

# ELECTRIC VEHICLES – IT'S NOT JUST ABOUT THE CAR

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One of the key characteristics of complex systems, such as the world's energy and transport sectors, is that when they change it tends not to be a linear process. They flip from one state to another in a way strongly analogous to a phase change in material science. We have written about this before, for instance [here](#) and [here](#).

A second important characteristic of this type of economic phase change is that when one major sector flips, the results rip through the whole economy and can have impacts on the societal scale.

We are seeing this effect in the electricity system right now. The rapid uptake of renewable generation in the power system, unstoppable now because of cost reductions in wind and solar, has not simply rendered a certain proportion of conventional generation uneconomic. It has fundamentally changed the way power markets work, making new investment in other sources all but impossible; it has changed the control paradigm for the grid from base-load-and-peak to forecast-and-balance; it has altered flows of investment throughout the power system and its technology providers; it is forcing through an accelerated digitisation of all electrical equipment. It is even changing the way buildings are designed, the training needed by the construction trades, and the way infrastructure is financed.

We've seen this effect before, and not just in the distant past. When the first cell phones appeared, the assumption was that they would be used like normal phones, but on the move. But as their costs came down, their uses rose and they demanded the digitization of the analogue phone network – just as renewable energy is doing now to the power network. Three decades on, cell phones have pushed fixed phones to the fringes; even more importantly, however, they have driven profound

changes in sector after sector of the wider economy – the type of holidays we take and how we book them, the mix of shops on high streets and in malls, the way we move around our cities. Mobile phones have eaten entire industries (cameras, alarm clocks, maps) and are set to do the same to others (newspapers, cash handling, music systems). No sector is immune, right down to furniture design, the size of pockets sewn into garments, even how many single diners a restaurant needs to plan for each night.

Over the past few years we at Bloomberg New Energy Finance have been devoting more and more of our attention to the transportation sector. Just as in 2004 we felt the energy industry and its mainstream analysts had failed to understand the scale, imminence and implications of the renewable energy revolution, so in 2010 we started to feel the same about electric vehicles. One of the Magnificent Seven long-term trends I highlighted at our Summit that year was “The Transformation of Transportation”, which I illustrated with pictures of what electric vehicles looked like up to that point – British milk floats, the Sinclair C5 (look it up!), various tiny and weird-looking cars like the G-Wiz – followed by pictures of the electric cars of the future, which looked like, well, normal cars.

This year, BNEF was the first mainstream energy research firm to publish a comprehensive forecast showing electric vehicles penetrating deep into the car market. The central scenario of our [Global EV Sales Outlook to 2040](#), published in February, was that 35 percent of new sales would be electric by 2040, and perhaps as high as 47 percent under certain conditions (higher oil prices, more widespread use of car-sharing). If anything, since publishing that forecast, we are tending to think EV penetration will be faster, not slower, despite persistently low oil prices. In the first half of this year,

worldwide EV sales were 285,000, up 57 percent on 2015.

The reason for our bullishness on electric vehicles is not just the fact that battery costs are dropping at the sort of rates we have seen in the solar industry, down 65 percent in the past five years. It is also that electric vehicles out-compete internal combustion cars in lots of important dimensions: they drive more smoothly yet accelerate better, they can be charged at home or at the office, they require much less maintenance, they help solve air quality problems, they improve the energy autonomy of oil-importing countries. Sure, they have limited range and take a while to charge, but this is, in practice, irrelevant for the vast majority of use cases. Up to 40 percent of the cars in the U.S. are second vehicles; can anyone think of a good reason to buy a diesel or petrol second car in 15 years?

Another powerful driver for the uptake of electric vehicles is that they are a vastly superior platform for autonomous driving, infotainment, connected vehicle and transport-as-a-service technologies, which are starting to transform the safety and experience of the travelling public. Put simply, our transport system is digitizing, just as the phone system digitized, just as the energy system is digitizing, and this will yield dramatic benefits in terms of asset utilization (in other words cost), flexibility, service levels and cleanliness. And it simply makes no sense to have an inherently analogue power unit – vibrating, volatile-liquid-consuming, hot-polluting-exhaust-producing – at the heart of a fully digital, sensor-pervaded, solid-state-electronics-controlled system.

The coming shift to electric, digitally-connected vehicles will have dramatic implications for the car industry. Much media attention focuses on Tesla Motors, the new entrant that parked EVs so firmly on the auto industry's lawn. Tesla's ability to maintain its early lead will be dependent on continued access to cheap capital, particularly over the next three years as it deals with scaling up production of its first mass-market model and at the same time faces rigorous scrutiny of its self-driving technology. It is perhaps just as well, as Bloomberg's Liam Denning explains [here](#), that its investor cheerleaders don't seem to care how much money it is losing, or by how much it misses its production targets. But that will change over time, which is why, seen through the lens of investor confidence, the acquisition of SolarCity looks like an unnecessary risk.

While Tesla basks in attention, there has been far too little robust scrutiny of incumbent auto companies' electric vehicle strategies. There is plenty of oohing and aahing over concept cars, electric model launches and press releases about ambitious plans; but which car

companies are really committed to electric vehicles and which ones are going through the motions? Which ones are betting on battery-only vehicles and which ones on plug-in hybrids? Which ones are still waiting for hydrogen fuel cells to descend from on high, on a beam of light? You wouldn't know by reading the mainstream business press.

Instead we get endless coverage of potential new entrants into the car business. Dyson makes a fine vacuum cleaner and has world-beating knowledge of batteries and motors, but is that really going to be enough to beat GM, Ford and Toyota? Really? Faraday Future previews an electric Batmobile and the world's press goes into hyperbole-drive. And then there's Apple. In Abu Dhabi, I stay on Al Maryah Island, reclaimed from the sea in 2007; Apple Maps still shows it as a network of roads in the middle of the sea. If Apple can't show my hotel car park, does anyone seriously think it can sell me a self-driving car? Even Google, while it appears to have established a very strong position in the machine-learning technologies that will underpin autonomous vehicle features, is unlikely to find that is enough to give it leadership of the car industry of the future.

More likely, to understand the future of the car over the next decade, you need to watch the mainstream car companies – the big U.S., European, Japanese, Indian and Chinese names. The most important news this year is not which executive left Google, or joined Apple; it may not even be the launch of Tesla's Model 3, it may instead be the \$15 billion settlement of Volkswagen's 'Dieselgate' lawsuits, which included a \$2 billion commitment to promoting zero-emission vehicles in the U.S. This was just part of \$11.2 billion VW intends to spend over the next decade on electric vehicles – a commitment that the company expects to result in up to 25 percent of its unit sales being electric by 2025. Put that in context: that would be 2.5 million vehicles a year in less than a decade – a cool 30 times Tesla's current 85,000 unit sales.

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For all the seismic shifts electric vehicles will bring to the car industry, as with mobile phones and cheap renewable energy, as with all transformations in major economic sectors, some of the biggest impacts may be felt in other parts of the economy. Here are some of the sectors that could be hit by the resulting tsunami:

### 1. Auto supply chain

Car companies are the keystone species in an ecosystem of technology and service providers, all of which are going to see extreme disruption from the shift to electric and digital vehicles.

The highest-profile beneficiaries are likely to be battery providers like Panasonic, LG Chem and Samsung, but there will be many others providing everything from software and sensors to asset tracking and cyber-protection, not to mention those who provide autonomous driving technology. As markets for internal combustion engines wither, there will be losers throughout their enormous supply chain, among manufacturers of gearboxes, fuel management assemblies, exhaust systems and catalysts, and the entire associated component supply industry. In 1904, there were 61,306 people employed making wagons and carriages in the U.S. By 1921, the figure was 8,025.

The chemicals industry will be profoundly impacted. Demand for battery chemicals – in particular lithium for the foreseeable future – will soar, as will demand for rare earth metals, which are needed in so many motors and other modern electrical components. The use of steel in electric vehicles will decline, as manufacturers strive to reduce weight to counteract the inevitable heaviness of the batteries, while the use of resins, composite materials and aerogels will increase.

## **2. Dealer networks**

It is not just manufacturing and commodities that will be hit. Expect to see numbers of car dealerships and repair shops decimated in coming decades.

Electric vehicles have dramatically fewer maintenance needs, as a result of having fewer moving parts – just a few sealed electric motors, steering and suspension assemblies. Hard data are sparse at this early stage in the industry, but it would seem reasonable to expect the main battery to last for at least 70,000 miles, and longer in future. Most system tweaks can be done remotely via software updates, rather than at the hands of a mechanic, and the annual service will be mainly about rotating the tires, replacing the occasional brake pad, and filling the windscreen wiper fluid.

At the same time, driver support software – collision avoidance, lane maintenance, platooning, tiredness alerts, driverless parking and so on – will dramatically reduce the number of accidents. While fully driverless vehicles, which might have a dramatic effect on the worldwide number of driving jobs, look like being some way away, the reduction of maintenance and repair work is happening now and will be picking up speed.

As for car retailing, with the economics of dealerships undermined by the near-elimination of maintenance and repair work, the rationale for the classic suburban car dealership is broken. Expect to see more showrooms in convenient locations (i.e. city centers and transport hubs), and out-of-town second-hand car markets.

## **3. Electricity system**

In our central [New Energy Outlook](#) forecast, published in June, we estimated that EVs will add 2,701 terawatt-hours, or 8 percent, to global annual electricity demand by 2040 – and more in the event of even more rapid uptake. This is welcome news indeed for utilities, supporting demand for their product at a time when energy-efficient devices will be having a strong opposite effect.

But it's not just about raw power demand: a large installed base of EVs means a huge potential increase in demand-response capacity – electric vehicles can be charged when the power price is low, when solar and wind energy are generating strongly, and they can (assuming the appropriate regulatory and commercial arrangements are in place) discharge back into the grid when the network is short of generation. This creates new opportunities for utilities – or others – to offer new ancillary services.

In addition, while the benefits to the grid of second-hand electric vehicle batteries have yet to materialize, they could be substantial. Once a battery's performance has degraded by around 30 percent, it could become available for stationary storage. Upcoming research by BNEF's advanced transportation team will suggest that by 2018 these second-life batteries could cost as little as \$49 per usable kilowatt-hour to repurpose, compared to the current new stationary battery price today of around \$300 per kilowatt-hour. If so, they will further support the economics of both renewable energy and electric vehicles, accelerating the uptake of both.

Then of course there are the off-grid markets, where any improvement in battery technology driven by electric vehicles could have profound benefits, perhaps seeing the demise of the trusty diesel generator, to be replaced by a clean, silent, low-maintenance mini- or micro-grid.

## **4. Oil companies and oil exporters**

The flip-side of additional electricity demand from electric vehicles is of course reduced oil demand versus the 100 percent liquid-fuel-based fleet. In our central NEO scenario, there is a reduction of 13 million barrels of oil per day by 2040. Of course, there are other moving parts when it comes to absolute levels of gasoline demand, including the impact of GDP growth on car ownership in emerging markets, further improvements in the efficiency of internal combustion engines, modal shifts in transportation, and penetration of compressed natural gas, biofuels and other alternative transport fuels. But what is clear is that a rapid shift to electric vehicles, on the scale we are expecting, would be bearish for oil demand.

Last month, Wood Mackenzie reported that upstream investment in the oil industry between 2015 and 2020 was slashed by over \$1 trillion in the aftermath of the 2014 oil price crash. The orthodox view – certainly held by Ali Al Naimi, Saudi oil minister at the time his country decided to open the taps – is that the oil price must inevitably soar again in due course, as demand growth absorbs excess capacity and new supply fails to materialize. A rapid uptake of electric vehicles, such as the one we envisage, makes this a whole lot less likely.

The very fact that there is now a scalable technology competitive with internal combustion vehicles means there is a cap on long-term oil prices – currently around \$80 per barrel but dropping fast. Never mind “lower for longer”, oil prices could well be “lower forever”. That would drive a lot more downsizing and consolidation among international oil companies and oilfield service providers, as well as deep pain and the need for economic restructuring among oil-exporting nations. Venezuela is unlikely to be the last oil-producing state to require international rescue.

### **5. Road and charging infrastructure**

Of course the uptake of electric vehicles will have to be accompanied by the roll-out of charging infrastructure. Think of the growth of ISPs during the crazy years of the internet revolution. Much commentator attention is focused currently on on-street charging, but the fact is the average EV owner will expect to be able to charge his or her car at home or on-street, at the office, at the shopping mall and on any major road during longer trips. That’s a lot of charging stations that need building.

The construction industry will be one of the big beneficiaries, as will power equipment and associated software providers. In the first instance, there will be a great deal of work digging up roads and pavements to install charging points and the associated cabling at homes, car parks and retail outlets. Over the medium and long term, building codes will be amended to require designs to provide for charging points in garages or outside homes, and there will be retrofitting work to some of the existing stock.

As for our highways and motorways, the tried and tested gasoline-age infrastructure has filling stations dotted around the outskirts of towns, at fairly regular intervals of 10-20 miles on trunk roads and every 20-30 miles on motorways/freeways service stations. All of this is up for grabs. It is too early to tell what the ultimate morphology will be: early on, many potential electric vehicle buyers may hang back unless they see massive numbers of charging stations on motorways; later, the numbers will

be driven by real levels of demand, as they are for petrol and diesel filling stations.

In the end, many electric vehicle drivers will likely try to avoid using charging stations on main roads and motorways for reasons of time and cost. Those that have to – perhaps because they are undertaking longer trips – will have to spend longer doing so, creating new retail and food service opportunities. Meanwhile, urban petrol stations will continue their long trend of thinning out as electric vehicles eat into their demand.

### **6. Cities**

There is an endless literature on how the advent of the car shaped the modern city, driving the creation of suburbs. The shift to electrification and digitization of transportation won’t undo that trend – indeed driverless vehicles would probably make possible longer commutes as drivers could productively use commuting time. Nevertheless, the shift to electric transportation is going to have a significant impact on our physical environment.

Most obvious will be the build-out of charging points. City after city has been ripping out traditional parking meters, now they have to start installing on-street charging stations. Perhaps more strikingly, charging stations will be ubiquitous in car parks, whether municipal and multi-storey ones, those belonging to employers, or those outside supermarkets, shopping malls and hotels and restaurants. Since many potential EV owners don’t own their own garages or driveways, retailers will lead the charge, as they realise free charging is a great way of securing regular, captive customers.

The electrification of urban transportation will have unexpected consequences. Many formerly fashionable boulevards in older cities are currently blighted by fast traffic, road noise and air pollution. At the same time, the digitization of bus services might reduce their concentration on a small number of heavily-trafficked bus routes. Could electric vehicles and digital transportation inadvertently reclaim our high streets and unlock vast real estate value?

### **7. Other transportation sectors**

The electrification of transportation will not be restricted to the car market. In fact, there are already 200 million electric bikes in China alone, and their use is spreading worldwide. Improved battery, motor and power control technology will challenge the dominance of small fossil-fuel engines in every light sector: motor boats, lawnmowers, snowmobiles, mopeds and motor cycles.

As battery costs drop, electrification will spread into heavier vehicles too. Delivery vans are a natural early

market, as they drive relatively small distances, and there is a high premium to be earned through eliminating noise and air pollution. Electric ferries are starting to appear, and Tesla, Mercedes and others are working hard to produce reference designs for heavy-duty trucks.

Last month, two Swiss adventurers, Bertrand Piccard and André Borschberg, completed the first ever round-the-world flight by a solar aircraft, Solar Impulse II. In 2009, when I first heard Piccard speak about the challenge, he was asked whether we would ever see solar-powered passenger planes, and his answer was a flat "No". The project was designed as an extreme engineering challenge and a communications vehicle. Yet this year, after completing the circumnavigation, he said: "I'm sure that within 10 years, we'll see electric airplanes transporting 50 passengers on short- to medium-haul flights." That is as good an analogy as any for the speed with which electrification technology is progressing, and the range of applications in which it might ultimately find a use.

## **8. Ministries of finance**

The final area that will be transformed if we are right about the scale and speed of transformation in transportation, is the world's finance ministries.

While it is obvious that anything that reduces oil demand would be seen as a negative by the finance ministers of oil-producing nations, the fact is that, even in consuming nations, the shift to electric and connected vehicles poses considerable headaches. First, particularly in Europe, petrol and diesel are heavily taxed, providing up to 7 percent of government receipts. Reduce their demand, and perhaps price, and government income is reduced. While there is an economic stimulus, there is the question of where replacement government income is to be found.

Second, at the same time, as described above, there are likely to be reductions in the number of people employed in maintaining, repairing, and eventually driving vehicles. While there might be an economic pay-off eventually as these people are freed up to fill other roles in the workforce, there is a real question as to whether they can acquire relevant skills. Expect the debate about guaranteed income to grow in volume if the transportation sector starts to shed millions of jobs worldwide even as economies grow.

Finally, clean energy and transportation technologies, almost by definition, require much more up-front investment, and much less on-going spending. Thus any major shift in their direction will require the creation of new pools of long-term capital, and have impacts at the macro-economic level on productivity and interest rates.

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If it is hard to predict when phase change in complex systems begins, it is even harder to predict where it ends. No list of potential impacts of the Transformation of Transportation can be complete. However, one thing is for sure: if our predictions for the uptake of electric vehicles are anything like correct, there is no part of the global economy which will not, in some way, be affected.

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*Disclosure: Michael has a modest investment in Chargepoint Inc., a US provider of electric vehicle charging technology.*

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