Electric dreams

Transporting us to the autonomous electric future

March 2019
The fast view

— Electric vehicle (EV) production is on the cusp of a step change in 2019-20.

— Policymakers are setting stricter emission standards, while China in particular sees EV manufacturing as an opportunity to compete and win.

— Manufacturers are planning launches across various models and price points, while planning dramatic improvements in both quality and mileage capacity for a single charge.

— Three possible implications:
  — More EVs or shared autonomous vehicles, alongside a broader energy transition, could see oil demand peak in the next decade.
  — Car miles driven could increase, leading to higher demand and replacement cycles, in turn increasing demand for metals, including battery components such as lithium, nickel, cobalt, graphite, manganese and copper.
  — Selected utilities could be big winners, especially those investing in grid improvements and preparing to meet the expected increase in electricity demand and infrastructure to charge EVs.

— Change could happen much faster than some expect, as EV unit costs fall, the pace of adoption rises, shared ownership increases and the auto industry innovates.

— We may well look back at this brief hundred-year hiatus between horse and robot where humans were allowed to drive life-threatening carbon-spewing machines as an anomaly in the history of how we move ourselves around.
In our paper – History: Burning the Midnight Oil, we looked at the historic evolution of the world’s energy system. In this article we will start by contemplating the evolution of personal transportation.

The first vehicle created to take us from A to B was the boat, and the earliest known vessels date back to around 7,000 to 10,000 years ago. The next was the horse and while it’s difficult to pinpoint exactly when two legs became four, most experts believe that domestication took place around 4,000 BC based on teeth records, butchering activities and shifts in settlement patterns. Public transportation went through multiple revolutions taking us from sailboats to steamships to railroads; but for personal transportation the horse reigned supreme for almost 6,000 years, until the advent of Henry Ford and his Model T in 1908.

Ford himself understood how disruptive his new invention was, allegedly saying, “If I asked people what they wanted, they would have said ‘faster horses.’” More recently, Steve Jobs said, “People don’t know what they want until you show it to them. That’s why I never rely on market research. Our task is to read things that are not yet on the page”. This sentiment is ingrained in the mentality of many of the companies which will be at the forefront of the transportation revolution that accompanies the energy transition – the move from horses to cars to electric robots.

We are at the tipping point for electric vehicles

Fast forward an entire century from 1908 to 2018. Electric vehicle (EV) production is on the cusp of a step change in 2019-20 for two major reasons.

1. Policy drives the supply side – this has come about partly because national and international policymakers recognise transport as a key contributor of greenhouse gas (GHG) emissions and are imposing increasingly strict standards on the transport sector.

2. Car manufacturers must meet these standards and to do that, they are manufacturing more EVs, across price points. Further, the latest EV models are equipped with fast-charging batteries and can be driven for longer distances than before, driving up demand.

Policy drivers

Transport accounts for a fifth of GHG emissions and around 60% of oil use. It is no surprise that policy makers are setting stricter standards to tackle these significant emissions, as they address climate change. China, in particular, has shown the greatest resolve in leading the race on EVs, not just to tackle pollution, but because it sees this arena as an opportunity to lead, and win. The Chinese government has recognised the automotive industry as strategically important – seeing the EV market in particular as an opportunity for Chinese companies to play a greater role – and offering it policy and government incentives, including national and local subsidies, taxation benefits and the construction of the network of infrastructure drivers need to charge their EVs.

World oil demand by sector

![World oil demand by sector](image)

Source: IEA, BP (2015)

EVs and related infrastructure are expected to be a significant contributor to China’s GDP (more than 4%), employment (approximately 4.7 million related workers), taxation (approximately 4.5%) and national retail sales (nearly 25%).

Chinese manufacturers, along with Tesla, dominate sales of EVs.

2. NIO IPO Prospectus.
In contrast, Chinese companies are seen as lagging behind global peers in traditional internal combustion engine technology. For that reason, coupled with pollution concerns, we expect government support for electrification to remain strong. The official target is two million electric vehicle sales in 2020 versus 800,000 in 2017, with a longer-term target for electric vehicles to be 100% of new car sales by 2030, versus 4% today.³

Elsewhere, where policy is less supportive, global automotive manufacturers have had little interest in selling EVs, which are typically lower margin or even loss-making while volumes are ramping up. There is a dearth of high-quality products outside of Tesla. However, the Volkswagen diesel emissions scandal has dramatically altered the ability of automotive manufacturers to meet government fleet emissions standards. The EU overall target for passenger cars is 95g/km by 2021, with a further 30% reduction required by 2030. The actual 2017 number was 199g/km. Every gram over the target incurs a €95 fine so, for example, were the industry to miss by 5g/km then sector-wide fines would be €7bn.⁴ The US, China and India all have similar targets.

The decline in diesel sales together with customer demand for larger engine cars, such as SUVs, have made these targets increasingly difficult to meet. These targets, the Volkswagen dieselgate scandal and the remarkable 500,000 pre-orders for Tesla’s mid-range Model 3 electric vehicle all added up to an existential crisis for the automotive industry.

Convinced there is a mass market willing to buy EVs, the German car industry has committed to invest €40bn in electric development over the next three years and one new fully electric model will be launched almost every month in 2019 with the pace quickening further in the early 2020s.⁵ Even the employees understand the need to adapt in order to future proof their jobs. In late 2015, the employees of Porsche agreed to abandon planned pay increases between 2016 and 2025 and expand the working week from 34 to 35 hours in order to part fund the €1bn required to build the Mission E – Porsche’s flagship electric car.

---

³. September 2017 speech by Xin Goubin, vice minister of industry and information technology.
⁵. Handlesblatt.
More EVs, everywhere

Chinese manufacturers and Tesla may not be so dominant for much longer. Between now and 2020 investors should expect to see the start of huge and growing numbers of new electric vehicle launches, particularly from European original equipment manufacturers (OEMs) which must meet EU targets to avoid fines as they catch up to the Chinese OEMs who are eager to lead in this market. In the US, General Motors has vowed to double its resources allocated to electric and autonomous vehicles by late 2020. These model launches accelerate into the next decade.

**EV boom: style and ranges available through 2020**

Source: Bloomberg, New Energy Finance
New EV models planned through 2025

Source: Wolfe Research, Autos & Auto Parts Initiation, 2018
The technology deployment for the next generation of electric vehicles offers significant improvement over previous models, enabling faster charging and longer distance travel.

From 2019, vehicles will be capable of reaching 400km on a single charge, subject to factors including driving style, outside temperature, use of air conditioning or the heater. This has not been available to consumers previously:

Soon a large range of vehicles will be capable of high charging power, which enables long distance travelling

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Total travel time</th>
<th>Time loss due to charging/fueling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional car</td>
<td>5:45h</td>
<td>0:10h</td>
</tr>
<tr>
<td>BMW i3</td>
<td>8:06h</td>
<td>1:46h</td>
</tr>
<tr>
<td>Tesla Model X</td>
<td>6:35h</td>
<td>1:00h</td>
</tr>
<tr>
<td>Porsche Mission E</td>
<td>6:05h</td>
<td>0:30h</td>
</tr>
</tbody>
</table>

Source: UBS, Investor Talk, Market Insights, 2018

The rise of EVs will have knock-on effects for traditional fossil fuels and demand for metals. The precipitous decline in diesel car sales, from a 52% market share in 2015, to 45% in 2017 and a predicted 5% by 2030, also tells a cautionary tale to those expecting a slow steady transition. It is entirely possible that consumers start seeing internal combustion engines as yesterday’s dirty technology, with real concern on residual values, creating a tipping point in electric vehicle adoption. Consumers have made significant shifts on environmental issues before: compare current attitudes to household and industrial recycling to that of a decade ago.
When thinking about the implications of EV adoption for global oil demand it is worth keeping in mind that oil demand is levered not to new car sales but to the car park and ultimately to miles driven.

BP’s long-term oil demand forecast expects autonomy to have an equal impact on oil demand as electrification.

While BP assumes that only 15% of the car park will be electric by 2040, because the shared autonomous fleet is 100% electric with much higher utilisation, 30% of miles driven are electric. The forecast has demand for transportation fuel broadly flat in 2040 versus current as the negative effects of efficiency, autonomy and electrification are offset by growth in global miles driven.

However, a more aggressive penetration of both electric and/or shared autonomous vehicles, as the energy system transitions, could mean a scenario where oil demand peaks in the next decade.

---

**Diesel demand in decline**

Source: LMC Automotive (LMC), European Automobile Manufacturers’ Association (ACEA), 2018

---


7. BP energy Outlook 2040.

8. Bernstein equity research.
Increased demand for metals

If fuel is the loser in this transition, metals and electrons are the clear winners.

There has been a lot written on the impact of batteries on metal demand with nickel, cobalt, lithium, graphite, manganese all included as major beneficiaries. With increased investment and innovation in battery research it is hard to predict which battery technologies will ultimately prevail and what their exact metal composition will be. However, with long lead times to commercial production, from exacting safety and quality standards, the overall composition of batteries over the next ten years is reasonably predictable.

As history constantly reminds us, it is not always the best technology that prevails but the most practical in terms of function, cost and security of supply. It is sensible to assume that companies will seek alternatives to cobalt, due to its concentration of reserves in the Democratic Republic of Congo – whose government has recently increased the royalties extracted from miners of the metal9.

These alternatives include lithium, which is abundant in many different geographies and geologies – from brines to clays to hard rock projects in North and South America and Australia – and which remains core to most technologies. Tesla favours nickel over cobalt for its batteries. Graphite is unusual in that it can be produced artificially and Syrah Resources, an Australian-based industrial minerals and technology company, is increasing extraction of natural graphite at its huge, high quality graphite mine in Mozambique.

The product quality required for batteries is increasing all the time – and this makes refining and processing critical to raw material suppliers and the value-in-use of the raw materials. For example, battery manufacturers are moving from lithium carbonate grades of 99.5% to 99.9% or moving to lithium hydroxide instead. This has major implications for miners as the cost of producing the higher qualities can depend not only on the raw material but also the types of impurities contained in it. In fact, mining raw materials is often the easiest part – for brines it is just pumping – whereas processing and refining is now comparatively far more critical to the success of the project. It even begs the question as to whether lithium is really a mining industry activity or is it more suited to chemical companies.

9. https://www.ft.com/content/f4d3567c-277b-11e8-b27e-cc62a39d57a0
The implications are significant. If 18% of new car sales are electric by 2025, then electric vehicle batteries would constitute more than 80% of lithium and cobalt demand, 40% of graphite demand, almost one third of nickel demand and about one twelfth of copper demand\(^{10}\), with further growth as penetration accelerates.

Changes in the electronic architecture of the cars and battery chemistry can significantly change the outlook for metals demand. Higher voltage EVs use significantly less copper – with Porsche’s Mission-E 800 volt architecture using less than half of the copper of today’s lower voltage electric vehicles. Moreover, Tesla has made a commitment\(^{11}\) to reduce cobalt to ‘almost nothing’ and the industry as a whole is moving gradually away from cobalt, partly because of the significant ESG issues around sourcing the metal sustainably.

Looking much further ahead, the growth of autonomous vehicles will mean the number of cars in circulation decreases as utilisation increases. But at the same time, we would expect replacement cycles to speed up as car life is correlated with miles driven as much as age.

The battery of the future storing 50kWh of energy requires:

<table>
<thead>
<tr>
<th></th>
<th>Traditional car</th>
<th>Current EV technology</th>
<th>Future goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 x batteries</td>
<td>1,900kg</td>
<td>2 x battery packs</td>
<td>1 x battery pack</td>
</tr>
<tr>
<td></td>
<td></td>
<td>400kg</td>
<td>190kg</td>
</tr>
</tbody>
</table>

Source: Bosch, Research & Technology Centre, 2018

---

10. UBS Equity research.
11. https://www.ft.com/content/1c154770-4eb6-11e8-a7a9-37318e776bab
Renewable energy becomes the fuel of the future

The utility sector is a potential winner in the changing energy mix. Over time, electrons will take share from fossil fuel as transportation, heating and low temperature industrial processes all need to electrify if we are to meet our carbon reduction goals. However, the incremental electricity demand from electrifying transportation is not as significant as perhaps some might expect, because the electric motor is almost four times as efficient as the internal combustion engine.

Hypothetically, electrifying the entire car park population in the United States would result in less than 30% incremental electricity demand growth. The impact on peak power demand and last mile networks, namely the final stage of the delivery journey to users, could be more significant should everyone decide to charge their cars at once. However, a smarter grid and enabling EVs to communicate with the power grid to return electricity should ultimately allow electric vehicles to help stabilise the electricity grid.

Utilities are also the main investors funding the rise of renewable energy, but are also the biggest owners of increasingly uneconomic fossil and nuclear capacity. Some of the more forward-thinking firms in the sector are already well into this energy transition and have established a competitive advantage in building renewables, either through fast adoption of new technology such as offshore wind or early investment in development sites, on which they can construct renewable assets. Regulated utilities with constructive regulators in general should have an easier transition and will see a prolonged period of growth in grid investments to facilitate intermittent renewables and electric vehicles.
How fast will change happen?

Oil forecasters suggest that EVs will reach 50 million users between 12 and 20 years from now. But this could happen more quickly – especially given the hand-in-glove relationship between EVs and autonomous vehicles. In our view, there are four compelling reasons:

1. The auto industry is adapting... fast

The first reason is that the auto industry is now at a point where a crossover between the cost curve of the internal combustion engine and the electric battery is inevitable and expected to occur in the early 2020s.

At this point, broad electric vehicle adoption will make sense not just on a regulatory basis, but on the basis of the economics of production as well.

The cost of manufacturing internal combustion compared to EVs

Source: Morgan Stanley & Investec Asset Management, October 2017. NOx = Nitrogen oxide emissions; RDE = real-world driving emissions. The chart assumes no major changes to battery calculations

2. A why not buy an EV moment?

The next factor is cost. At $850 in 1908 the Model T was significantly more expensive than the average horse which ranged in price from $25 to $200, whereas the upcoming electric vehicles will be priced in line with internal combustion engines.
From horses to horsepower.
The rapid 1900s horse-to-car transition

Source: US Census Bureau and Burstein analysis, 2018
3. Adoption cycles are speeding up

It’s also probably fair to argue that generically product cycles have speeded up since then. Recent consumer tech has shown much faster adoption curves.

Another factor is the network effect. Here we look at how long different technologies have taken to get to 50 million users. What we see is that for airlines, automobiles, electricity and telephones, which started life in the first half of the last century, it took approximately 50 to 60 years. For credit cards and television, where adoption curves started in the sixties, it took about 20 to 30 years. For computers and mobile phones in the nineties that fell to 15 years, and the internet took seven years to get to 50 million users.

We have looked at current projections for EV adoption and measured the same metric, using 2012 as the start date (the year Tesla launched the Model 3), and found that big oil’s forecasts look very conservative and even Bloomberg New Energy Finance, which is considered to be the most aggressive forecaster in the market, is not out of line with adoption curves for other technologies.

How fast will electric vehicles take share?

Forecasts are inherently limited and should not be relied upon as an indicator of the future.

Source: Visual Capitalist, BoAML Global Research (October 2018). Reference year for Electric cars is 2012, the year the Tesla Model X was launched.

Potentially more interesting is the far right of the chart where adoption has been almost exponential. Pokemon Go took 19 days to get to 50 million users because of the huge network effects inherent in the business model. This demonstrates the impact of what is known as Metcalf’s Law: “the value of a network is proportional to the square of the number of users”.

There are huge network effects inherent in any shared autonomous fleet business model and hence we see potential for accelerated adoption once fleets are rolled out more widely. Without the fuel and the driver, fleet economics for robotaxis are driven by percentage utilisation.

Hence, there will be an arms race to build out fleets and grab digital real estate on the smartphone homepage and ultimately market share. It is interesting to note that all the key participants – Google/Waymo, Apple, GM Cruise/Softbank and Didi Chuxing are only looking longer-term at building out autonomous electric fleets.
4. Does it make sense to own your vehicle?

A third factor is unit economics. The way consumers access mobility is being disrupted. If we take the economic argument to its logical conclusion, consumers should choose shared mobility over vehicle ownership and the industry should attract operators to compete for the USD 0.46 per mile saving, which is the revenue and profit earning opportunity.

For the unit economics to make sense, namely bringing the autonomous car not just below the traditional taxi (which on a cost per mile basis is the most expensive way on earth to get around) but below the personal car, we need to lose not just the driver but the fuel as well. Ride sharing in the US in 2018 costs around $1.50/mile\textsuperscript{13}, of which about $1.10 goes to the driver and $0.10\textsuperscript{14} to the oil company. This $0.10 falls by more than half when the car is electric, and gets to c.$0.46 matching many existing forms of public transportation.

How far can you travel on $100? A comparison of various forms of transportation (miles)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional taxi</td>
<td>33</td>
</tr>
<tr>
<td>Uber et al.</td>
<td>50</td>
</tr>
<tr>
<td>Private plane</td>
<td>83</td>
</tr>
<tr>
<td>Personal car</td>
<td>143</td>
</tr>
<tr>
<td>Autonomous electric taxi</td>
<td>217</td>
</tr>
<tr>
<td>Ferryboat</td>
<td>286</td>
</tr>
<tr>
<td>Commercial plane</td>
<td>444</td>
</tr>
<tr>
<td>Commuter bus</td>
<td>635</td>
</tr>
</tbody>
</table>

Source: ARK Asset Management, 2017. Prices are taken from ARK’s estimates with a range applied / Autonomous estimate is based on various industry forecasts

---

12. Bernstein equity research
13. Evercore ISI.
The long-term vision – is the future autonomous?

Self-driving technology enables a vehicle to operate without a driver – along with electrification, this is required to provide the opportunity for shared mobility to proliferate. At the centre of this project is sensor fusion, which is a combination of machine learning and artificial intelligence which fuses together inputs from tens of hardware components, such as cameras and radars. With this information, a course of action is then determined and implemented by the vehicle, without the use of a driver.

This is a quantum leap from the assembly plants of Detroit which is why companies from Silicon Valley with more adept skills are entering the industry.

How sensor fusion turns modern cars into autonomous vehicles

Source: Texas Instruments & Ninety One, 2019
There is effectively now an arms race to develop self-driving technology. The participants can be categorised into traditional auto component and manufacturing companies in one corner, and the Silicon Valley disrupters – those with specialisms in artificial intelligence or shared mobility – in the other corner. Traditional auto manufacturers do not have the requisite expertise in artificial intelligence, and the technology companies do not yet have sufficient expertise in auto manufacturing.

Consequently – and with rare exception, such as GM – these gaps in expertise have led to mass collaboration across the industry in a way which is unprecedented for any technological change which has gone before.

It may well be that the next generation will view personal transportation quite differently to ours. Widespread individual car ownership may become a thing of the past regardless of what the market research says. Instead autonomous vehicles may well be a truly disruptive innovation.

Seamlessly integrated public and private transportation, all controlled via a smartphone, with options for private or public pods depending on the situation, could be ‘good enough’ for the vast majority of the market.

As we produce this research, 50% of car buyers are under 50\(^\text{th}\), but 90% of Uber users are under 50\(^\text{th}\), and the global car fleet is one of the world’s least sweated assets, with average utilisation under 5%.

We may well look back at this brief hundred-year hiatus between horse and robot where humans were allowed to drive life-threatening carbon-spewing machines as an anomaly in the history of how we transport ourselves.


Important information

This content is for informational purposes only and should not be construed as an offer, or solicitation of an offer, to buy or sell securities. All of the views expressed about the markets, securities or companies reflect the personal views of the individual fund manager (or team) named. While opinions stated are honestly held, they are not guarantees and should not be relied on. Ninety One in the normal course of its activities as an international investment manager may already hold or intend to purchase or sell the stocks mentioned on behalf of its clients. The information or opinions provided should not be taken as specific advice on the merits of any investment decision. This content may contain statements about expected or anticipated future events and financial results that are forward-looking in nature and, as a result, are subject to certain risks and uncertainties, such as general economic, market and business conditions, new legislation and regulatory actions, competitive and general economic factors and conditions and the occurrence of unexpected events. Actual outcomes may differ materially from those stated herein.

All rights reserved. Issued by Ninety One, issued March 2020.