FUNDAMENTALS

The driving machine transformed

After more than a century of incremental change, technological trends and consumer demands around road vehicles are converging.

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While the headlines are predicting an inevitable and seamless transition to electric and even autonomous vehicles, we believe that this outcome relies on a number of technological and market developments. We cut through the noise to examine these components in more detail, and assess the outlook for "the car of the future". The automotive industry has been ripe for innovation for some time, given the inefficiencies that have persisted for many decades. Today, futuristic vehicle developments are on the horizon, as the hardware and software improvements required to address these issues are now within reach. Much like Henry Ford's original low-cost assembly line, these innovations are capable of redefining the future of transportation.

CRITICAL ISSUES THAT PROLIFERATE THE NEED FOR CHANGE

Safety: The number of Americans that die per 100 million vehicle miles travelled has been on a steadily declining trend (apart from the last two years) and is down almost 50% since the early 1990s. Nevertheless the statistics remain scary: 3,500 people die in traffic accidents every day and some estimates suggest that around 93% are caused by human error.

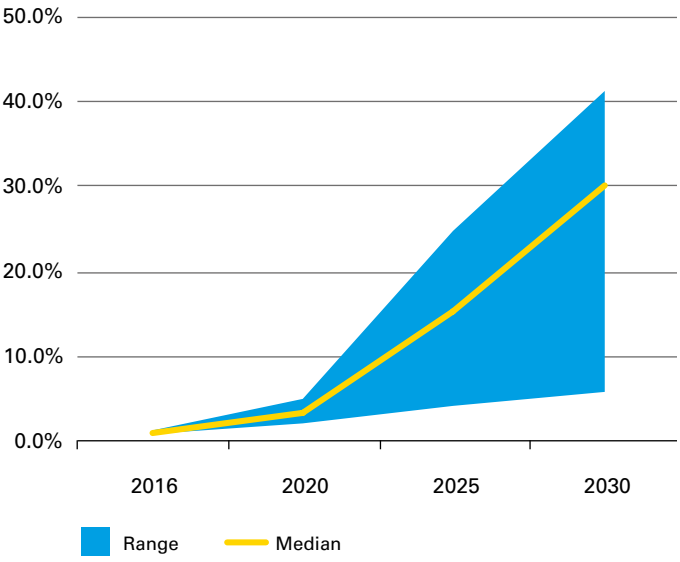
Utilisation and cost of ownership: Cars spend the vast majority of their time parked, be it on a driveway, or at a train station. The utilisation rate is a meagre 4% and gets even worse on a per seat basis. Car seats are empty around 99% of the time! Given how much capital each of us has tied up in our car, that feels like a terrible waste.

Inability to multi-task: Cars are huge time wasters. Morgan Stanley estimates that globally around 400bn hours of non-productive time is spent driving cars, plus another 200bn hours for passengers.

Environmental impact: It will come as no surprise to anyone that the environmental impact of running automobiles, including CO2 and NOX emissions and the production of commodities, can be reduced.

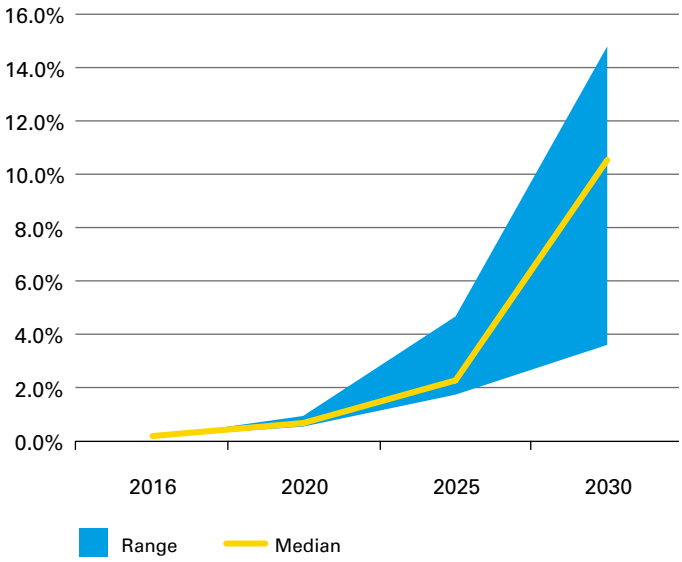
Legal & General
INVESTMENT MANAGEMENT

Figure 1: Estimated EV sales as % of total cars sold



Source: LGIM

Figure 2: Consensus range of EV % of global car parc (vehicles on the road)



Source: LGIM

The shift in the industry has seen three key trends emerge in recent years; electrification, autonomous driving and the sharing economy. These are big trends that will take many years to play out fully, and we have greater confidence in the direction of travel than the precise speed or path of each trend. Attempting to forecast the exact shape of the adoption curve of electric vehicles, the progress of autonomous car technology or the extent of car connectivity and its role in the sharing economy could inevitably result in the wrong conclusions. We find it more valuable to identify if this is the technological trend that is about to hit parabolic growth, establish the winners and losers and finally assess how much risk is priced into certain assets as a result of the threats posed.

THE ELECTRIC SHIFT

Electric vehicle (EV) penetration broadly depends on the ability of OEMs (original end manufacturer), the auto parts supply chain, and semiconductors and capital goods manufacturers to work together to address key factors around the transition away from the internal combustion engine (ICE). These chiefly include the reduction in costs and increased regulatory compliance. Developments within each of these manufacturing groups are particularly important when we consider the factors driving the shift towards EV.

THE REVOLUTION IS BATTERY-POWERED

On a price basis, electric vehicles have not historically been able to compete with conventionally powered cars. As a result, few electric car models have crossed 100,000 units a year (out of 110 million cars sold globally). The most advanced electric cars on the road today are the Tesla Model S and Model X, which come with a price tag of over £70,000. While this may be about to change with the launch of the Tesla Model 3, cost has clearly been an issue — the biggest component being the battery, which has an estimated cost of $20,000-30,000. Importantly for the industry, car manufacturers (and analysts) estimate that battery costs will continue to decline, moving closer towards cost parity with ICEs over the next decade. We estimate they will hit around $100/kWh by 2020, reducing the battery cost to under $15,000. This may sound unlikely, but only assumes that the average annual cost declines of the past two decades continue, an assumption that seems plausible given the huge amount of investment in the area.

REGULATION, REGULATION, REGULATION

Despite the media noise around the cost of ownership, a significant part of the EV revolution is being driven by the sharp rise in regulatory compliance on existing ICEs. A growing number of countries are tightening emission norms, but the room to further improve a mature technology like the ICE is very limited in the existing format. The only realistic way to reduce the overall emissions is to sell more electric vehicles (zero emission).

Looking ahead, it is also likely the risk seems skewed toward tighter norms from regulators, rather than looser.

A shift in the powertrain towards pure electric or hybrid solutions is primarily being driven by auto companies trying to cope with the rising pressure from CO2 and NOX emission standards, where OEMs are required by regulators to reduce their overall fleet emissions. To understand how important this is, think back to the VW debacle last year. Most of the big wins have been made within the ICE, with today's cars coming with much smaller engine sizes and lightweight materials to deliver similar power at reduced emissions. Unfortunately, these are still oil-burning engines, so the reduction in emissions can only be taken to a certain point. Beyond that level, the mix has to be shifted to higher percentage of sales emitting zero in order to meet the 2020 and 2025 required targets.

Given the need for OEMs to dramatically shift their manufacturing facilities to adapt to the new powertrain evolution, this has created a significant capex requirement across the industry to meet best-practise standards. In this instance, automotive supply companies, such as Valeo, are well positioned to benefit from this trend. Valeo designs cutting-edge solutions for smart mobility, and every product generation the company develops is designed to deliver at least a 20% reduction in emissions. Other revolutionary technology, like the stop-starter or the 48 Volt, has a much larger impact on the emission footprint of their clients.

Suppliers and part-providers are able to focus on the R&D spend required to innovate products for both new and existing powertrains, before selling their technology across a broad base of customers. Ultimately, this helps mitigate rising capex requirements for OEMs.

HOW HAS THE MARKET INTERPRETED THESE DEVELOPMENTS?

Given all these rising pressures, the market has been quick to discount OEM valuations down to low single digit P/E multiples on a trailing basis, with dividend yields in excess of 5% and operating cashflow yields of over 25%. This suggests the market sees margins halving in the next five years due to rising capex spend. In comparison, technology companies catering to the theme, which don't carry the historical cost base and are currently making no margins, are significantly more expensive — several times that of OEMs. On this basis, the market appears willing to make the assumption that only the technology companies are likely to emerge as winners as the future powertrain competition heats up. This represents a clear disconnect in risk perception, in our view.

Within car manufacturers, Mercedes-Benz, owned by Daimler, recognises the threats posed by tech companies such as Tesla, Google and Uber, and is now well placed to deal with the challenge head on. In the current environment, OEMs have to be more tech-focused, going beyond their traditional roles as manufacturers. Daimler management have ambitious plans when it comes to electrification, increasing their R&D budget accordingly to reflect increased investment for future growth. They are positioning the group for EV sales hitting 25% of their total by 2025. In addition, they have the most advanced autonomous systems in the market, comparable to Tesla's Model S. This example highlights that investing for these trends is a complex issue, with many potential market participants.

THE VIEW FROM THE ENERGY THOUGHT LEADERSHIP TEAM

Autos have always been important for oil demand, accounting for about one third of oil demand globally. The big question is therefore whether electric vehicles mean the end for oil demand? We don't think so – at least not any time soon.

There is a range of estimates for how rapid this transition will be – and a lot of uncertainty about the level and pace of EV penetration. Estimates of EV penetration by 2025 average around 2%, which would imply demand destruction of about 500k barrels of oil per day, or about 0.5% of daily demand. In the near term, this leads to the conclusion that demand destruction from electric vehicles is likely to be limited.

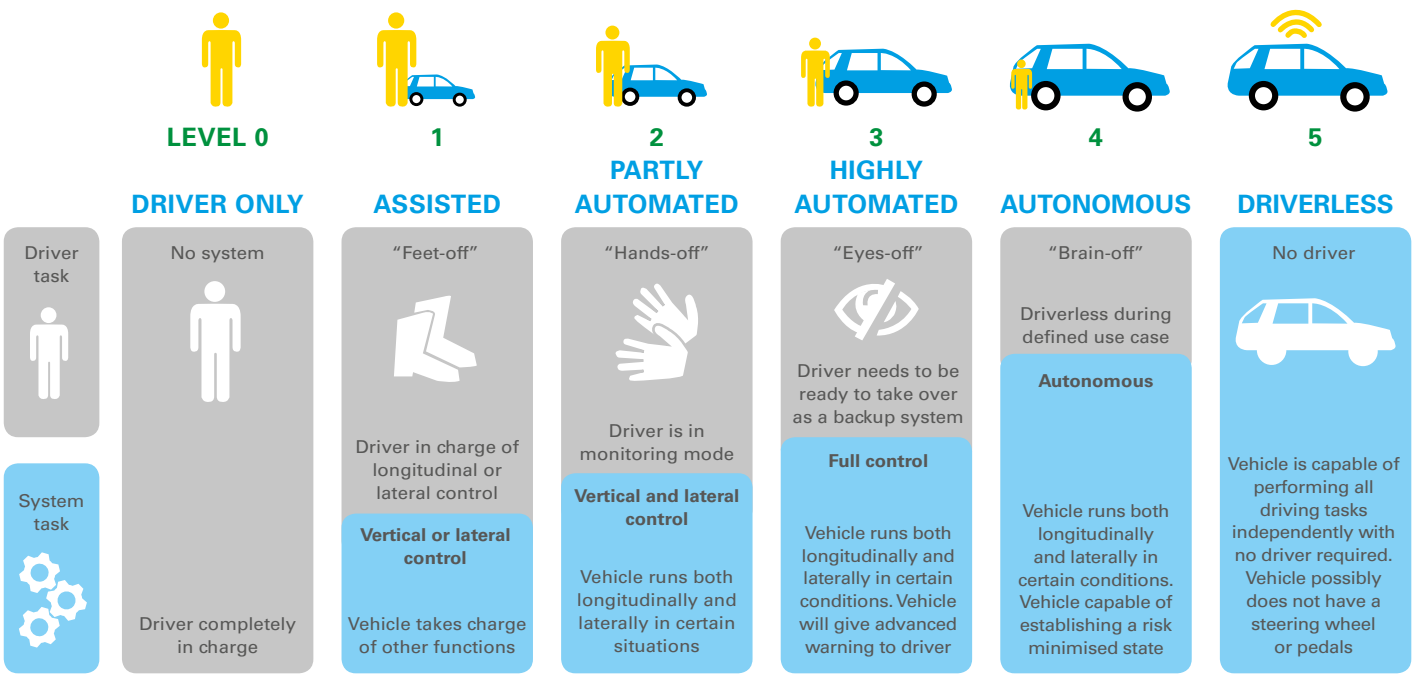
By 2030 the picture starts to look different. The uncertainty range another five years out is large, with implied demand destruction (on the same assumptions) of between 1-4m barrels per day, equating to between 1% and 5% of daily demand. Still not the death knell for the oil industry, but we are shifting towards a trend. Beyond 2030 the impact will only grow. Uncertainty may increase, but the potential impact on oil demand starts to become very significant indeed.

SIGNPOSTS TO WATCH TO PREDICT THE TREND

- Battery cost reduction, range capability, charging speed and charging infrastructure
- Consumer take up rate of EVs versus internal combustion engines, with and without subsides
- Further regulation tightening of emission targets or subsidies to drive EV adoption

DISTINGUISHING BETWEEN THE LEVELS OF AUTOMATION

Figure 3: 5 levels of automation



Source: Barclays Research

The journey from today's human-driven cars to self-driving cars has many steps, best summarised by the SAE's five levels of automation. As we race towards the development of autonomous vehicles, the gradient of the technological progress and adoption curves are very important. So far, most systems on the market have been between Level 2 and Level 3. Even the greatest optimists acknowledge that it will take several years to get to Level 4 or 5. We are already moving to the phase of parabolic improvement where more capital and resources are devoted to improving the technology. Intel's acquisition of Mobil Eye, Uber's launch of autonomous functions, the four-fold increase of semiconductor firm Nvidia's share price in the last 15 months and the creation of separate autonomous driving units at Apple and Google (Waymo) indicate that the development of autonomous is definitely front and centre of both the industry's and investors' minds.

WHAT OPPORTUNITIES DOES AUTOMATION CREATE?

While autonomous cars won't eliminate accidents completely since they can't suspend the laws of physics, it seems likely they will be able to achieve safety records many orders of magnitude better than human drivers. Advanced driver systems have already contributed to improvements in blind-spot monitoring and auto emergency braking. This will move further into software-driven intersection pilot, valet park assist, 3D cloud based navigation and more sophisticated collision-avoidance technology. Legislation also has an important part to play, as regulations should move in step with radical technological change. Fault-based liability in accidents, alongside data protection laws and harmful malware, present challenges for the Department of Transport.

In addition, technology companies are convinced that cars could be the next big hardware wave after smartphones, with similar adoption rates. Remember that smartphones have only really existed for around seven years, and yet they have become an integral part of most people's lives across the world. Within five years an autonomous car is expected to have the computing power of five CPUs and transmit close to one terabytes of data a month (1000x that of a

smartphone). Given the possible capability enhancements from this technology, cars could be ripe for a similar adoption wave.

Looking at this from a different perspective, the prospect of autonomous cars and a seamless experience opens up a big opportunity for companies to sell more services. As just one example, the average American spends two hours per day in a car, and given that both Google and Facebook generate over $120bn in revenue a year from ads, the incremental time spent on these platforms in autonomous vehicles is potentially an enormous business opportunity.

Of the listed European names, Daimler sees an opportunity to leverage the enthusiasm around ride-hailing and self-driving cars. After previously agreeing a deal with Uber, they have more recently penned a venture with automotive supplier Bosch to deliver a commercial system for urban autonomous taxis on the road in 2021. Daimler has also explored other areas where they can harness the power of such innovative technologies. Last-mile delivery operations, featuring fully-automated cargo space and integrated drones is another example, providing a foretaste of future opportunities in automation.

SIGNPOSTS TO WATCH TO PREDICT THE TREND

- AI capability to interpret images, road signs and people
- Regulation allowing for Level 4 and Level 5 Autonomous
- Consumer confidence and trust towards AI/ computers operating and driving vehicles
- Insurance liability shifting from man to machine

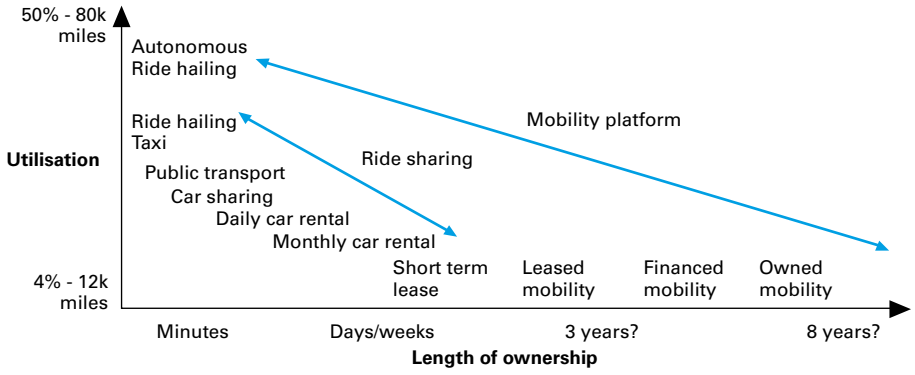
RETHINKING OWNERSHIP – THE SHARED ECONOMY

The third technological change converging on the auto sector is the sharing economy. 80% of Americans say they would rent, lease or borrow items instead of buying them if they could do so easily. Given low utilisation rates — cars spend most of their time sat on their owners' driveways - this trend is particularly pertinent for the auto sector.

There are multiple ways shared autonomous vehicles can increase car utilisation rates, with two scenarios most likely:

1) In the 'household model' consumers would still own cars, but share the mode of transport within the household. Rather than owning on average 2.1 cars per household, most families would own one autonomous car, which we feel is supported by usage statistics.

Figure 4: Varying utilisation levels for varying ownership models



Source: Morgan Stanley research

2) In another scenario, perhaps initially more likely to be adopted in densely-populated metropolitan areas, car usage shifts towards a fully shared and autonomous model (think Uber, Lyft and other tech companies catering to this trend). Fleet operators would own the majority of the car parc and sell autonomous rides.

Higher utilisation rates come with the need for an accelerated replacement cycle; cars would wear out more quickly and would subsequently be replaced more quickly than today. Indeed, if the cost of transportation declines and journey time becomes enjoyable or productive, we may end up taking more trips that are currently uneconomical. It's also possible that higher-quality electric and autonomous cars command a higher price and specification than their predecessors. With increased utilisation rates, the cost equation on a $/mile basis could dramatically decline despite headline prices of cars rising.

SIGNPOSTS TO WATCH TO PREDICT THE TREND

- Will the social trend towards a sharing economy persist?
- Will the car's decline in aspiration rankings continue?
- How quickly can shared and autonomous models be offered outside densely populated areas?

UNIT ECONOMICS – COST ANALYSIS

By 2020 the average cost of an electrical vehicle is expected to reach the levels demonstrated below, which is still before hitting cost parity with current ICEs. Additionally, we are yet to see increased utilisation driven by autonomous but, if the technology develops, and with an uplift in sharing, utilisation levels are expected to hit 12%+. We ran some analysis using market data to understand these cost changes, and our understanding is that this should result in the running cost of a car dropping by 30% and 2.5hrs a day in freed up time (average time spent driving by American adults).

HOW IMPORTANT ARE SUBSIDIES?

The crux of the adoption question is cost parity. Costs will only come down as the volume of production increases significantly, and therefore one of the most significant determinants dictating the path of adoption is government, subsidies. Using Denmark as a case study, we can see the removal of subsidies led to electric vehicle sales falling 60% year-on-year, highlighting how sensitive penetration is to consumer activity. The higher the initial subsidy, the quicker the volume growth and the faster OEMs can benefit from scale production. This, in turn, lowers manufacturing costs and works to sustain a virtuous circle driving down the price and increasing adoption.

Figure 5: Per mile cost comparison (today vs. future)

	New car today	Used car today	Car of the future
CAPITAL COSTS			
Average price of a car (€)	18,900	8,505	30,000
Year in service	5	5	4
Residual value	8,505	5,698	13,500
Interest Rate	5%	5%	5%
Annual capital cost	0	0	0
Insurance	471	212	615
Registration, taxes	167	75	435
Annual fixed costs (€)	638	287	1,050
Passenger miles	10,000	10,000	30,000
Utilisation	4%	4%	12%
Fixed cost / mile (€)	0.06	0.03	0.04
Variable cost / mile (€)	0.16	0.30	0.14
Total cost / mile (€)	**0.23**	**0.33**	**0.18**
VARIABLE COSTS			
Oil Price (per lt) (€)	1.15	1.15	
Mileage (mpg)	55.0	26.0	
Price per mile (gas / electric) (€)	0.09	0.20	0.03
Maintenance	0.05	0.08	0.07
Tyres, etc	0.02	0.02	0.04
Estimated trip cost Shepherds Bush to One Coleman street			
Travel	8 Miles	8 Miles	8 Miles
Travel cost	2.01	2.89	1.54
Parking	£5	£5	
Congestion Charge	£11.50	£11.50	
Total Cost	£18.51	£19.39	£1.54

Figures based on 2017 VW Golf and 2010 VW Golf (published city mileage)

Source: LGIM

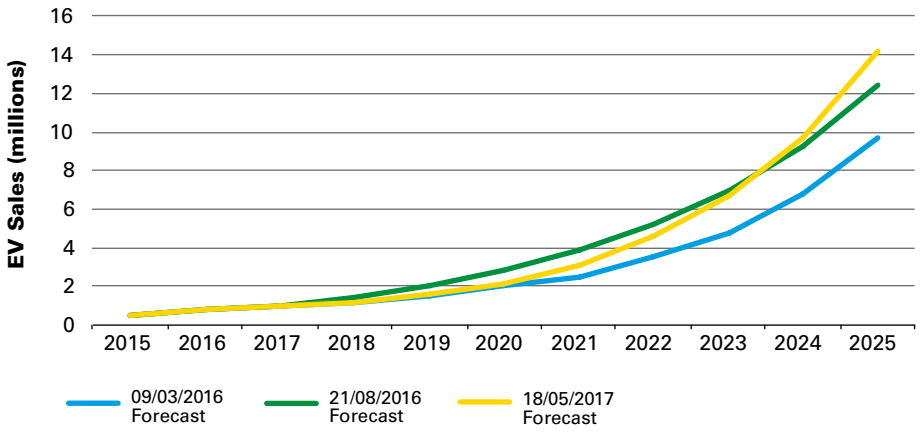
WHERE DO WE GO FROM HERE?

Precisely calling the point of acceleration can prove to be difficult, but we know that EV adoption forecasts have themselves been accelerating. The charts below show estimates of EV sales through 2025 from both a sector specialist team and that of an auto supplier (Continental). From the data, we can see it is clear that in the last two years the expectations have more than tripled. Keeping an eye on the forecast momentum lets us monitor whether the technology trends discussed above are progressing as expected.

In previous pieces we have tried to lay out a framework to distinguish the different phases on the hype cycle to identify trends and innovations that are primed for exponential growth faster and sooner than most expect. With this in mind, the auto sector appears to be subject to one of the most important technological revolutions, and one that is about to hit the growth section of the S-curve.

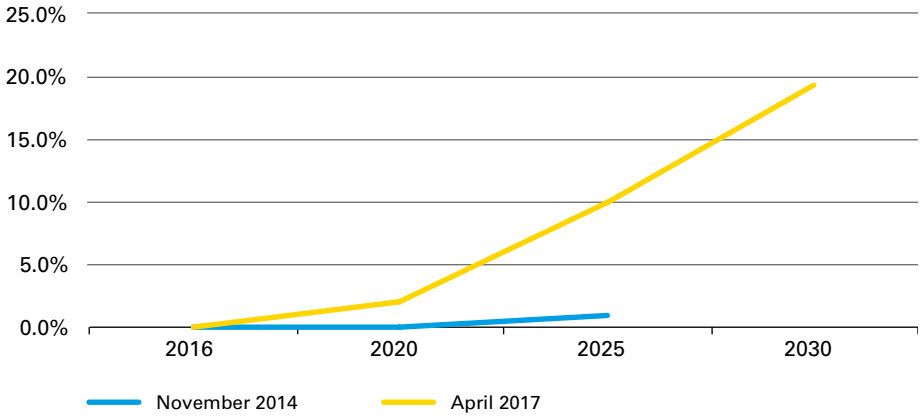
The speed of adoption will have wide ranging implications, and not just for the auto sector. To put some numbers behind what could be at stake; annual auto sales are ~$2 trillion plus an additional $1 trillion from auto parts; global oil revenue is $1.4 trillion (of which cars and trucks make up around one third).

Figure 6: UBS EV sales forecasts



Source: LGIM, UBS estimates.

Figure 7: Continental's EV sales forecasts



Source: LGIM, Continental estimates

Another way to measure what's at stake are the 10 trillion miles travelled and several hundreds of billions of hours spent in vehicles freed up for other uses.

Beyond the obvious implications in the auto and tech sectors, fewer accidents will impact the insurance sector, public transportation infrastructure will have new competition, real estate may be freed up from car parks and easier commuting may change relative real estate prices. The direction of travel appears clear.

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