Back to the future: electric vehicles and oil demand

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Consider a time in which electric vehicles account for a third of all vehicles on the road. And in which electric cars outsell gasoline cars ten to one.

An encouraging milestone on the road to a cleaner, low-emissions future?

Or a remote possibility that will take far longer to reach than the current hype would have us believe?

Neither! Rather, it refers to the US car market at the end of the nineteenth century.[1]

Electric vehicles have been around for a long time; longer than gasoline cars. But the advent of the Model T Ford and the mass production of affordable gasoline cars led to their demise in the early 1900s.

One hundred years on, electric cars are back.

It's not a question of if or when, it's now.

What was once the aspirational domain of one or two niche manufacturers has become a central element in the strategies of virtually all of the world's major car manufacturers, with plans to produce ever-increasing ranges of electric vehicles (EVs) in order to meet ambitious sales targets.

Yes: the current market for EVs is still very small, accounting for just 0.1% of the global stock of cars. But the direction of travel is clear.

The re-emergence of EVs will bring many advantages.

Perhaps most importantly of all, they will help to improve air quality in urban centres. This is already of huge importance, with air quality in cities stretching from Delhi to London, Beijing to Brussels judged unsafe.[2] And its importance will only increase as the number of people living in urban

[1] See EIA (2014) 'The History of the Electric Car' and Electric Auto Association (2016) 'EV History'.

[2] See WHO (2016) 'Urban Air Quality Database' Beijing, Brussels, Delhi and London all have higher concentrations of small particulate matter in the air than the WHO's Ambient Air Quality Guidelines.

centres expands from less than 4 billion people today to close to 6.5 billion by 2050.[3]

At the same time, EVs will help to increase the efficiency of passenger vehicles and reduce CO_2 emissions.

More fundamentally, EVs are likely to be part of a broader transformation of the transport sector, revolutionising the way we think about and use our cars: autonomous driving, shared-car ownership, and ride pooling are set to reshape our relationship with our cars.

The transportation sector is changing and changing fast.

The emergence of EVs raises (at least) two big questions for the energy industry.

First, just how quickly will EVs grow and penetrate the passenger vehicle market?

Second, as they do, what implications will EVs have for the global energy system?

For the purpose of today's discussion, I will sidestep the first question of "how quickly" this transition could occur. This is a live question within BP – as it is across all energy market participants – and we plan to return to it in the next edition of BP's Energy Outlook, published next January. So watch this space.

Instead, my focus for today's discussion is on the second question: "so what?" In particular, just how significant could EVs be for oil demand and for the growth of CO_2 emissions over the next 20 years or so?

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[3] UN (2014) 'World Urbanization Prospects' – The global urban population is projected to grow by 2.5 billion urban dwellers between 2014 and 2050, rising from 3.9 billion (54% of the world's population) to 6.3 billion (66%).

A few facts and figures

Before speculating about the future, let me start by summarising some facts about the current structure of oil demand and the importance of oil as a fuel for cars.

There are currently around 900m cars on the world's roads, consuming around 19 Mb/d of oil.[4]

So a rough rule of thumb to keep in your head is that 100m cars – today – roughly require around 2 Mb/d of oil to fuel them. But that "today" qualification is important and I will come back to that.

The 19 Mb/d of oil being used to fuel the global car fleet accounts for only around one-fifth of the total market for oil, currently around 95 Mb/d (**Chart 1**). Total transportation, which also includes rail, shipping, air and road haulage, accounts for a little over half of total oil demand, while industrial demand accounts for almost a third.

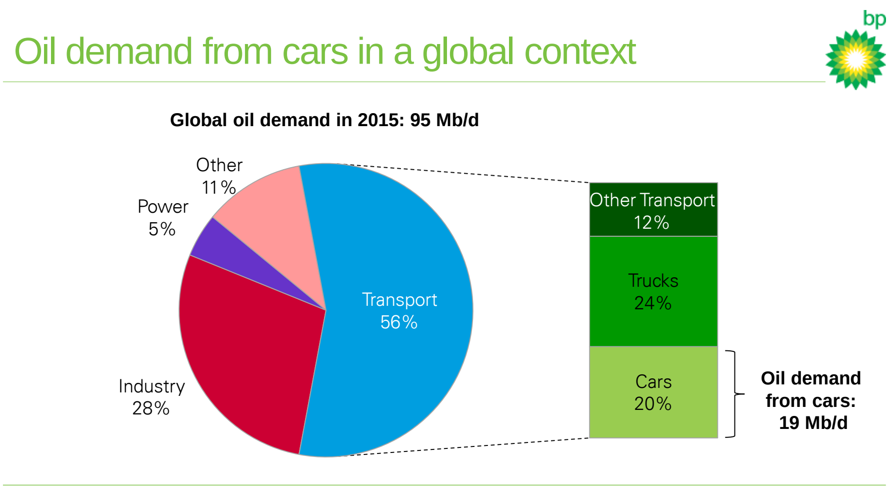

Chart 1

It's useful to keep the share of oil demand for cars in our minds when thinking about the possible implications of EVs. It's possible that electrification may gradually spread to other forms of transportation, such as light trucks, long-distance road haulage, marine transportation. But the

[4] Note, this 900m figure for the global car parc excludes all vehicles classified as trucks, including some SUVs classified as light-duty trucks.

distances travelled and loads transported greatly increase the demands made on electric batteries, making an early electrification of these markets less likely. Over the next twenty years, the biggest concentration of EVs will be cars, which account for a fifth of total oil demand.

EVs and future oil demand

So how important might EVs be for the global energy system over the next two decades?

In this year's BP Energy Outlook, global oil demand was projected to grow by around 20 Mb/d over the next 20 years.[5]

All of this growth in oil demand was expected to come from developing economies, especially fast-growing Asian economies, as productivity and hence prosperity in these economies increase. Oil consumption within the developed world has been falling for much of the past 10 years and that trend is likely to continue. In contrast, around 2 billion people in emerging market economies are likely to be lifted out of low incomes by 2035. It is this increase in prosperity and living standards in some of the most populous countries on the planet that is likely to drive increases in the global demand for oil.

Around 12 Mb/d of the projected increase in global oil consumption comes from the transportation sector, with that increase spread relatively evenly across: planes, trains and boats 3 Mb/d; trucks 4 Mb/d; and cars 5 Mb/d. Much of the remainder reflects increased industrial demand for oil, which is expected to be the fastest growing element of oil demand over the next 20 years (**Chart 2**), especially as a feedstock in the petro-chemical sector.

[5] See BP Energy Outlook 2016 Edition

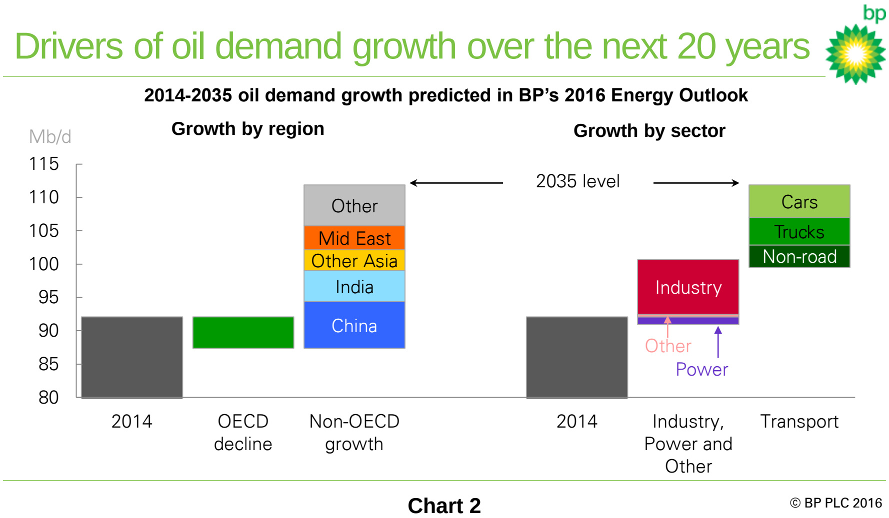

Chart 2

Let's consider the factors driving the projected increase in oil demand for cars in a little more detail.

The increasing prosperity within the developing world is likely to lead to a substantial increase in global car ownership, as hundreds of millions of families are able to afford their first ever car. In the Energy Outlook, we estimate that the global car parc will roughly double over the next 20 years from around 900m cars to 1.8 billion, with virtually all of that doubling concentrated in the developing world (**Chart 3**).

Within that, the total number of electric cars is assumed to increase from around 1.2 million today to around 70 m in 2035, accounting for a little under a tenth of the total increase in the global car fleet.[6]

[6] Electric cars here include both full Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs). BEVs run on electric power only, while PHEVs use a combination of both electric power and an internal combustion engine.

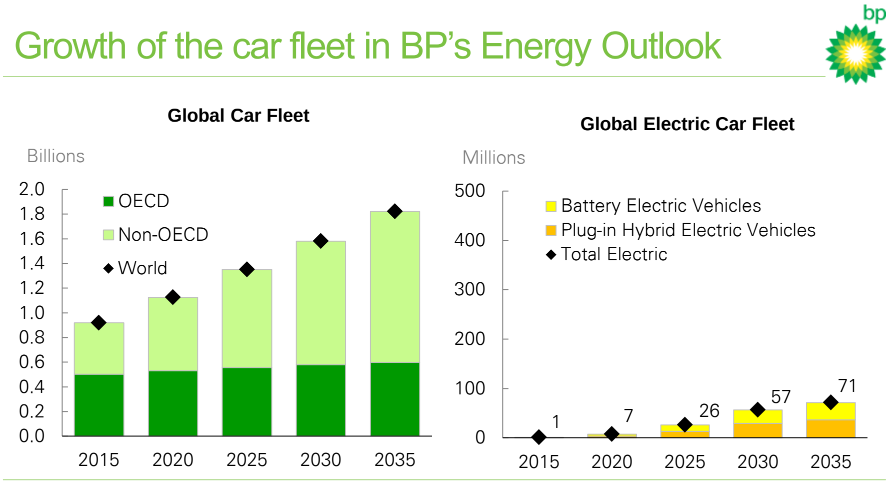

Chart 3

Other things equal, a doubling of the number of cars on the world's roads might be expected to lead to roughly a doubling in oil demand for cars.

But other things are not equal.

Vehicle efficiency is likely to develop substantially over the next 20 years mitigating the extent to which oil consumption increases. I will come back to the central role improving vehicle efficiency is likely to play in tempering oil demand growth in a moment.

The projected increase in EVs also reduces the growth in oil demand that might otherwise occur, since the electricity powering the EVs is likely to be largely generated using fuels other than oil. However, the impact of this expected increase in EVs on oil demand is likely to be relatively limited: reducing the increase in oil demand by less than 1Mb/d over the next 20 years (**Chart 4**).[7] This is because, in spite of their rapid growth, EVs are expected to still represent a relatively small proportion of the overall car parc in 2035.

So the bottom line – based on this projection at least – is that EVs not likely to act as a major disrupter to oil demand over the next 20 years.

[7] See Annex for a detailed discussion of the assumptions underpinning the calculations presented here.

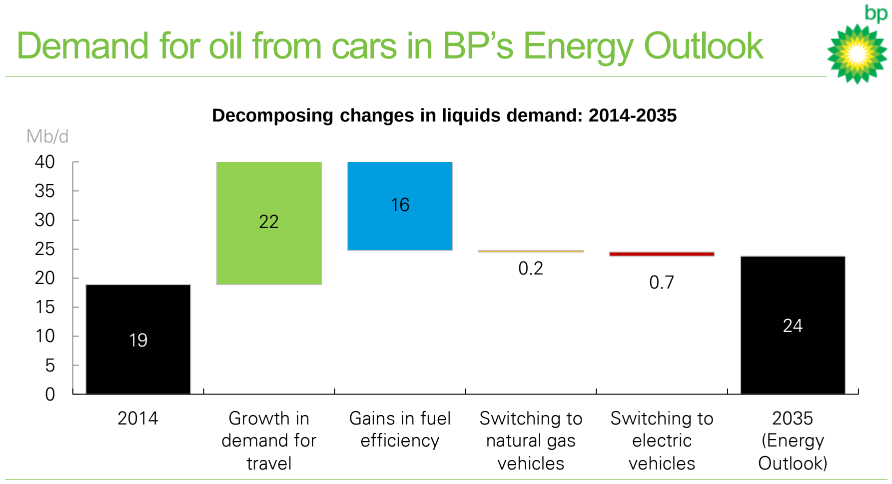

Chart 4

Faster Penetration of Electric Vehicles

But I can see some of you thinking: of course BP would say that! Who knows how quickly EVs will grow and penetrate the car market? EVs could grow far more rapidly that we expect.

And indeed there are a number of reasons why that might happen.

Technology may progress far more quickly than anticipated, reducing costs and offering even greater benefits. One particular possibility is if EVs become synonymous with a broader transformation of the car market over the next two decades, interacting with other disruptive mobility trends like autonomous driving, shared car-ownership and ride pooling. EVs may be integral to a broader mobility revolution.[8]

Or a faster pickup may be driven by social preferences.

I have an iPhone. It doesn't make economic sense for me to have an iPhone: I could buy an Android phone which replicates the vast majority of the functions of my iPhone but which is much cheaper. But I like my iPhone: I like using it, I like what is says about me. It's cool.

[8] The other elements of such a mobility revolution: autonomous driving, shared car-ownership, and ride sharing, also have potential implications (in both directions) for oil demand for cars. These are not explored here, but will be considered as part of the 2017 edition of BP's Energy Outlook.

Suppose people buy electric cars, even if they are more expensive, because they like what the car says about them: how modern they are; their responsibility to the planet. Because they're cool.

Economists don't do cool, but it can be a huge factor in how quickly some new technologies are adopted.

So what happens if EVs grow far more rapidly than we expect?

To explore this possibility, consider the profile for EVs built into the IEA's latest 450 scenario.[9] The IEA's 450 scenario sets out a pathway for the entire energy system consistent with limiting global CO_2 emissions such that there is a better than evens chance of global mean temperatures increasing by less than 2 degrees Celsius by 2100.

The scale of this challenge is huge and the required changes across all dimensions of the energy system are extremely stretching to say the least.

In the IEA 450 scenario, the stock of EVs is presumed to reach around 450 million by 2035, some 380 million vehicles more than we envisage in our Outlook, with EVs accounting for half of the total increase in passenger vehicles over the next 20 years (**Chart 5**).

This is at the very top end of the range of external forecasts I have seen; consistent with very significant changes in technology or policy. Either that or a very large cool factor.

[9] IEA (2016) – World Energy Outlook 2016

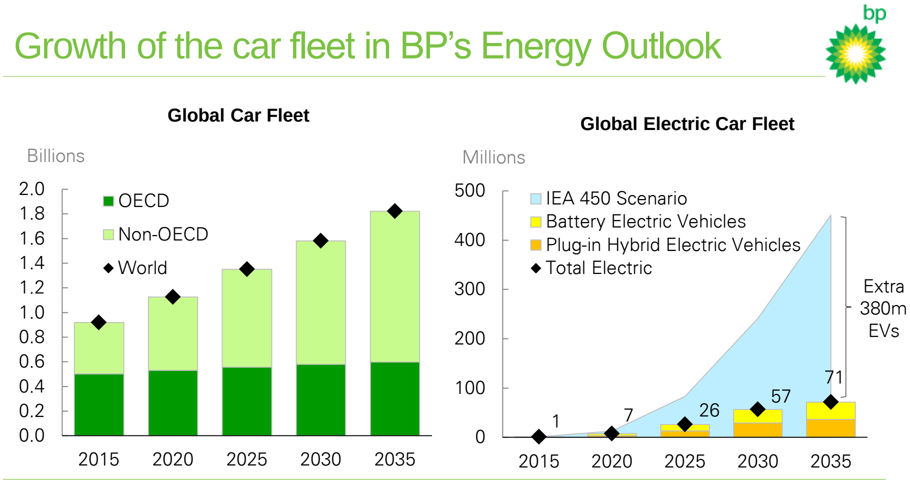

Chart 5

As you would expect, this more rapid penetration in EVs dampens the prospective increase in oil demand. We estimate that the growth in oil demand in this case would be almost 5 Mb/d lower relative to the case in which the stock of EVs didn't increase at all (**Chart 6**).

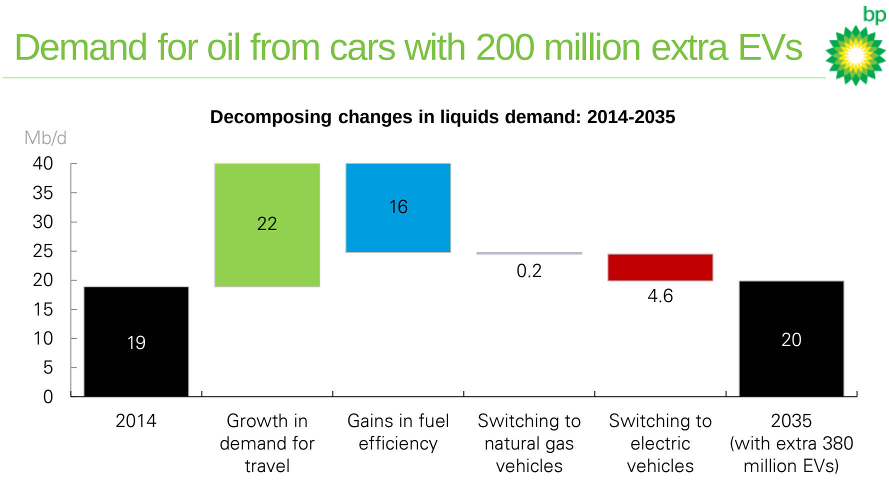

Chart 6

This reduction in the pace of growth is by no means trivial – it is enough to erase most of the projected growth in oil demand from cars over the next 20 years. Oil demand in the past has typically grown by around 1 Mb/d per year, so this very rapid expansion of electrical vehicles over the next 20 years has the potential to offset five years of historical demand growth.

That said, even under this scenario of very rapid growth, the emergence of EVs doesn't look like it will stop global oil demand from growing significantly over the next 20 years: the increasing prosperity within fast-growing Asian economies is likely to continue to drive significant increases in global oil demand through other sectors that today account for 80% of oil demand.

But I can see some of you thinking: didn't he just tell me that 100 million vehicles require around 2 Mb/d of oil to fuel them?

So if, in the IEA scenario, EVs increase by 450 million cars, why doesn't that reduce oil demand by something closer to 9 Mb/d?

Good question.

The answer is the continuing improvement in vehicle efficiency that I just mentioned.

Over time, passenger vehicles have become increasingly efficient, driven by a powerful cocktail of increasing regulation, improving technology and changing societal preferences. Twenty years ago, a typical car would achieve something like 25-30 miles per imperial gallon. That number today is more like 30-35 miles per gallon.

This process is set to continue over the next twenty years. Indeed, the mounting pressure to reduce greenhouse gas emissions and improve air quality means the pace of efficiency improvements is likely to quicken over the next 20 years. That 30-35 miles per gallon for a typical car today could be over 50 mpg by 2035.

Put more starkly, the rule of thumb that 100 million vehicles today require roughly 2 Mb/d to fuel them, looks set to decline to around 1.4 Mb/d by 2035.

That is a huge saving.

In the context of an outlook in which the number of cars on our planet is likely to increase to almost 2 billion by 2035, these efficiency improvements equate to a saving of over 15 Mb/d of oil!

A key point to note here is that the implications of these efficiency gains for oil demand are several times greater than the potential savings associated with EVs, even if EVs were to increase very rapidly: over 15 Mb/d saving of oil consumption due to efficiency gains compared with 1-5 Mb/d stemming from EVs.

When considering the forces that could disrupt oil demand over the next 20 years, perhaps we should place more attention on the pace of gains in vehicle efficiency and less on the growth of EVs.

Implications of EVs for CO_2 emissions

To pursue this point a little further: the importance of efficiency gains in dampening oil demand growth relative to the emergence of EVs is symptomatic of a more general bugbear of mine.

Almost all of the discussions on climate change in which I participate tend to focus on the fuel mix: on the need to switch to cleaner, lower-carbon fuels.

The need to switch is, of course, important.

But the counterpart to this focus on the fuel mix is that considerably less attention is typically placed on the importance of promoting and incentivising improvements in energy efficiency. Yet in almost all the analyses I have seen of possible pathways to a lower emissions energy system, it is improvements in energy efficiency which account for the biggest savings over the next 20 years.

And this relative importance of efficiency gains versus fuel switching also seems likely to be true for reducing CO_2 emissions from cars – at least over the next 20 years when oil-powered cars are likely to make up the majority of the global car fleet. EVs are happening and are likely to dampen the growth in oil demand and hence CO_2 emissions. But during the transition phase when electric cars account for a minority of passenger cars – a phase which may last many decades – those benefits are likely to be outweighed by the potential gains associated with oil-powered cars becoming ever more efficient.

The precise reduction in CO_2 emissions associated with the growth of EVs depends, of course, on the fuels used to produce the electricity that powers them.

Despite what my children seem to think – and, indeed, what some "zero emission" EV regulation seems to imply – electricity doesn't grow in walls.

And in countries or regions in which the power sector is heavily reliant on coal, the reductions in carbon emissions associated with switching to an EV may be minimal or even worse: it is tantamount to switching from an oil-fuelled car to a coal-powered one.

Trying to calculate the exact CO_2 emission savings associated with the increasing use of EVs is far from straightforward. Amongst many other things, it depends on: the distribution of EVs across different parts of the world and the structure of their power systems; the pace and extent to which the fuel mix used within different power sectors changes and/or Carbon Capture and Storage (CCS) is deployed; and even potentially on the time of day at which EVs are typically recharged (since in some countries the relative importance of renewable energy in power generation varies significantly through the day).

I have not attempted such a detailed calculation here.

But it's possible to get a rough ball-park estimate of the potential reduction in CO_2 emissions offered by EVs by using an assumption about how the average emissions of the global power grid are likely to evolve in the future.

In the IEA's 450 scenario, average CO_2 emissions from the global power grid are assumed to fall from around 570 g CO_2 / KWh in 2014 to as low as 180 g CO_2/KWh by 2035.[10] To put those figures in perspective, a modern Combined Cycle Gas Turbine (CCGT) power station produces around 420 g CO_2 / KWh – so again it is fair to think of this as a stretching outlook consistent with rapid decarbonisation of the global power sector and hence of the electricity used to power the EV fleet.

Based on this outlook for the global power sector, the increase in EVs envisaged in the Energy Outlook would reduce CO_2 emissions by up to 75 million tonnes per year by 2035 relative to a case in which there was no growth in EVs. This saving would increase to 480 million tonnes per year by 2035 under the rapid penetration built into the IEA's 450 scenario.[11]

These are significant savings: 480 million tonnes per year is more than the UK's current CO_2 emissions and accounts for just under 1.5% of global emissions.

But there are other ways of achieving similar-sized reductions

For example, a 4pp shift today in the global power sector away from coal-fired generation to gas generation would lead to broadly the same saving in CO_2 emissions associated with even the very rapid growth of EVs assumed in the IEA 450 scenario.

And the size of some of the incentives currently being offered to encourage the take-up of EVs suggests this could be achieved at a significantly lower cost. The coal to gas mix in the UK shifted by around 20pp over the past year alone following the doubling of the minimum carbon price to £18.08 per tonne of carbon dioxide (roughly $22 / tonne). A carbon price of $22 is many times lower than the implied cost of carbon

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[10] The IEA's 2016 World Energy Outlook indicates that emissions from global electricity generation could fall to 264 g CO_2 / KWh by 2030 and to 106 g CO_2/ KWh by 2040, implying a figure of around 180 g CO_2 / KWh for 2035.
[11] See Annex for the assumptions underpinning these calculations.

abatement associated with many of the current government incentives to encourage the purchase of EVs.[12]

This raises potentially important issues for policymakers.

Incentivising the growth and expansion of EVs has many attractions.

It brings substantial benefits in terms of urban air quality.

It helps lay the foundation for future reductions in CO_2 emissions, as the importance of renewables within the power sector grows.

And it has the added attraction that it mitigates the "free-rider" problem associated with most domestic climate policies - the benefits of EVs accrue to domestic citizens immediately through improved air quality, rather than to global mankind many years in the future.

But in terms of a narrow focus on reducing carbon emissions over the next 20 or 30 years, there may be more cost-effective policies. Be that within the transportation sector: encouraging greater gains in vehicle efficiency. Or more generally within the energy system, where prompting a substantial reduction in the use of coal within the global power system could generate carbon savings many times greater than that associated with the expansion of EVs.

Of course, in an ideal world, we should do all these things at once. But in the real world, the limits on resources, both financial and policymaking bandwidth, means that in practice choices have to be made. Massive increases in R+D on EVs may slow the pace of efficiency gains in oil-fuelled cars. Fiscal subsidies used to promote EVs reduce the amount available for incentivising CCS. Political capital used to advocate one set of policies cannot be spent advancing another.

[12] The IEA's (2016) Global EV outlook notes that EV subsidies in China can be worth up to $10,000 per car. Based on the emission savings highlighted above, 450 million EVs could prevent up to 480 million tonnes of emissions, so each EV could save just over a tonne of CO_2, implying a carbon price of $10,000 per tonne of CO_2..

Conclusion

In 1900, there were 600 electric taxis driving around New York.

A few months ago, a new electric taxi was launched in Singapore.

Back to the future!

But EVs are back with a difference: the electric taxi currently driving around Singapore is one of the world's first self-driving taxis.

The affordability and convenience offered by the Model T led to the eventual demise of electric vehicles at the beginning of the twentieth century. Improving technology, falling battery costs and the increasing importance of improving urban air quality means EVs Mark II are far better equipped to compete against the internal combustion engine and look set to grow rapidly over the next 50 years.

EVs are not likely to be a game changer for the growth of oil demand over the next 20 years, where the increasing prosperity in emerging Asia is likely to swamp the impact of even a very rapid increase in electric cars.

And there may well be more cost effective methods of reducing CO2 emissions over this period, be it by encouraging even greater improvements in vehicle efficiency, prompting a switch away from coal in the power sector, or incentivising increased investment in CCS.

But that should not detract from the many potential benefits that electric vehicles may bring. Improving air quality in the rapidly growing urban centres of the world. And along with autonomous driving, shared-car ownership and ride pooling, revolutionising the very way in which we use and interact with the cars of tomorrow.

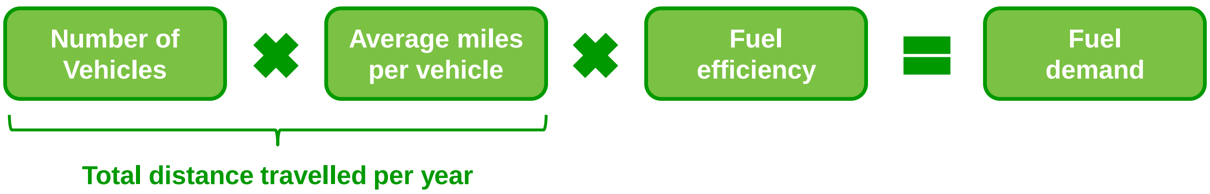
Despite Doc Emmett L. Brown's prediction: where we're going, we do (still) need roads. But the roads of the future are likely to be increasingly frequented by electric vehicles. It should make for an exciting journey.

Technical annex

This annex describes in more detail the framework and assumptions underpinning the calculations referenced in the speech. These assumptions will be reviewed and updated ahead of BP's next Energy Outlook, which will be published in early 2017.

Impact of EVs on oil demand: framework and assumptions

The demand for energy used by cars is determined by two core variables: 1) the demand for travel by cars and 2) the efficiency with which each cars converts fuel into kinetic energy for travel. The demand for travel by cars can then be decomposed into the number of cars on the world's road and the distance each car travels per year.



The demand for travel by car - the total distance travelled per year – is affected by various factors including society's wealth, the cost of travelling by car, the geographic distribution of the population and consumer preferences. In BP's 2016 Energy Outlook, we assumed that the total distance travelled by cars would more than double from 13.2 trillion Km in 2014 to 28 trillion Km by 2035. The majority of this increase is assumed to be met from rising car ownership – the global car fleet is expected to increase from 890 million cars in 2014 to around 1820 million by 2035. By contrast, we assumed that the average distance travelled per vehicle will remain broadly stable at around 15,000 km per year (**Chart A1**).

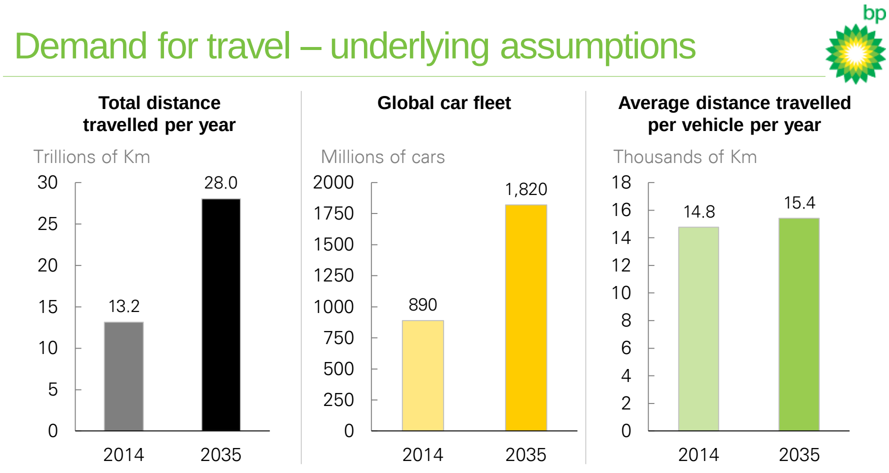


Chart A1

In order to identify the impact that EVs could have on fuel demand, we need to make an assumption about the proportion of the total distance travelled by electric cars and those powered by internal combustion engines (ICEs).

For simplicity, we assume that the driving habits of ICE and EV owners are the same regardless of which powertrain is used; i.e. the average mileage of an EV and ICE car in any given year are broadly the same.[13]

Within the EV category, we also have to make an assumption about the split between Battery Electric Vehicles (BEVs) that are powered solely by electricity, and plug-in hybrids (PHEVs), which use a mixture of ICE and electric powertrains. In BP's 2016 Energy Outlook, we assumed a roughly even split between BEVs and PHEVs. We assume the same split for the IEA's 450 Scenario.

Chart A2 shows the various sensitivities we explore. In the first case there are no EVs in 2035, in the second case (BP 2016 Energy's Outlook) we assume there will be 71 million EVs by 2035, and in the final case

[13] A 2014 study by the Idaho National Laboratory estimated that the annual average mileage of EVs ranged from 9,700 miles for BEVs like the Nissan Leaf to over 15,000 for PHEVs like the Toyota Prius. It is unsurprising that early adopters of EVs display a wide range of driving habits, but it is noteworthy that a weighted average of the EVs in the study, which covered over 20,000 vehicles, showed an average annual mileage of 11,700 miles per year - similar to the national average for ICEs of 11,350 miles.

(which is consistent with the profile embodied in the IEA's 450 scenario) there are around 450 million EVs.

Number of cars – underlying assumptions

	2014	2035 No EVs	2035 BP Energy Outlook	2035 Extra 380m EVs
All Cars	890	1820	1820	1820
Internal Combustion Engine (ICEs)	890	1820	1749	1370
Electric Vehicles	0	0	71	450
Plug-in Hybrid Electric Vehicles (PHEVs)	0	0	36	225
Battery Electric Vehicles (BEVs)	0	0	35	225

Figures have been rounded to the nearest million cars

Chart A2

We also need to make assumptions about fuel efficiency. In BP's 2016 Energy Outlook, we assumed that an average ICE vehicle would see its efficiency improve by around 40% between 2014 and 2035 – driven by weight-saving, mild-hybridisation and other refinements to existing ICE technology. The efficiency of the average BEV is also expected to improve as a result of some of these technological advances, but by around half the rate - as electric motors already operate closer to optimal efficiency (**Chart A3**).

Fuel efficiency – underlying assumptions

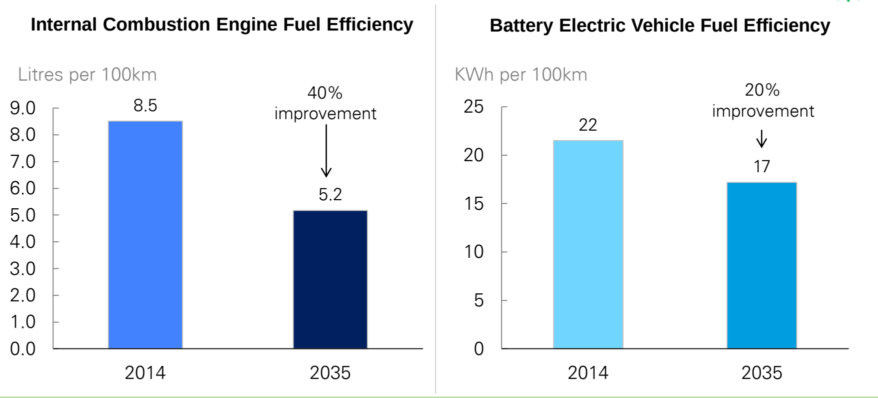


Chart A3

For PHEVs, we assume they drive half their miles under ICE power and half under electric power and that the efficiency assumptions underpinning each powertrain apply.[14] This means that every PHEV is effectively equivalent to half an ICE and half a BEV. Put differently, in BP's 2016 Energy Outlook we assume there are 1749 million ICEs, 36m PHEVs and 35m BEVs by 2035 - this is equivalent to there being 1767 million ICEs and 53m BEVs.

Given those assumptions, we can calculate the impact EVs have on oil demand (**Chart A4**).

Oil Demand – key outputs

		Number of ICE equivalent cars* (Millions)	Average Distance travelled per car (Km)	Fuel Efficiency (litres / 100km)	Oil Demand† (Mb/d)
2014		890	14,800	8.5	19
2035	No EVs	1820	15,400	5.2	25
	BP Energy Outlook	1767	15,400	5.2	24
	Extra 380m EVs	1482	15,400	5.2	20

*ICE equivalent cars = Pure ICE cars + 0.5 x PHEV cars
Based on the assumption that PHEVs drive half their miles under ICE power

†Oil Demand in Mb/d = Number of cars x average distance x fuel efficiency x conversion factor
The latter term converts oil demand from hundreds of millions of litres per year into million barrels of oil per day using this formulae:
(1/100)*(1/159)*(1/365) = (converts hundreds of millions to millions) x (litres to barrels) x (annual demand into daily demand)

Chart A4

By multiplying the number of ICE equivalent cars by assumptions about average miles driven and fuel efficiency we can see the impact on oil demand. In the case with no EVs, oil demand for cars would rise from 19 Mb/d to 25 Mb/d between 2014 and 2035. But in the alternative cases, the growth in oil demand is projected to be between 1-5 Mb/d lower than this depending on the level of EV penetration.

CO2 emission calculations

[14] The Idaho National Laboratory's 2014 study covered five types of PHEV and showed a wide variety of fuel usage in PHEVs. For vehicles like the Chevrolet Volt, 75% of vehicle miles were powered by the electric engine and only 25% by the ICE engine, whereas for cars like the Honda Accord, the ratio was reversed. Given the variability and inconclusive trend so far, we have assumed for a 50:50 split between EV and ICE power for PHEVs.

The calculations for the CO_2 emission figures quoted in the text are based on a simplified method that skirts over many of the intricacies required to produce precise estimates. As such, the figures below should be viewed as indicative only.

To calculate CO_2 emissions from the car sector, we need to estimate emissions from both electric-powered cars and from conventional ICE-powered cars. To do that, we need to make assumptions about the amount of fuel consumed by each type of vehicle (electricity and oil) and the amount of CO_2 emissions that each fuel produces when used.

For EVs, we use the same approach and assumptions as for oil demand to calculate the total amount of electricity used by EVs, i.e. multiply the number of EVs by the average distance each EV travels by its fuel efficiency. Based on these assumptions, electricity demand from the car sector rises from essentially zero in 2014 to 140 TWh by 2035 in BP's 2016 Energy Outlook and to 900 TWh under the alternative case when there is an additional 380m EVs (**Chart B1**).

Electricity Demand – key outputs

		Number of BEV equivalent cars* (Millions)	Average Distance travelled per car (Km)	Fuel Efficiency (KWh / 100km)	Electricity Demand (TWh)
2014		0	14,800	21.5	0
2035	No EVs	0	15,400	17.2	0
	BP Energy Outlook	53	15,400	17.2	140
	Extra 380m EVs	338	15,400	17.2	900

**Number of BEV equivalent cars = Number of BEV cars + 0.5 x Number of PHEV cars*
Based on the assumption that PHEVs drive half their miles under electric power and have similar fuel efficiency

All figures have been rounded to three significant figures.

Chart B1

For conventional ICE cars, we convert the estimates (from Chart A4) from barrels of oil consumed per day into energy units - million tonnes of oil equivalent (MTOE) – by multiplying by a standard conversion factor (where

45 MTOE is assumed to equate to approximately one million barrels of oil).

Next we need to make an assumption about the amount of CO_2 emissions produced by each fuel. For electricity consumption, we use the IEA's average emission value for the global grid in their 450 scenario, which equates to around 180 g CO_2/ KWh. For oil, we assume that every tonne of oil consumed produces three tonnes of CO_2.[15]

Based on these assumptions, **Chart B2** calculates the effect of EVs on carbon emissions in the different scenarios.

CO_2 Emissions in 2035

		No EVs	BP Energy Outlook	Extra 380m EVs
Electricity	**Electricity consumption from EVs** (TWh)	0	140	900
	CO_2 emissions from power (g CO_2 / KWh)	180	180	180
	CO_2 emissions from EVs (Million tonnes of CO_2)	0	25	160
Oil	**Oil demand from cars** (MTOE)	1033	1000	820
	CO_2 emissions from oil (Tonnes of CO_2 per TOE)	3.0	3.0	3.0
	CO_2 emissions from ICEs (Million tonnes of CO_2)	3100	3000	2460
Total	**CO_2 emissions from all cars** (Million tonnes of CO_2)	3100	3025	2620

Chart B2

Under a scenario with no EVs, the world's cars are estimated to produce 3100 million tonnes of CO_2 in emissions per year by 2035. That figure falls by 75 million tonnes based on the amount of EV switching assumed in BP's Energy Outlook, and by a further 405 million tonnes under a scenario with an additional 380 million electric vehicles. To put those figures in context, total CO_2 emissions from global energy consumption in 2015 amounted to 33.5 billion tonnes.

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[15] According to the IPCC (2006) Guidelines for National Greenhouse Gas Inventories, the default CO_2 emission factor for gasoline is 69300 Kg/TJ and for diesel is 74100 Kg/TJ, implying an average emission factor of around 71700 Kg/TJ for road fuel. Since one MTOE equates to 41868 TJ, one MTOE of road fuel will produce around 3 million tonnes of carbon when combusted.