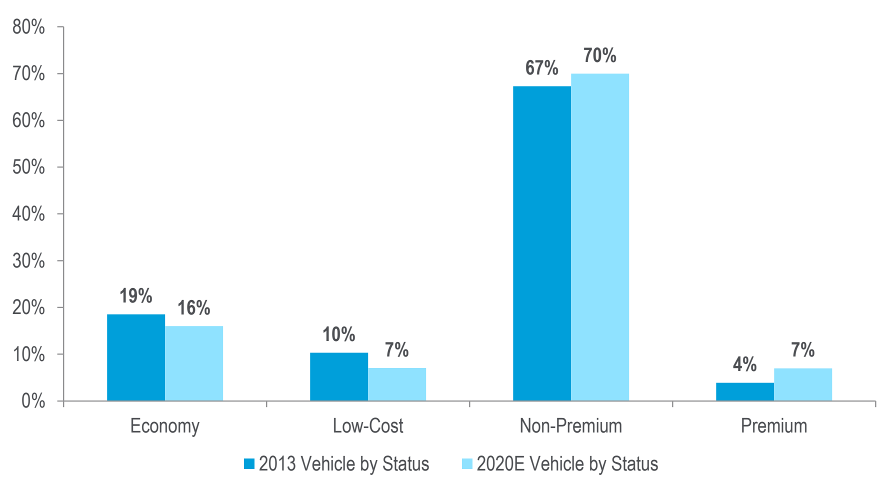
"Going Bigger"

This growth catalyst is predicated on the notion that the consumer in China will shift to larger vehicles (CUVs/SUVs). Shifting to larger vehicles will: (1) help satiate the basic driving need; (2) show off the consumer's personal tastes; and (3) show off the consumer's lifestyle. Additionally, wealthier consumers are more apt to purchase SUVs; however, the "Going Bigger" trend can only take hold as long as the consumer can afford it.

"Trading Up"

The premise of this growth catalyst is that aggressive marketing, higher incomes, and the desire to replace an entry-level vehicle will cause Chinese consumers to purchase higher-priced cars. While the *LMC* production estimates don't actually quantify price bands, we can view market status on the basis of: (1) economy vehicle; (2) low-cost vehicle; (3) non-premium vehicles; and (4) premium vehicles. We start off looking at each market status as a percentage of aggregate production in China for 2013 and 2020E.

Figure 125. LMC China Production Forecast – % of Varying Market Status Production



Source: LMC, Citi Research

Trends in Europe Based on OEM Expectations for Global Trends

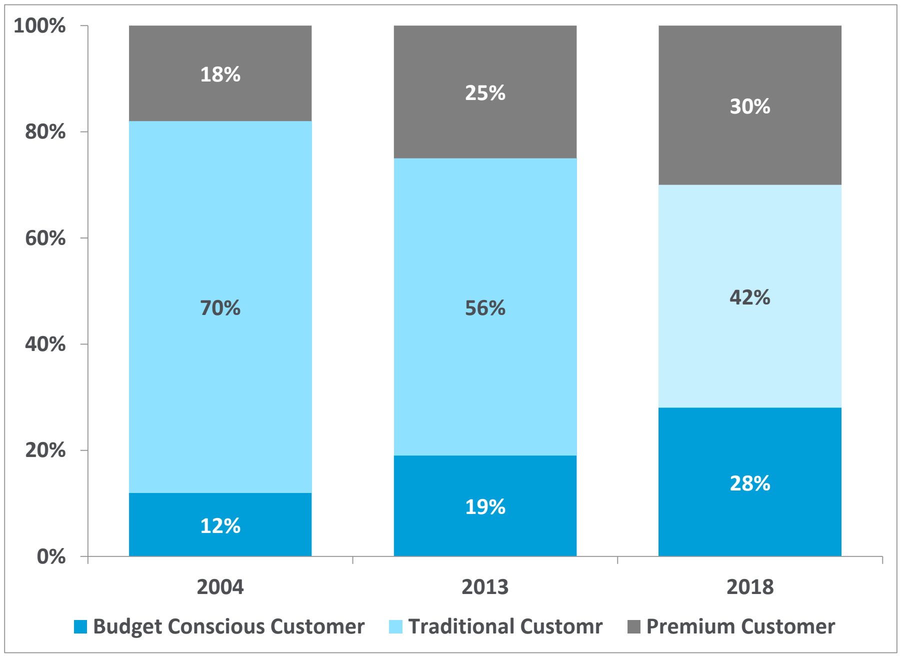
Premium, Basic, and SUVs are the some of the most popular models and their popularity is growing.

Across the world, there seems to be three noticeable trends in the development of vehicle style and size.

4. A divergence between consumer choices with entry level cars outperforming the market;
5. Premium also outgrowing the market; and
6. SUVs, particularly medium-sized SUVs, are growing in popularity.

In this context we note that the middle segment of the market, where market share is being eroded, currently has some of the lowest margins in the industry.

Figure 126. Increasing Bipolarity of Customer Base

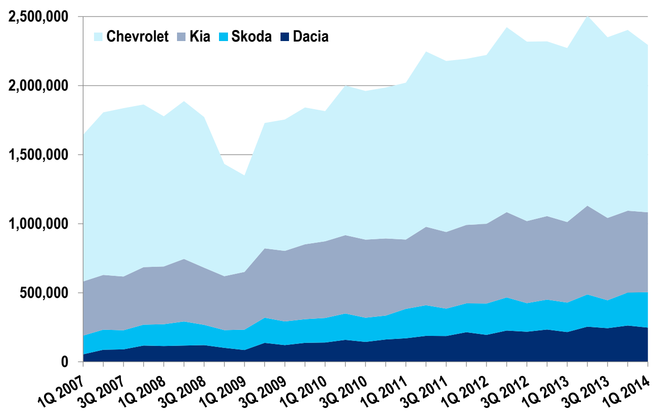


Source: Fiat

Growth in Entry-Level Vehicles

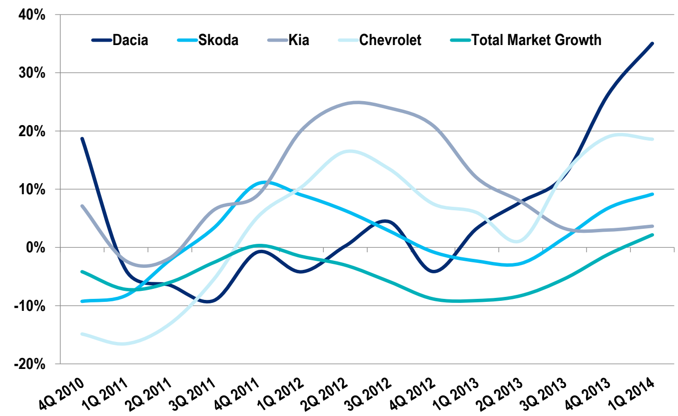
Entry-level cars have been growing in popularity in most regions even in a mature market like Western Europe.

Figure 127. World sales in Entry-Level brands



Source: LMC

Figure 128. European Entry-Level growth vs Total Market

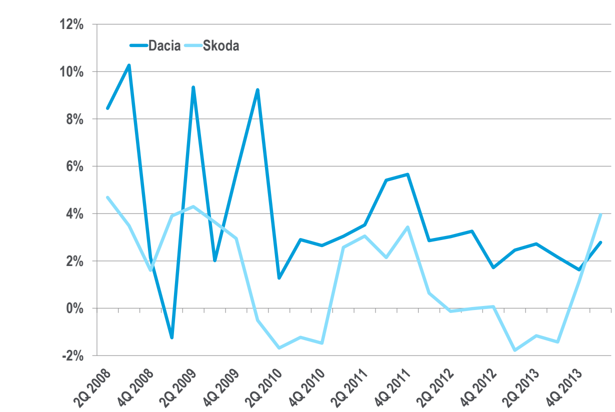


Source: LMC

In general, entry-level cars have proved more profitable and their growth could allow OEMs exposed to this segment to raise their overall margins.

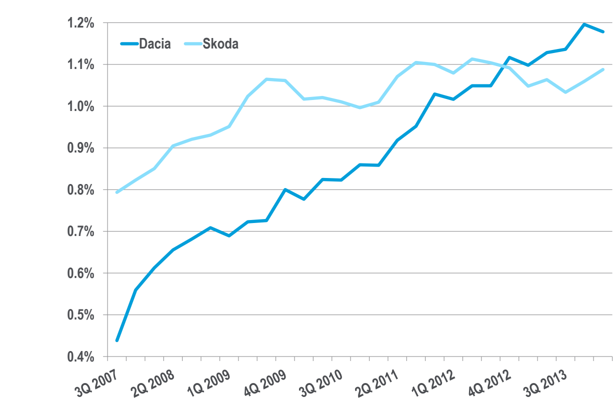
In Europe, the success of entry-level brands has helped Renault in particular through the rapid growth of its Dacia brand. With its no-frills low costs, a common platform, and production in lower-wage regions, Dacia's margin at >6% margin is around three times higher than the rest of the automotive group. Dacia's CEO believes that a shift in the attitude to buying by many Europeans has meant many are less keen to spend so much on a car. *The New York Times* recently called Dacia the 'hottest car in Europe'. With cars starting at €7,700, Dacia has been able to capitalize on this as well as, according to IHS,[3] to attract buyers who would normally buy cars secondhand. As a result, the growth of Dacia, we believe, could have added 80-100bps to Renault's gross margin since 2009.

Figure 129. Change in world market share for Dacia and Skoda



Source: LMC

Figure 130. Dacia and Skoda world market share



Source: LMC

From 2014-2021, the market share of A- and B-grade cars is forecast by LMC to have a CAGR 0.7% higher than the rest of the market; and as sales in these segments grow, so, we believe, should the margins of the OEMs who are supplying the market

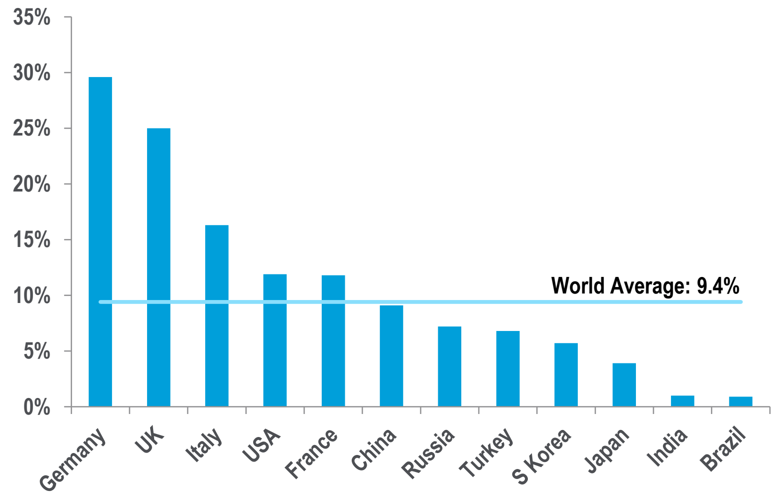
[3] http://www.nytimes.com/2013/12/18/business/international/europes-hottest-car-the-no-frills-dacia.html?pagewanted=1&_r=1

Growth in Premium Vehicles

Premium cars have also significantly outperformed the market, gaining share.

Entry-level cars are only half the story as the premium segment with higher margins has also grown significantly in recent years with penetration rates particularly high in Western Europe.

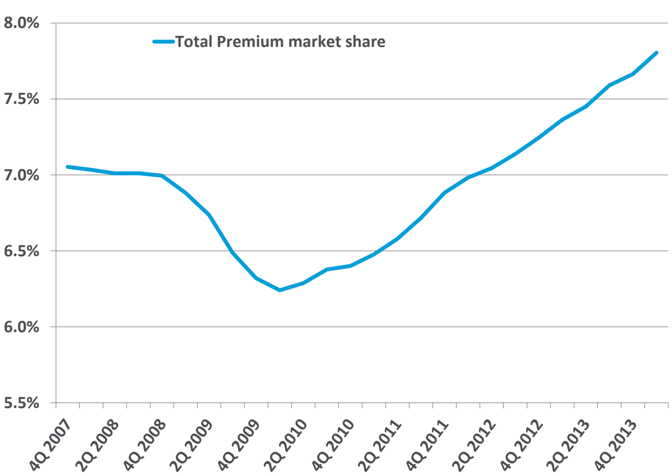
Figure 131. Premium Segment Share of Total Car Market by region, 2012



Source: BMW, LMC

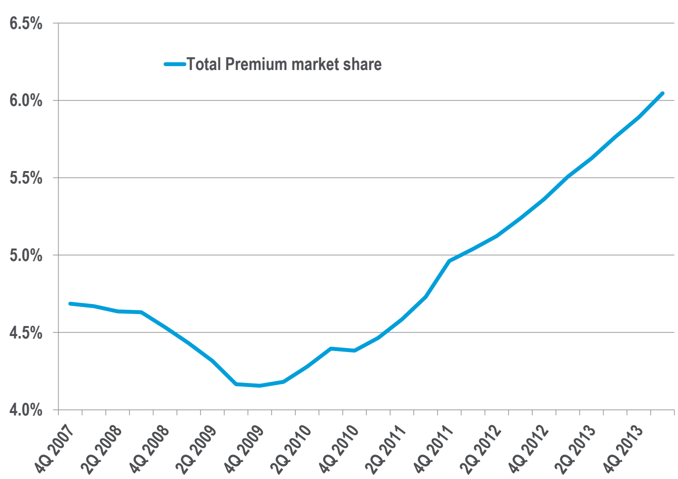
Data below highlights recent growth rates in the premium sector including and excluding Europe where growth has been lower due to already high penetration.

Figure 132. Total Premium Market including Europe



Source: LMC

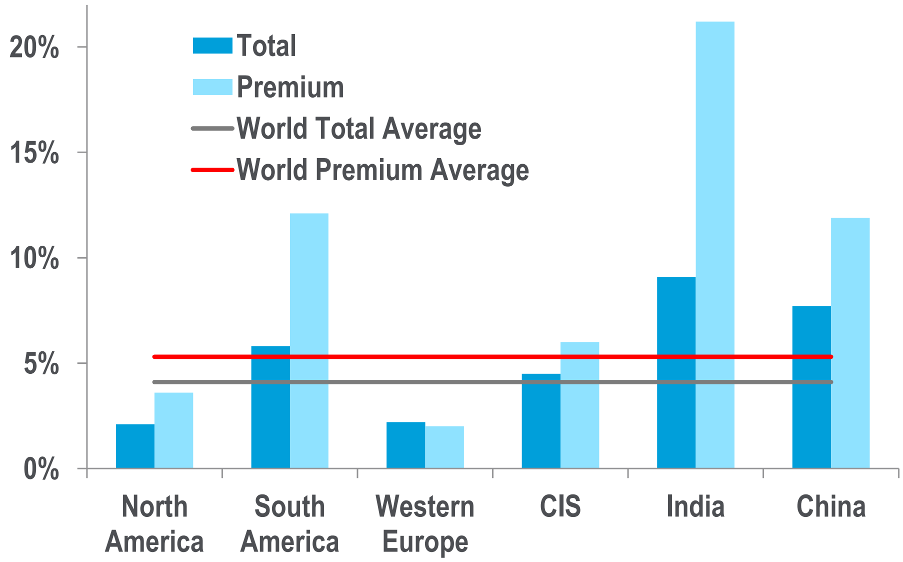
Figure 133. Total Premium Market excluding Europe



Source: LMC

We also highlight IHS forecasts for likely premium growth in major regions between 2012 and 2018 in the figure below; once again, likely growth in Europe is lower than in other regions due to the already high penetration of premium in Europe.

Figure 134. Premium vs. Total, Global CAGR 2012-2018E



Source: IHS

The high penetration of premium cars in Europe is also reflected in relatively high penetration of high-end components supplied by the major suppliers. For example, the market penetration rate for LED headlights is almost twice as large in Europe (4%) as in the rest of the world (2%).

Growth in SUVs

Between 2012 and 2018, SUVs are likely to outgrow all segments of the market.

Finally, SUVs are likely to have the highest sales growth of any segment between 2012 and 2018.[4] With the launch of the Mercedes GLA in 2013 and the Porsche Macan in 2014, it is the compact SUV that has received the most consumer attention, a trend that we think is likely to continue given this segment's aesthetic attractions and robustness with a particular appeal to young urban dwellers.

Figure 135. SUV Growth, 2011-2013

	2011	2016E	2021E	CAGR 2011-2021E
Lower Medium SUV	-	22,543	58,871	41.4%(1)
Upper Medium SUV	4,752,193	6,373,479	7,551,470	4.7%
Large SUV	1,742,670	2,149,477	2,297,452	2.8%
Large Plus SUV	129,101	182,172	157,552	2.0%
Total Market	*76,928,943*	*96,944,030*	*115,192,265*	*4.0%*

Source: LMC. (1) Lower Medium SUVs CAGR calculated from 2014

In fact, IHS Automotive believes that the US industry has reached an "inflection point"[5] as compact CUVs (SUV-like functionality with car-like driving characteristics[6], including Audi Q5, BMW X3, VW Tiguan) have overtaken sedans as the most popular segment for the first time in ten years.

[4] According to Volkswagen

[5] http://blog.polk.com/blog/blog-posts-by-tom-libby/small-crossovers-outpace-sedans-for-first-time-ever

[6] http://blog.polk.com/blog/blog-posts-by-tom-libby/small-crossover-sales-explode-in-february

Affordable Cars

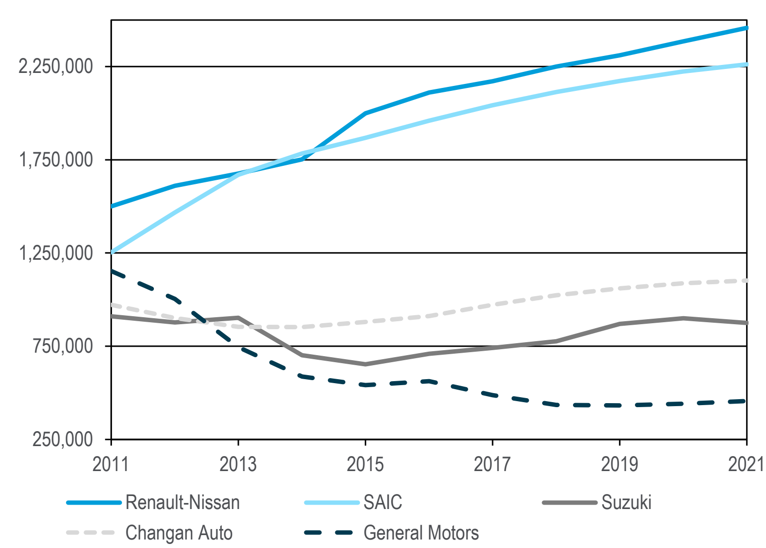
The Global Market for Affordable Vehicles

The Affordable Car segment, comprising compact and low-cost offerings, is a large sub-group of the global vehicle market at roughly 12 million unit sales (15% share) annually, and estimates have the segment potentially expanding to 20% in the next decade. As the base of consumers looking to own passenger vehicles widens, they will help maintain the affordable car segment as the global auto market continues to expand. Helping drive this segment is a growing middle class in emerging markets as well as demand in developed markets from consumers looking for affordable, efficient passenger vehicles that can serve as a commuter vehicles or backup vehicles in the family fleet. But what makes a car affordable? “Affordable” is a relative term based on the affluence of different geographic locations. In the U.S., where the average new car purchase is roughly $30,000, affordable cars are generally those that fall in the $20,000 or lower range. Price points are similar in Europe and other developed markets, and then decline precipitously in the emerging markets. In emerging markets, “affordable cars” may serve as tradeoffs to motorcycles and other alternative methods of transportation, in many cases coming with price tags under $5,000.

Affordable Cars by OEM and Geography

Almost all major OEMs have entry-level or compact vehicles that qualify as “affordable” offerings. Looking at the Figure below, the five largest producers of affordable cars globally, based on 2013 volumes, are: Renault-Nissan, SAIC, Suzuki, Changan Auto, and General Motors. Renault-Nissan and GM, though, are the only OEMs that have affordable car offerings across most regions, whereas SAIC and Changan operate almost exclusively in Asia.

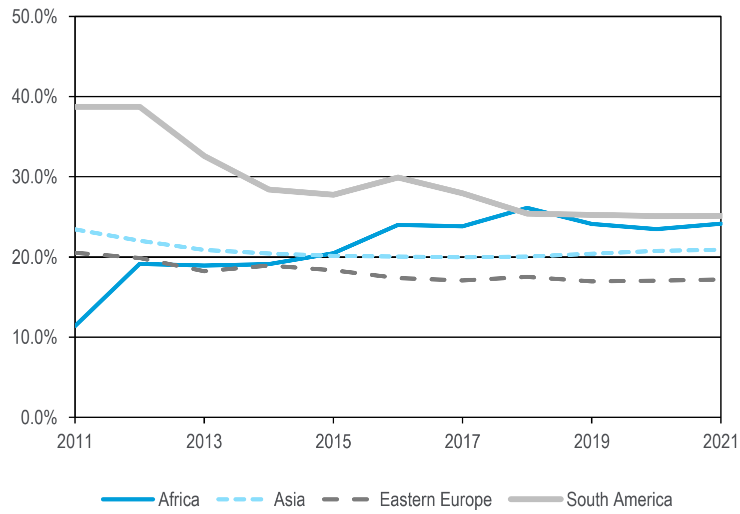
Figure 136. The Largest Manufacturers of Affordable Cars – Production Estimates to 2021E



Source: Company reports, Citi Research

Not surprisingly, emerging markets see a greater share of affordable cars as a percentage of overall volume. South America has the highest percentage of affordable cars at 33% of 2013 volume, while Asia (21%), Africa (19%), and Eastern Europe (18%) followed closely behind.

Figure 137. Affordable Cars as % Total Market by Geography



Source: Citi Research

A list of the top 20 affordable car offerings by 2013 production volumes is also provided in the Figure below.

Figure 138. Global Top 20 Economy/Low-Cost Models

Sales Group	Model	Biggest Markets	2013 Volume
SAIC Group	Wuling Hong Guang	China, India	553,000
SAIC Group	Wuling Sunshine	China	464,000
Volkswagen Group	Volkswagen Gol	Brazil	456,000
Suzuki Group	Suzuki Alto	India, Japan, China	411,000
Renault-Nissan Group	Dacia Duster	E. Europe, Brazil, India	387,000
General Motors Group	Chevrolet Matiz/Spark	Korea, India, China	380,000
Renault-Nissan Group	Dacia Sandero	Brazil, E. Europe, Columbia	371,000
SAIC Group	Wuling Rongguang/Xingwang	China	360,000
Changan Automobile Group	Chana Changan Automobile Mini Bus	China	298,000
Hyundai Group	Hyundai i10	India, Turkey	275,000
Renault-Nissan Group	Dacia Logan	E. Europe, Brazil, Iran	244,000
Geely Group	Emgrand EC7	China, Russia, Ukraine	215,000
Fiat Chrysler Automobiles	Fiat Palio	Argentina, Brazil	213,000
SAIC Group	Wuling Mini Truck	China	182,000
Renault-Nissan Group	Lada Granta	Russia	173,000
Toyota Group	Toyota Etios	India, Brazil, Indonesia	173,000
Dongfeng Motor	Dongfeng Mini Bus	China, Thailand	166,000
Suzuki Group	Maruti Wagon R	India, Indonesia	166,000
BAIC Group	Beijing BJ 2020/BJ 6400	China	153,000
Tata Group	Tata Ace	India, Indonesia	132,000

Source: Company reports, Citi Research

"Affordable" Can't Simply Mean Cheap…

While the main focus of affordable cars is a price point that can fit low-budget consumers, it is important for automakers to keep perspective on how to effectively compete in the market — mainly, price can't be the only point of differentiation. Tata Motors released the Nano in 2009, billed as a city car that consumers may substitute for motorcycles. It sells for around USD $2,500, making it one of the cheapest cars on the market. Manufactured and sold in India, Tata had early expectations that volumes could hit near 250,000 units annually. However, the Nano has not quite delivered on those lofty sales expectations, with less than 300,000 units sold since its debut. Many consumers reasoned that it was not quite a car, but rather something in between a car and a motorcycle (not by its design but by perception). They therefore eschewed the Nano for other affordable options such as the Suzuki Alto or A-Star (280,000 units annually) and the Hyundai i10 (250,000 units annually). One point that this reveals is that a "cheap" price tag is

not necessarily the only concern of consumers looking for affordable cars. Other factors include safety, reliability, and low operating costs. In the case of the Nano, new design changes such as power steering, air conditioning, and more contented interiors are being discussed to improve the vehicle and make it more aspirational, and competitive, albeit at a higher price.

Low-Cost Cars, High-Quality Components…

As the affordable car segment expands, auto suppliers are following OEMs in their pursuit of providing content on these vehicles. As noted above, vehicles need to offer more than “cheapness” in order to gain a foothold with consumers. The value that suppliers can provide is in technologies that are minimalistic, yet state-of-the-art, and make driving a safe and enjoyable experience. Some technologies to highlight:

High-performance airbag systems

Entry-level models can be fitted with high-performance airbag systems that are smaller and lighter than standard airbag systems. Smaller vehicles with less installation space make the reduction in size necessary, while lower engine outputs and lower overall vehicle weights enabled the airbag system to be downsized.

Driver assistance systems

Preventive safety systems will see higher penetration rates across vehicle classes following with the development of mid-range radar. The radar sensor has the ability to scan ahead for oncoming traffic and obstacles to a distance of up to 150 meters and can also give advanced warning of potential rear-end collisions.

Emissions technology

Stop-start systems that automatically turn off idling engines are particularly important in geographies where pollution and a focus on cutting emissions is a key concern.

Hybrid and electric systems

Vehicles with hybrid/electric drive systems can help lower fuel use and cut emissions, a positive development for both vehicle cost of ownership and environmental focus.

Enhanced User Experience Features

Many state-of-the-art features can now be developed at price points that make them feasible on affordable cars. Examples include air conditioning, simple navigation using networked radios, keyless access and control systems. Product solutions that incorporate a diverse range of functions into one single system present an opportunity to reduce costs.

Indonesia auto maker investment will be in the affordable car/low-cost green car

Technological development is a powerful weapon to boost market share and profitability

Indonesia's total domestic car market was about 1.2 million units in 2013, the largest in the ASEAN region and we expect this to go up to around 1.32 million units in 2014 and 1.52 million units in 2015. The most popular model in Indonesia's four-wheel (4W) market is still MPV/SUV (7-seaters multipurpose vehicle) that is relatively efficient and costs less than US$20k. The Japanese automakers are dominating the Indonesian car market with market share of around 91%. Another trend is that affordable cars (and low-cost green cars) with small engines are also getting more popular, especially in big cities where traffic is bad, as this type of car will be easier to drive and maneuver. MPVs are considered more efficient as family cars and are a relatively low price. This type of car is generally fuel efficient, except Toyota Kijang Innova, as the engines are usually less than 1,500cc and can carry more passengers.

Cars in the MPV categories are the highest in demand in Indonesia as they can be used for different purposes and have relatively lower prices. City cars/affordable cars are also rising in demand due to high fuel efficiency and also being smaller in size which is more suitable in crowded cities. As such, we believe the low-cost green car (which we would consider as a city car) could drive demand for 4W volume in the future.

Figure 139. Indonesia Auto Volume since 2006

Car volume Yearly ('000)	2006	2007	2008	2009	2010	2011	2012	2013	2014E	2015E
Astra										
Toyota	123.7	150.7	212.2	186.9	281.0	311.1	406.0	434.9	460.4	529.5
Daihatsu	33.0	52.0	78.0	77.5	118.6	139.5	162.7	185.9	184.5	212.2
Isuzu	16.6	18.3	25.3	15.2	24.0	28.7	33.2	31.5	37.6	44.0
Others	1.5	2.2	2.4	1.3	2.8	3.2	3.3	2.2	3.8	4.2
LCGC (*low cost green car*)								30.0	100.0	130.0
Total Astra volumes	**174.8**	**223.1**	**318.0**	**281.0**	**426.4**	**482.7**	**605.2**	**654.5**	**686.4**	**789.9**
Non-Astra volumes										
Honda	30.0	40.0	52.5	39.6	61.3	45.4	69.3	91.5	103.6	119.2
Mitsubishi	47.0	61.5	87.5	61.7	106.5	134.4	148.9	157.4	170.0	195.5
Suzuki	44.8	58.1	73.1	44.7	71.2	94.6	126.6	164.0	171.8	206.1
Nissan	4.0	21.1	34.3	21.4	37.5	56.1	67.1	61.1	89.8	100.1
Other Brands	18.2	30.6	42.4	37.7	61.7	81.0	99.1	101.4	95.9	110.2
Total Non-Astra Volumes	**144.0**	**211.3**	**289.8**	**205.0**	**338.3**	**411.5**	**511.0**	**574.9**	**631.1**	**731.2**
Total 4W volume	**318.9**	**434.4**	**607.8**	**486.1**	**764.7**	**894.2**	**1,116.2**	**1,229.5**	**1,317.4**	**1,521.0**
Growth (YoY)	**-40%**	**36%**	**40%**	**-20%**	**57%**	**17%**	**25%**	**10%**	**7%**	**15%**

Market Shares (%)	2006	2007	2008	2009	2010	2011	2012	2013	2014E	2015E
Astra										
Toyota	38.8	34.7	34.9	38.5	36.7	34.8	36.4	35.4	34.9	34.8
Daihatsu	10.4	12.0	12.8	15.9	15.5	15.6	14.6	15.1	14.0	14.0
Isuzu	5.2	4.2	4.2	3.1	3.1	3.2	3.0	2.6	2.9	2.9
Others	0.5	0.5	0.4	0.3	0.4	0.4	0.3	0.2	0.3	0.3
Total Astra volumes	**54.8**	**51.4**	**52.3**	**57.8**	**55.8**	**54.0**	**54.2**	**53.2**	**52.1**	**51.9**
Non-Astra volumes										
Honda	9.4	9.2	8.6	8.1	8.0	5.1	6.2	7.4	7.9	7.8
Mitsubishi	14.7	14.2	14.4	12.7	13.9	15.0	13.3	12.8	12.9	12.9
Suzuki	14.0	13.4	12.0	9.2	9.3	10.6	11.3	13.3	13.0	13.6
Nissan	1.3	4.9	5.6	4.4	4.9	6.3	6.0	5.0	6.8	6.6
Other Brands	5.7	7.0	7.0	7.7	8.1	9.1	8.9	8.2	7.3	7.2
Total Non-Astra Volumes	**45.2**	**48.6**	**47.7**	**42.2**	**44.2**	**46.0**	**45.8**	**46.8**	**47.9**	**48.1**

Source: Citi Research, Indonesia Auto Association (Gaikindo)

"Affordable car" will create a new segment

Introduction of Eco car to boost four wheel vehicle sales volumes as some used car and two wheel buyers will switch to Eco

We believe the introduction of an affordable car in September 2013 will boost car volume in Indonesia in 2014 as we expect a certain percentage of people to switch from motorcycle to car. The price range for affordable/low-cost green cars is Rp70-100m (US$6k-9k), which represents about 5-6x of the price of a 2W (US$1,300-1,500). We expect income per capita to continue rising, doubling from US$3,000 in 2010 to US$6,000 by 2015.

2W volumes are 8x more than 4W volumes and Eco car will narrow the price gap significantly

We expect this new LCGC car segment to target the higher-income 2W buyers who wish to migrate to 4W as well as the buyers of used car. We believe that Toyota, Daihatsu, Suzuki and Nissan will all have a new model plan, pricing the car at around Rp60-100m. Indonesia's 4W penetration of less than 5% is one of the lowest in the region and we expect rising income per capita will boost this.

Indonesia's car volumes have been growing at 8% CAGR over the past 10 years vs. India and China at more than double-digit levels.

Affordable Car/ Low-Cost Green Car (LCGC)

Affordable car accounted for 13% of total 1Q14 Indonesian car volume

The low-cost green car, which is priced less than Rp100mn ($9k) for price-sensitive customers, started to be sold in Indonesia in September 2013. The Indonesian government is very supportive of this new car and is offering tax incentives to producers that meet the requirement of fuel efficiency targets via LCGC production. The luxury goods tax will also be reduced for LCGC cars, with a 20% tax reduction for low carbon cars and a 100% reduction for environmentally-friendly cars. LCGC sales are also expected to reduce the import of fuel in order to curb the current account deficit. Through October 2013, the introduction of LCGCs has contributed to an 8-9% increase in total 4W sales. There are in total five LCGC cars in Indonesia currently. Toyota Agya and Daihatsu Ayla are the first two vehicles that were certified in the LCGC program in September 2013, followed by Honda Brio Satya in October and Suzuki Karimun Wagon R in January 204. Nissan will launch Datsun Go and Go+ in mid-May 2014.

Toyota started exporting Toyota Agya to other ASEAN market this year

Low-cost green cars are expected to become popular, especially in the ASEAN region due to the region's significant growth coupled with its large population. The proponents of the policy believe by providing incentive towards LCGCs, Indonesia might become the promoter of an environmentally-friendly lifestyle. However, allowing LCGCs to enter the market will overburden the country's poor infrastructure and more traffic congestion is expected. Opponents of the regulation prefer the investment towards LCGC be allocated to improve infrastructure. Even though the debate is ongoing, LCGC sales have been growing since launching in September 2013.

Figure 140. Affordable car sales since launch in September 2013

	2013		Jan-14		Feb-14		Mar-14	
1	Toyota Avanza	213,458	Toyota Avanza	16,312	Toyota Avanza	15,708	Toyota Avanza	16,315
2	Daihatsu Xenia	64,611	**Toyota Agya**	**6,522**	**Toyota Agya**	**7,461**	Honda Mobilio	10,592
3	Toyota Innova	64,539	Toyota Innova	5,384	Honda Mobilio	6,241	**Toyota Agya**	**6,648**
4	Suzuki Ertiga	63,317	Suzuki Ertiga	5,378	Daihatsu Gran Max PU	5,207	Toyota Innova	5,428
5	Daihatsu Gran Max PU	48,012	Daihatsu Xenia	4,636	Toyota Innova	5,179	Suzuki Carry PU	4,362
6	Suzuki Carry PU	46,208	Suzuki Carry PU	4,172	Daihatsu Xenia	5,137	**Daihatsu Ayla**	**4,333**
7	Nissan Grand Livina	35,442	**Daihatsu Ayla**	**3,774**	**Daihatsu Ayla**	**4,590**	Daihatsu Gran Max PU	4,093
8	Toyota Rush	35,004	Suzuki APV	3,182	Suzuki Carry PU	3,861	Daihatsu Xenia	3,640
9	Mitsubishi T-120	29,662	Mitsubishi T-120	2,732	Suzuki Ertiga	3,216	Suzuki Ertiga	3,475
10	Honda Jazz	27,803	Daihatsu Rush	2,592	Suzuki APV PU	2,859	Toyota Rush	2,962
11	Mitsubishi L-300	27,498	Mitsubishi L-300	2,550	Toyota Rush	2,806	Mitsubishi T-120	2,603
12	Daihatsu Terios	25,674	**Honda Brio Satya**	**2,297**	Mitsubishi T-120	2,767	Mitsubishi L-300	2,514
13	**Toyota Agya**	**22,376**	Nissan Grand Livina	2,100	Mitsubishi L-300	2,656	Nissan Grand Livina	2,041
14	Honda CR-V	20,385	Honda Jazz	1,893	**Suzuki Wagon**	**2,158**	**Suzuki Wagon**	**2,037**
15	Suzuki APV PU	19,567	Daihatsu Terios	1,875	**Honda Brio Satya**	**2,061**	Daihatsu Terios	1,912
16	**Daihatsu Ayla**	**19,141**	Honda Brio	1,864	Daihatsu Terios	1,947	Suzuki APV PU	1,898
17	Honda Freed	18,595	**Suzuki Wagon**	**1,693**	Nissan Grand Livina	1,799	Honda Jazz	1,632
18	Toyota Fortuner	17,475	Honda Mobilio	1,508	Toyota Etios	1,670	Toyota Fortuner	1,409
19	Daihatsu Gran Max minibus	15,678	Toyota Etios	1,378	Toyota Fortuner	1,659	Toyota Etios	1,305
20	Suzuki APV minibus	14,531	Toyota Fortuner	1,329	Honda Brio	1,378	Suzuki APV minibus	1,104

Source: Citi Research, Indonesia Auto Association (Gaikindo). * PU: Pick Up

Car Sharing

Car sharing is a unique and emerging business model entailing a consumer renting a vehicle for a shorter duration than that of a typical rental; often this is done on a per hour basis. The allure of this rental model revolves around its ability to minimize costs for the consumer who cannot justify vehicle ownership, given the amount of driving they see themselves doing. According to Frost and Sullivan, the catalysts for this business model stem from: 1) age; 2) transportation alternatives; 3) car ownership; 4) pricing and model; and 5) familiarity with car sharing.

1. **Age –** People between the ages of 25-34 who are well educated with low access to vehicle ownership have a high level of interest in car sharing; roughly 31% of students are interested.
2. **Transportation Alternatives –** Car sharing must co-exist with public transport. People ideally would prefer a city transport operator to serve as a car sharing operator and expect parking spaces in front of public transport locations.
3. **Car-Ownership –** About 40% of car owners with one car are expected to give up their vehicle when membership to a car sharing service is obtained; ~60% of non-car owners will not consider purchasing a car in addition to car sharing membership.
4. **Pricing & Model –** The top preferred use case is a gas engine 4-seater for pick-up/drop-off at a station within 200 meters, this translates into $20.67 per hour, but a decline to $9-$15/hour would further increase share.
5. **Familiarity –** Only ~25% of non-car sharing members are familiar with the concept and furthermore only 28% are interested in membership. After a detailed introduction of the concept, ~38% were more interested in the relevance of the concept.

Figure 141. Frost and Sullivan Study – "Voice of the Future Car Sharing Customer: It's All about Wholly Sharing and Partly Pairing"

	Current Car Sharing Members	Future Car Sharing Members
Age	53% up to 34 years old 41% in the age group 25-34	49% are up to 34 years old 36% in the age group 25-34
Gender	Male – 54%	Female – 56%
Business Travel	Heavy business traveler	Business traveler
Car Ownership	51% do not own a car	50% do not own a car
Education	Higher Education	Higher Education
Household size	2 members	2 members
Marital status	Married/with a partner and without children	Married/with a partner and without children

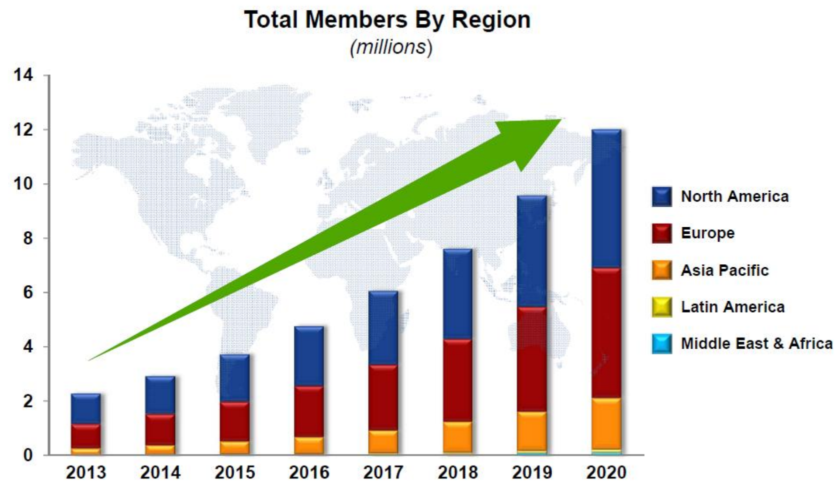
Source: Frost and Sullivan

Additionally, tying to the points above, ZipCar, a car sharing company owned by Avis, conducted a 2013-2014 millennial survey in which 53% of drivers surveyed claim that the cost of a vehicle makes it difficult to own a car, 50% of drivers say they would drive less if more options were available, and 35% are actively seeking transportation alternatives. Additionally, the University of Michigan transportation institute highlights 22% of licensed drivers are teenagers or in their 20s.

By nature, the car sharing model revolves around the growing number of members, of which incremental users are targeted by adaptive car sharing use cases. In order to gain members, certain factors must be present in a target market, including: (1) the target must have a high population density; (2) the target area's cost of car ownership must be high; (3) the target area must already have a strong public transportation system; and (4) the target area must have a solid, developed middle class.

According to Navigant Consulting, worldwide car sharing membership was 2.3 million in 2013 and is expected to grow to more than 12 million by 2020. Additionally, we know that North America and Europe will make up the lion's share of active members, as per Navigant Consulting research.

Figure 142. Car Sharing Global Members



Source: Navigant Consulting, Avis Budget Group

To look at this member growth from the perspective of the largest car sharing company globally, we take a look at ZipCar. Based on a ZipCar (Avis) investor report in February 2014, they had 860,000 members or ~34% of the total global 2013 members. Additionally, at a recent Avis Investor Day, they (ZipCar) revealed a target of achieving 1 million members by 2015.

With regards to the four factors mentioned above about choosing a proper target market, we cite a recent ZipCar study and a Frost & Sullivan study to assess market size potential for key markets.

Figure 143. Market Size Potential

Source: ZipCar Study, Frost and Sullivan

In order to quantify the potential benefit of car sharing as revenue generating, we look at certain items: 1) acquisition costs per customer; 2) annual spend per consumer; and 3) relationship duration. Utilizing a car sharing presentation by ZipCar, pre-acquisition, we can see how these metrics drive incremental benefit. This is very rough and approximate math, meant only as an example.

Figure 144. 2011 Established Market Proven Member Unit Economics

Proven Member Unit Economics zipcar

Acquisition Cost / Member	$46
Member Lifetime Activity Metrics	
Annual Spend	$427
Relationship Duration	5 Years
Average Member Lifetime Value	**$600 (Net)**

Based on Established Markets in 2011

Source: ZipCar

Figure 145. Revenue Sensitivity Analysis for 2013-'20E Memberships (net of acquisition cost per incremental member of $46)

Members	Annual Member Spend $425	$475	$525	$575	$625	$675	$725
2,300,000	$977,500,000	$1,092,500,000	$1,207,500,000	$1,322,500,000	$1,437,500,000	$1,552,500,000	$1,667,500,000
2,912,200	$1,209,523,756	$1,355,133,750	$1,500,743,745	$1,646,353,739	$1,791,963,733	$1,937,573,727	$2,083,183,722
3,687,351	$1,531,467,367	$1,715,834,935	$1,900,202,504	$2,084,570,073	$2,268,937,642	$2,453,305,211	$2,637,672,780
4,668,828	$1,939,103,951	$2,172,545,348	$2,405,986,745	$2,639,428,142	$2,872,869,539	$3,106,310,935	$3,339,752,332
5,911,548	$2,455,242,740	$2,750,820,136	$3,046,397,531	$3,341,974,926	$3,637,552,321	$3,933,129,716	$4,228,707,111
7,485,047	$3,108,764,185	$3,483,016,557	$3,857,268,929	$4,231,521,301	$4,605,773,674	$4,980,026,046	$5,354,278,418
9,477,371	$3,936,235,957	$4,410,104,528	$4,883,973,100	$5,357,841,672	$5,831,710,244	$6,305,578,815	$6,779,447,387
12,000,000	$4,983,959,086	$5,583,959,086	$6,183,959,086	$6,783,959,086	$7,383,959,086	$7,983,959,086	$8,583,959,086

Source: ZipCar Established Markets 2011 Data, Citi Research

Does Car Sharing Pose a NT Headwind for SAAR Growth?

We're often asked whether car sharing poses a threat to the US new car sales (SAAR) cycle. Our view is that the answer is No, and in fact we think that car sharing could be positive for new vehicle demand in the short/medium term. First, it's important to consider that the target market for car sharing is a consumer base that either would have purchased a used car or no car at all. Remember that in the US, the new buyer age demographic tends to concentrate above the age of 40. With car sharing, a young consumer forgoing a used car purchase would therefore consume miles on a new car. And a young consumer who wouldn't have otherwise purchased any car now enjoys the freedom of mobility on a new (or newer) car. Outside surveys also show that Gen-Y consumers still hold an emotional attachment to their cars (63% Gen-Y vs. 51% Boomers according to a GfK survey). In our view, this could be a function of a desire for personal space in households starting to raise children (child seat installation, etc.).

The situation in Europe is also interesting. Lower penetration of cars particularly in European cities and for younger people is a keen challenge for OEMs focused on developed markets. PSA Peugeot Citroen faces one of the most acute challenges as it is still predominantly a European player. To address this, PSA is rolling out two different schemes, Peugeot Mu and Citroën Mobility. Peugeot Mu works by allowing customers to rent across Peugeot's range including cars, bicycles, vans and even accessories by booking online or using their mobile, and then collecting the car at over 90 dealership sites in Europe, with 100 being added per year. At its recent capital day, Peugeot indicated that 30% of Mu customers did not own a car, while 55% wanted to buy a car in the next two years. Citroën Multicity, launched in 2011 in France and 2012 in Germany, is a similar scheme for Citroën, but also allows peer-to-peer car sharing as well as carpooling. Aimed at environment- and cost-conscious consumers, Citroën Multicity will show customers the cheapest way to complete their journey as well as the CO2 emissions for each trip.

Daimler has a similar system called Car2Go, one of the largest car sharing schemes in the world. It operates 10,500 cars in 26 across 8 countries, allowing its users in one city to use the service in another city. This system is targeted at young people in cities, allowing reservations up to 30 minutes in advance, often using electric vehicles. Car2Go has more than 600,000 users across the world (compared with about 1.6mn cars sold by Mercedes-Benz in 2013), around 25% of the total car sharing market. We do not believe that this will fully substitute for the potential loss of new car volumes as certain demographics "de-motorize", but it is an innovative approach that could attract up to 12 million customers by 2020, according to Navigant Research.

LED: a lighting revolution

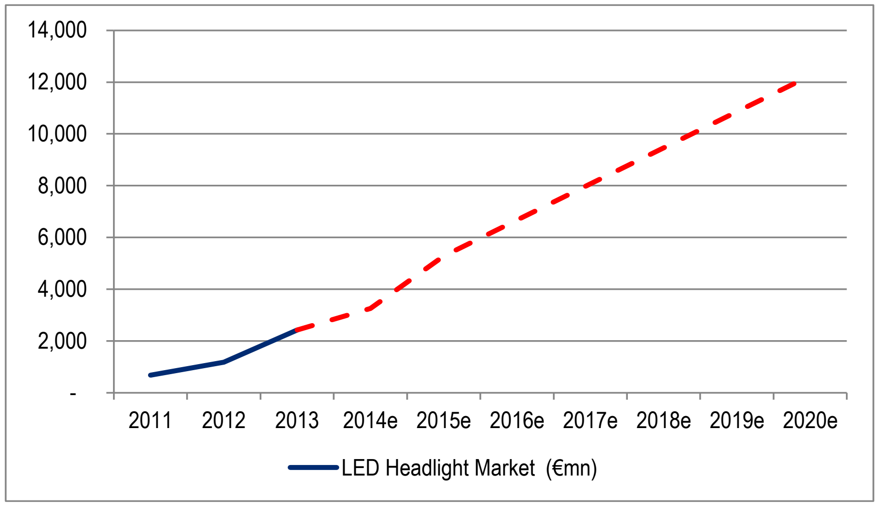
Figure 146. Auto Investing Framework

	LED Lighting
Is There a Specific Regulatory Driver?	
Consumer Value (Perform, Safe, Connect)?	
Do OEMs Use This As a Selling Point?	
Is It Reasonably Affordable to Consumers?	
Is it Globally Scalable?	
How is the Competitive Landscape?	
Can It Be Funded by Content Reductions?	
Applicable to OEM Investing?	Yes

Source: Citi Research

Automotive lighting is relatively unusual in that it is something that end-customers can easily observe. While Halogen dominates the market with about 80% of front headlights using Halogen bulbs, LED could cannibalize this market, with a 20% market share by 2020. Penetration rates of Front Lighting LED are currently only 2-3% globally and 4% in Europe though penetration rates are higher for LEDs in Rear Lighting at 22-23% globally and 30% in Europe. We believe that the LED market could grow from around €2.4bn ($3.3bn) today to €13bn ($18bn) by 2020.

Figure 147. LED Market Size growth (€mn)



Source: Citi Research

Every car has at least 4 lamps, 2 at the front, which typically emit more light than rear headlamps and are used for vision, and 2 lower beam rear headlamps. Headlamps are basically constructed from a light emitting device with a casing often in plastic and electrical elements that are typically out of view from the car buyer but embedded in the vehicle. There are 3 main types of headlamp:

Figure 148. Comparison of Headlights

	Halogen	Xenon	LED
Light Source	Coiled filament	Discharge lamp	Semiconductor
Light Colour (Kelvin)	3,200	4,000	6,000
Lifetime (hours)	300-1,500	2,500	10,000-20,000
Wattage	55	35	<20
Luminous Flux	3,200	3,200	5-500
Efficiency (lm/W)	25	90	100
Fuel Consumption		25% saving vs halogen	40% saving vs halogen

Source: Citi Research

1. **Halogen:** Halogen lamps have been used in cars since the 1960s. These generate light by heating a filament of tungsten to >2,500 C, turning it incandescent. The bulb is made of resistant glass and is filled with a halogen gas, which allows the filament to last longer and emit a brighter light.

2. **Xenon:** Also known as High-Intensity Discharge headlamps (HIDs), the blue-ish tint of Xenon headlamps comes from the xenon gas that surrounds two tungsten electrodes. Light is generated from sparks that jump between the electrodes when electricity is passed through them, creating an 'electronic arc' and the Xenon serves to amplify the brightness of the light.

Figure 149. Valeo BeaumAtic Premium LED

Source: Valeo

Figure 150. Valeo PeopLED

Source: Valeo

3. **LED:** The newest and fastest growing type of headlamp is LED largely replacing Xenon. LED stands for Light Emitting Diode and these work by connecting a 1mm-wide diode (an electrical component allowing electricity to flow in only one direction) to an electrical current that releases 'photons', which appear as light. The color of the light differs depending on the energy gap in the diode, which means that LEDs can come in a variety of colors, using little electricity to become bright (see Figure 151). LEDs have a lifetime of up to 20,000 hours, an average of 20x longer than halogen. In an LED headlight, the diode is covered by a reflective body and lens, which is in turn encased in the plastic that forms the basis of the headlight design. LED headlights, unlike LEDs for use in household appliances, are also built with a heat sink to dissipate heat away from the diode. The average price of a Front LED light is c. €120-130 ($165-180) we estimate about 3x that of a standard Halogen light partly reflecting higher electronic content and the higher cost of an LED bulb of €10 vs.€0.50 ($14 vs. $7) for a Halogen bulb.

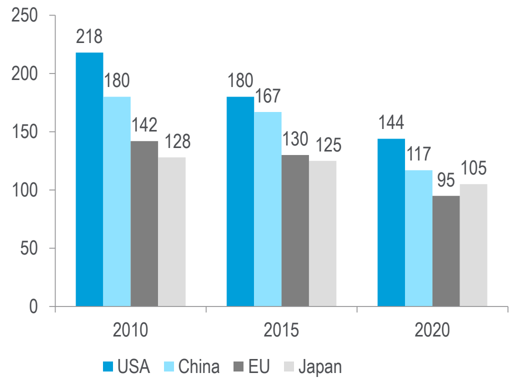
Figure 151. Valeo LED rear lights

Source: Valeo

Why is LED lighting growing so fast

1. **Fuel efficiency:** LED lights offer greater energy reduction than other lights in the region of 1-2 g of Co2 per km for the average car which is relatively significant in light of 2020 emissions rules targets of 95g of Co2. As a further example the average amount of wattage used in halogen lights is 135W, for the same amount of emitted light, Xenon lights uses 90W, while LEDs use only 50W. Improving technology could reduce this wattage of LEDs over time to c. 30W.

Figure 152. World CO_2 regulation, 2010-2020



Source: Continental, Citi Research

Figure 153. Change in CO_2 emissions by car company, 2009-12

	Average CO_2 emissions (grams per km)			
	2009	2010	2011	2012
BMW	150	148	145	138
Daimler	160	158	150	140
Fiat		131	125.9	123.3
Peugeot	135.8	131.8	127.5	122.5
Renault		137	131.7	125.5
VW	151	144	137	134

Source: Company Data, Citi Research

…and this will be an important consideration as regulation means OEMs must lower CO_2 emissions by km by car

2. **Design flexibility:** LEDs give OEMs far greater control over the design and unique branding of their marques and increase the value proposition also for LED automotive supplier. Essentially, the flexibility reflects the small size of the diode vs halogen and xenon bulbs. Auto consumers can easily observe innovation in new model launches with Lighting able to provide a much more modern and sleek image for cars and contribute to brand development. Furthermore, LEDs offer too less deep casing suggesting more manufacturing flexibility for car makers.

LED flexibility means that headlights can be automated: adaptive cut off lines, lighting up corners

3. **Automation:** The relatively small size of LEDs (1mm^2) in particular facilitates the automation of headlights, with each light able to be individually controlled. As a result, new systems with LEDs can automatically dim or turn off; they can adjust to road conditions and move in order to illuminate bends in the road or for corners. This element is particularly useful in avoiding dazzling oncoming cars.

LEDs produce the same light color as daylight and Valeo believes that this improved visibility could reduce braking distance by 6 meters at 120km/h

4. **Safety benefits could lower road accidents:** The light colour of LED, which is similar to daylight (5,500K), provides additional safety benefits compared to halogen and Xenon. Indeed, Valeo indicates that the additional visibility of LEDs shortens braking distance by 6 meters at 120km/h.

Spotlight on Japan

Koito Manufacturing has issued a forecast of the light source breakdown for automotive headlights, in which it projects the global weighting of LEDs to rise to around 25% (over 50% in Japan) in fiscal 2018 from 7% (13%) in fiscal 2014. The Lexus LS 600h was the first mass production model to adopt LED headlights in 2007, and the number of models featuring LED headlights rose rapidly to 40 (including four motorcycle models) in fiscal 2014 from 15 in 2013. Technological progress in LED light intensity has reduced the number of LED units required and driven down costs. LED headlights made by Koito are fitted as standard in the 2014 Corolla (launched in September 2013) in North America. The main shift at present is to LEDs from high-intensity discharge (HID) light sources owing to cost considerations, but we also expect some replacement of halogen light sources owing to the low power consumption of LEDs (less than half that of halogen and HID sources), and greater design appeal accompanying LED miniaturization. Koito expects the number of models fitted with LED headlights to rise to 101 (including 12 motorcycle models) in fiscal 2016 from 62 (including nine motorcycle models) in fiscal 2015, but we see a possibility of adoption accelerating with the launch of ultra-low-cost LED headlights. At rival Stanley Electric, we estimate an LED headlight weighting of 5% in fiscal 2014, rising to 12% in 2015. The company's sales of LED headlights started in earnest with the Japan launch of Honda's Fit in September 2013. Koito has been the clear leader in the LED headlight market thus far (with proactive adoption in hybrid models by its core customer Toyota), but Stanley's core customer Honda has now started aggressively adopting LED headlights due to progress in cost cutting.

Appendix A: Fuel Economy Technologies

Variable valve timing (or cam phasing). Valves are used to allow air and exhaust gases to respectively enter (intake valves) and exit (exhaust valves) the combustion chambers (cylinders) of the internal combustion engines that currently power the vehicle fleet. Traditional valve opening and closing is controlled by fixed cams located on one or more camshafts that are driven by the rotation of the engine crankshaft, limiting the ability to tailor either intake or exhaust performance to specific engine operating conditions. Variable valve timing technology allows the timing of intake and/or exhaust valve openings to vary in accordance with engine speed and load. This allows for improved breathing (intake air and exhaust gas movement) and more efficient combustion.

Variable valve lift. Variable valve lift is an adjunct to variable valve timing technology, which allows valve opening height (and duration) to also vary with engine speed and load. This further improves breathing and combustion efficiency.

Camless valve actuation. Camless valve actuation allows for valve functionality that is fully independent of crankshaft and/or cam operation. Electromechanical actuators allow valve operation to be continuously varied in accordance with engine speed and load, so that breathing and combustion efficiency can be optimized. In addition, the elimination of mechanical camshafts and actuators reduces engine load and friction. Camless valve actuation is not included in the technology packages evaluated for this analysis due to current costs that outweigh the additional efficiency potential relative to less expensive variable valve timing and lift systems.

Cylinder deactivation. Cylinder deactivation technology effectively "shuts off" engine cylinders under operating conditions where their output is not necessary for performance purposes. This essentially creates a smaller displacement engine that operates closer to its optimum efficiency speed and load conditions. When the smaller displacement configuration is not adequate for demanded performance, the deactivated cylinders are "turned back on" and the performance capacity of the larger displacement engine is restored. For this analysis, it is assumed that cylinder deactivation technology can be effectively applied to engines of 6 or more cylinders, but that 4-cylinder engines are not viable technology candidates.

Turbocharging. Turbocharger technology utilizes some of the energy that leaves engine cylinders in the form of exhaust heat to drive a compressor in the engine air intake manifold. This compressor increases the quantity of air delivered to the combustion chambers, and this increased change density allows for greater engine power (than would be delivered by the same size non turbocharged, or naturally aspirated, engine). This higher specific power allows for a smaller (and more efficient) engine to be used for a given level of performance. For certain engines (e.g., DOHC V6 engines), the cost savings associated with engine downsizing can offset the incremental cost of the turbocharger. However, the savings are reduced if 2 valve per cylinder OHV engines are simultaneously converted to 4 valve per cylinder DOHC configurations. Cost savings associated with downsizing a 4 cylinder engine is substantially less than the savings for 6 and 8 cylinder V block engines (as the downsized engine will retain all cylinders, valves, camshafts, etc.).

Gasoline direct injection. "Conventional" gasoline engine fueling is accomplished through relatively low pressure fuel injection outside (at the air intake ports) of the engine cylinders. This currently conventional multiport fuel injection technology allows for significantly enhanced fueling (and efficiency gains) relative to the predecessor carburetion technology, but even greater advantages can be attained through higher pressure fuel injection directly into the engine cylinders. This so called gasoline direct injection (GDI) technology allows for much more precise fuel control, higher compression, increased exhaust gas recirculation (EGR), and stratified lean burn (more air/less fuel per unit of power than conventional non stratified combustion) under certain operating conditions. For this analysis, it is assumed that stratified operations would be avoided (i.e. the GDI system benefits assume stoichiometric operation) so that no additional exhaust gas aftertreatment costs are incurred.

Cooled and Boosted Exhaust Gas Recirculation (EGR). Modest levels of EGR have been used in conventional gasoline engines for decades, primarily as a method of controlling engine out emissions. However, higher levels of EGR can result in significant efficiency synergies. Low load pumping losses can be reduced by allowing stoichiometry to be maintained with less throttling. At higher loads, cooled EGR allows for reduced pre ignition (which allows for both increased compression ratio and increased spark advance) and lower combustion temperatures (which alleviates the need for enriching fueling ratios to control exhaust temperatures). Such systems are particularly synergistic with turbocharging technology, which by design pushes engine operation into higher load regimes.

Direct injection diesel engines. Direct injection diesel engine technology is well established and offers considerable efficiency benefits relative to current gasoline engines, primarily through high compression throttle less lean burn combustion characteristics. About one half of all vehicles currently sold in the EU are diesel powered, but more stringent emissions requirements as well as continuing (but no longer justified) stigmas of noise, soot, etc. and a higher fuel price must be overcome in the U.S. market. The cost impacts assumed in this analysis include both downsizing credits for 6 and 8 cylinder engines and additional exhaust aftertreatment costs for all diesel applications.

Transmission technology. Increasing the number of steps between the lowest and highest transmission gear ratios allows the engine to operate in the region of greatest efficiency more often. For this reason, significant movement from four speed toward five and six speed automatic transmissions is already underway, and seven and eight speed automatic transmissions have entered the market. Continuously variable transmission (CVT) technology, which provides an essentially "infinite" range of gear ratios, allows the engine to operate in the region of greatest efficiency most often. Historically, torque limitations have hindered the widespread application of CVT technology, but improved technology has extended potential application to most light duty vehicles. The most significant advance expected over the mid-term is, however, the adoption of automated manual transmission technology, which combines the efficiency of manual transmissions with automatic transmission convenience. This technology essentially electronically automates transmission shifting, allowing for the elimination of the automatic transmission torque converter (and its associated losses).

12 volt idle off technology. Considerable fuel energy is used during engine idle operations in typical urban driving environments. Turning the engine off during these operations would improve the overall driving cycle average fuel efficiency of the vehicle. A 12 volt belt driven alternator/starter (BAS) system can offer a

relatively simple solution, allowing automatic engine shutdown and automatic, fast, and reliable restart (upon brake release).

42 volt integrated starter/generator (ISG). A step up from the 12 volt BAS, the 42 volt ISG is a small, high performance electric motor that is either integrated into the driveline of a vehicle (generally referred to as a flywheel alternator/starter or FAS) or belt driven like the 12 volt BAS. Like the 12 volt BAS, the technology allows the vehicle engine to be turned off at idle and instantaneously restarted (both automatically) and accessories to be powered electrically during the engine off period. However, the higher system voltage also allows for regenerative braking (where braking energy is captured and stored for later use) and a modest level of launch assist (where electrical energy is used to supplement internal combustion engine performance). Sometimes termed a "mild hybrid" as a result of these features, the 42 volt ISG system is capable of controlling all light duty engines. The costs estimated for this analysis include an associated electrical system upgrade.

Improved aerodynamics. In urban driving, 20% to 30% of motive energy is expended in overcoming air resistance, 50% to 65% at highway speeds. More streamlined designs that allow for less turbulent airflow reduce fuel use.

Reduced rolling resistance. 30% to 40% of motive force is expended overcoming the resistive torque of tires. Improved tire designs (and reduced vehicle weight) can reduce this force, but tradeoffs in traction, etc. are limiting.

Reduced vehicle weight. Vehicle weight affects both the force required to overcome rolling resistance and the force required to induce a given motion. Generally, each 10% weight reduction reduces fuel use by about 7%. However, the efficiency advantages of weight reduction must be considered in conjunction with possible safety concerns.

Advanced power steering. Electric and electrohydraulic power steering systems offer improved efficiency over conventional hydraulic systems. Conventional hydraulic power steering systems rely on a pump that is connected to the engine via a belt, and this pump places a continuous load on the engine. Conversely, the electric and electrohydraulic power steering systems are operated electronically on an as needed basis, resulting in improved engine efficiency through the elimination of the continuous load otherwise placed on the engine by a conventional power steering pump.

Electric hybrid powertrains. Two hybrid electric designs were evaluated as part of the technology packages included in this analysis. Since hybridization facilitates several complementary technologies, simple hybridization of the engine was not evaluated in isolation, but instead included as a supplementary technology for conventional engine improvements. For most vehicles, "P2" HEV technology was assumed due to benefits that rival those of the more complex Prius type "power split" technology, but at a significantly reduced cost. The P2 system allows for both electric only and combined engine/motor operation using a single electric machine integrated into the driveline of a vehicle. For vehicles requiring conventional type towing capability, 2 mode HEV technology was assumed. The 2 mode system, with two electric machines, is a higher cost approach with reduced efficiency benefits commensurate with the increased reliance on the conventional engine to provide extended power and towing capability on demand.

Plug in hybrid electric powertrains. Plug in hybrid electric technology was considered in the analysis, but is not required to meet the evaluated 2020 CAFE target. This technology essentially consists of hybrid electric technology combined

with a larger storage system (e.g. battery) to allow for an extended electric only driving range. Combined with offboard recharging capability, such vehicles can substantially reduce conventional engine usage for certain (short range) driving patterns. However, the added battery capacity leads to both higher costs and reduced conventional engine efficiency (relative to onboard only hybrids) due to the increased battery weight. Although both 20 and 40 mile electric only range plug in hybrids were included in the analysis (PHEV20 and PHEV40 respectively), the CAFE values were assumed to be identical for both. This is because the CAFE procedures for plug in hybrids are still under development and current CAFE requirements would treat such vehicles as dual fuel (electric and conventional) vehicles, basing net vehicle CAFE on a 50/50 weighting of CAFE determined independently for each fuel. Since the weighting is fixed, regardless of the electric only range of the vehicle, CAFE is independent of that range. It is likely that this will change over time, but since such vehicles are not critical to the attainment of the 2020 CAFE target evaluated in this analysis, no attempt was made to hypothesize what such change will entail.

Electric only powertrains. Electric only technology was considered in the analysis, but is not required to meet the evaluated 2020 CAFE target. This technology consists of an electric only drivetrain combined with a battery system of sufficient capacity to allow for an extended driving range. The necessary battery capacity leads to significantly higher costs. Although the analysis ostensibly included electric only technology with 75, 100, and 150 miles driving ranges (EV75, EV100, and EV150 respectively), only the latter was included in determining system cost-effectiveness. Since no "penalty" is assumed for the reduced driving range relative to that of conventional vehicles, only the highest range vehicle was considered. Further refinement of this approach is appropriate before the cost-effectiveness of CAFE targets that require electric only technology for compliance can be accurately determined. That does not mean that such vehicles will not be introduced between now and 2020, but simply that such introduction will not be necessitated by a CAFE target of the magnitude evaluated in this study (although CAFE benefits will nevertheless accrue to the associated manufacturer, albeit in a cost inefficient manner).

Figure 13. Guide to Popular Industry Acronyms

Abbreviation	Term	Outline
ABS	Anti-lock Braking System	Prevents tires from skidding and improves vehicle control during emergency braking.
ACC	Adaptive Cruise Control	Automatically adjusts vehicle speed to maintain a safe distance to the vehicle in front.
ADAS	Advanced Driver Assistance System	Uses cameras and radar to detect obstacles and warn the driver, and to control the vehicle.
AEBS	Advanced Emergency Braking System	Uses radar to measure the distance to the vehicle in front and apply brakes if necessary.
ECU	Electronic Control Unit	Electronic circuits that act as the brain of an electronic system in vehicles.
EGR	Exhaust Gas Recirculation	Improves engine fuel efficiency by recirculating exhaust gas to the cylinders after combustion.
EPS	Electric Power Steering	Assists vehicle steering by using a motor instead of hydraulics.
ESC	Electronic Stability Control	Controls brakes and the engine to secure turning direction stability.
ETC	Electronic Toll Collection	Electronic systems that collecting tolls automatically.
EV	Electric Vehicle	Uses electrical energy stored in a battery to power the vehicle.
xEVs	Inclusive term of HEV, PHEV and EV	A general term for EV, PHEV and HEV.
FCV	Fuel Cell Vehicle	Uses electrical energy generated from hydrogen using a fuel cell stack to power the vehicle.
FCW	Forward Collision Warning	Warns the driver of pedestrians and obstacles ahead.
GPS	Global Positioning System	Satellite navigation system that provides location information.
HEV	Hybrid Electric Vehicle	Uses electrical energy stored in a battery to assist with vehicle acceleration.
HUD	Head Up Display	Automotive display that presents data directly in viewpoints.
IGBT	Insulated Gate Bipolar Transistor	Semiconductor technologies that control electricity.
ISS	Idling Stop System	Turns off the engine when a vehicle is not moving.
LDW	Lane Departure Warning	Warns the driver when the vehicle starts to drift from its lane.
LED	Light Emitting Diode	Semiconductor technologies that transfer electricity into light.
LKA	Lane Keeping Assist	Helps keep the vehicle in its lane when it starts to drift
MCFC	Molten Carbonate Fuel Cell	Fuel cell technologies used in large size power plant.
MCU	Micro Control Unit	An integrated circuit containing programs.
MEMS	Micro Electro Mechanical Systems	Semiconductor technologies used for sensors.
MLCC	Multilayer Ceramic Capacitor	Small capacitor chips made from ceramics.
MOSFET	Metal Oxide Semiconductor Field Effect Transistor	Semiconductor technologies that control electricity.
NCAP	New Car Assessment Programme	Testing programs that measure the safety of vehicles.
NHTSA	National Highway Traffic Safety Administration	An agency of US government for transportation issues in highway.
NVS	Night Vision System	Detect obstacles at night.
OAA	Open Automotive Alliance	An automotive industry association led by Google.
PAFC	Phosphoric Acid Fuel Cell	Fuel cell technologies used in small size power plant.
PCU	Power Control Unit	Electronic circuits that control power management in vehicle.
PD	Pedestrian Detection	Warns the driver when the system detects pedestrians ahead.
PEFC	Polymer Electrolyte Fuel Cell	Fuel cell technologies used in fuel cell vehicles
PHEV	Plug-in Hybrid Electric Vehicle	Uses electrical energy stored in a battery to power the vehicle, but also has an internal combustion engine.
PND	Portable Navigation Device	Portable navigation systems for vehicles.
SOFC	Solid Oxide Fuel Cell	Fuel cell technologies used in middle size power plants.
TPMS	Tire Pressure Monitoring System	Monitors tire pressure.
TSR	Traffic Sign Recognition	Recognizes road signs and shows them on a display.
VVT	Variable Valve Timing	Engine Improves engine fuel efficiency by controlling the opening/closing of valves.
ZEV	Zero Emission Vehicle	A general term for EV, PHEV and ECV.

Source: Citi Research

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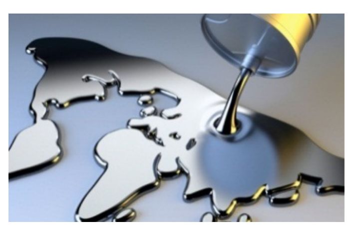

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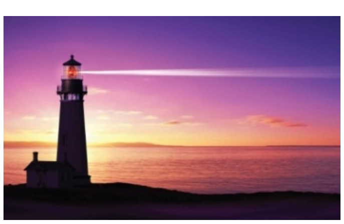

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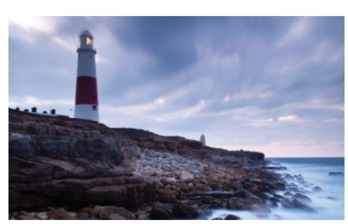

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Key Insights regarding the future of the Automobile

INNOVATION

Today, road fatalities claim over 1 million lives around the world each year – placing car accidents within the top 10 global cause of death. Human error accounts for over 90% of traffic accidents. / Advanced Driver Assistance Systems (ADAS), which alert drivers to potential hazards or even temporarily take control of the car to avoid dangerous situations, are being developed and pushed into production both by regulation and by consumer demand.

SUSTAINABILITY

Long automotive product cycles essentially force automakers to make large calls on a few chosen technologies a number of years before market implementation. / Global regulatory requirements are now largely enacted through the middle of this decade, and it's clear that proposals through 2025 call for even greater stringency requiring a greater mix of non-conventional technologies such as alternative fuels, electrification and perhaps even hydrogen fuel-cell. Automakers are adopting different strategies and pathways towards satisfying not only these regulatory demand, but also consumer demands.

TECHNOLOGY

Infotainment in an automobile has evolved from simple technology such as an AM/FM tuner and cassette player into more advanced capacity touch screen human machine interfaces (HMI), which can control multiple aspects of one's vehicle. / Touch screens are a crucial component of Citi's Car of the Future and are a mission critical piece of the puzzle as more and more information is required by the end user.