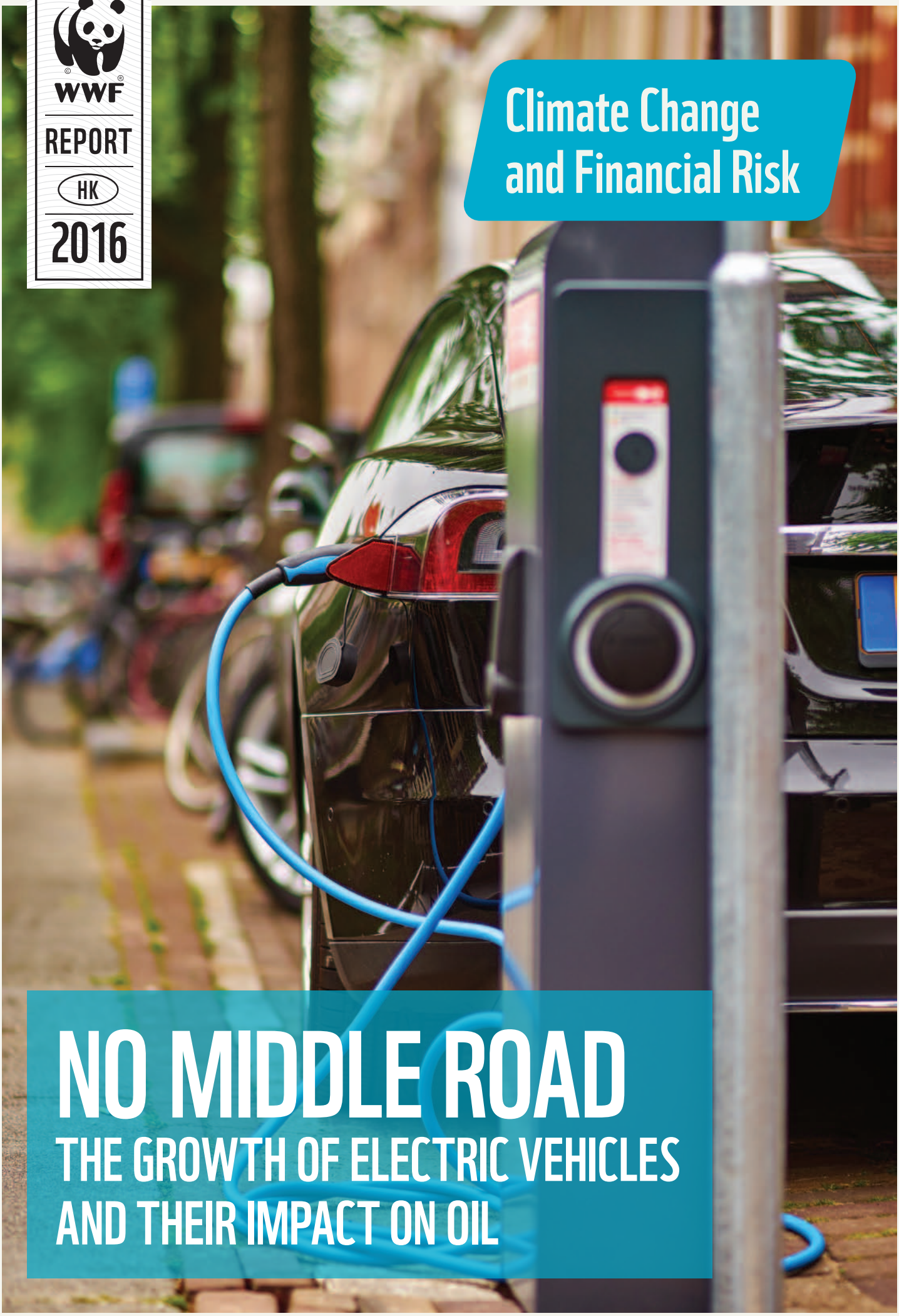
WWF

REPORT

HK

2016

Climate Change and Financial Risk



NO MIDDLE ROAD

THE GROWTH OF ELECTRIC VEHICLES AND THEIR IMPACT ON OIL

About WWF

WWF is one of the world's most respected conservation organizations, with a network active in more than 100 countries. WWF's mission is to build a future in which humans live in harmony with nature, by:

- conserving the world's biological diversity
- ensuring that the use of renewable natural resources is sustainable
- promoting the reduction of pollution and wasteful consumption.

WWF-Hong Kong has been working since 1981. In support of our global mission, WWF-Hong Kong's vision is to transform Hong Kong into Asia's most sustainable city where nature is conserved, carbon pollution is reduced, and consumption is environmentally responsible.

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FOREWORD

Climate change poses an unprecedented, global challenge for humanity. An ongoing rise in global temperatures will lead to a proliferation of problems such as more frequent heat waves, rising sea levels, a reduction in agricultural production, a scarcity of water resources, the spread of disease, and ecological and environmental imbalances. Humanity has known for some years that the main reason driving this is the burning of fossil fuels. At the current rates of fossil-fuel extraction, the Earth's temperature is projected to increase by somewhere between 4°C- 6°C. This will cause catastrophic damage to life, so as a society we must collectively limit this rise to well below 2°C.

Achieving this requires a global transition from fossil fuels to renewable sources of energy, as well as using energy more wisely. To have a chance of keeping the rise in the Earth's temperature below 2°C, 80% of known fossil-fuel reserves must stay in the ground. Hong Kong and many Asian stock exchanges feature companies heavily dependent on fossil fuels. Oil, coal and gas companies have been valued by how much carbon they burn and also by how much they can potentially burn in the future by measuring their reserves as assets.

However, we now know we cannot burn all the proven fossil fuel reserves if we are to keep the global average temperature rise below 2°C. This indicates that what were once considered assets will now have to face large write-downs. Given the increasing resolve of governments worldwide to limit the use of fossil fuels, coupled with advances in low-carbon technology, there will inevitably be major devaluations for these companies. This in turn poses a major threat to unprepared investment portfolios. Some 65 listed companies across Asia with large capitalizations have been identified that represent the more risky investments.

While some investors are waking up to the new reality, there remains a general lack of understanding of this threat – especially among Asia's investors. With this in mind, WWF is building a programme on climate finance based in Hong Kong, staffed by seasoned finance professionals. Their aim is to not only accelerate the trend away from high-carbon and towards low-carbon investments, but also to highlight and explain the dangers of not preparing investment portfolios for climate change and climate-change mitigation.

Their first analysis – No Middle Road – details the rise of one of the many solutions to climate change: the growth in electric vehicles (EVs) in China. EVs offer lower and potentially CO2-free transport, and their rapid adoption is being driven by evolutions in technology and also through government policy. Crucially, as they quickly scale up, they will vastly reduce the demand and need for oil.

The information detailed in this report should be of great interest to the institutional investor community of asset owners and asset managers, as well as other investors with a longer term perspective such as endowments, foundations, sovereign-wealth funds, pension funds, banks, insurers, central banks and fund companies that manage assets day-to-day.

By encouraging asset owners and managers to question carbon-exposed companies and de-risk their investments in these companies, an incentive for carbon-exposed companies is created to rethink their business strategies and their exposure to carbon. It can also help low-carbon competitors to become comparatively more attractive investments, thus accelerating the trend and the growth of solutions to climate change.

Climate change represents a fundamental risk to our planet and our way of life. By allocating funds away from fossil fuels and into companies offering sustainable solutions, we can ensure that both our investments and our planet can continue to prosper.

Gavin Edwards
Director of Conservation
WWF-Hong Kong

EXECUTIVE SUMMARY

In this report, we highlight the opportunities and risks arising from the next technological revolution in climate finance: the proliferation of electric vehicles (EV). Our key conclusions are as follows:

CONCLUSIONS

- **The cost of EVs is likely to fall, due to continued improvements in battery technology.** The battery technology used in EVs should improve over time, whereas crude oil is a finite resource. Cost convergence, therefore, appears certain.
- **We expect cost parity with internal combustion engine (ICE) vehicles in the mid-2020s.** EV sales should rise gradually to account for 100% of all vehicle sales between 2025-2045. It is difficult for us to imagine mass adoption taking place over a materially shorter period, given the average useful lives of vehicles in general. However, it would be hard to argue it taking longer than 20 years before car dealers stop carrying ICE vehicles altogether.
- **As a direct consequence of EV proliferation, 1 million b/d of crude oil could be displaced by the late 2020s.** This could rise to 2-4 million b/d by 2035 and 4-6 million b/d by 2045. This may not seem like a catastrophic outcome for oil producers: after all, 1 million b/d is a small amount compared with current global oil demand of 95 million b/d. But it is important to remember that marginal changes in supply and demand – and the speed of change – determine commodity prices.
- **Facing the risk of holding a permanently impaired asset, rational oil producers would have no choice but to offload their oil reserves quickly.** The resulting excess supply would drive prices down further, resulting in a downward spiral. Our view is that asset prices will begin to adjust well before actual oil displacement takes place on a massive scale. As we progress towards the mid-2020s, the risk of permanently cheap oil should be priced in gradually. With each successful delivery of cheaper, more reliable EV models, the risk of re-pricing increases.

RECOMMENDATIONS

We believe the best course of action for Asian institutional investors is to:

- **Establish a prudent carbon risk-exposure policy consistent with global commitments to tackle climate change.** Compared with their European counterparts, very few Asian asset owners have developed an explicit risk policy that sets forth their portfolios' maximum exposure to carbon-related assets. This is partially a function of the scarcity of publicly available environment, social and governance (ESG) disclosures.
- **De-risk or engage if appropriate.** There is an overwhelming case for a significant reduction in exposure to fossil fuel-related assets. There may also be a case to engage with companies if it is possible for them to transform their business to be compatible with a low-carbon economy. Our analysis in this report shows that prudent climate and investment policies are not necessarily in conflict.
- **Construct a dynamic hedging strategy.** We highly recommend a strong carbon risk policy and a de-risking approach, however we recognize in certain circumstances, this may not be feasible in the immediate term. Therefore a dynamic hedging strategy can be utilized. The decarbonized index is effectively a "free option on carbon", allowing investors to substantially reduce their exposure to carbon risks while maintaining a very similar risk-reward profile to their benchmark index.

SIGNIFICANT FINDINGS

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On the back of battery technology maturing, we expect EVs to become a cost-competitive alternative to ICE vehicles in the mid-2020s.

"There is no chance that the iPhone is going to get any significant market share. No chance." That is what Microsoft's former CEO, Steve Ballmer, said of the Apple invention almost 10 years ago. If history has taught us anything, it is that innovation can make or break entire industries. The failure to anticipate transformational technologies has cost corporations and their investors billions in the past. Yet, the need to deliver short-term results at the expense of long-term capital growth and preservation guarantee that history will repeat itself.

Our goal in publishing this report is to encourage asset owners, particularly those with a long-term investment horizon, to position themselves for what we perceive to be one of the next seismic shifts in technology: the proliferation of EVs. We show, through simplified but compelling illustrations, that EVs are likely to become the predominant mode of road transportation in the next 15-20 years. This could make ICE vehicles obsolete, gasoline irrelevant, and crude oil a stranded asset. Investors may disagree on the speed of change but, in the face of continued innovation, we believe there is simply no middle road.

Our premise requires only a moderate pace of technological advancement over time and no precision over when significant breakthroughs will take place – just that they will. On the back of battery technology maturing, we expect EVs to become a cost-competitive alternative to ICE vehicles in the mid-2020s. EVs will become cheaper to own and more convenient to operate. In the meantime, ICEs will be increasingly difficult to service, as repair parts turn scarce and the economics of gas stations and electric charging terminals converge.

We expect the late 2020s and the 2030s to be a period of widespread adoption, playing out over 10-20 years given the typical vehicle replacement cycle. Again, we do not attempt to identify the precise tipping point (the EV equivalent of the launch of the iPhone 3G in 2009). The beauty of EV batteries is that they are a technology that is bound to improve over time, whereas crude oil is a finite resource (or regenerates too slowly). Cost convergence, therefore, appears certain.

Should our views be correct, the impact on the oil industry would be catastrophic, with the impact felt globally. However, in this report, we focus primarily on the perspective of the Asian investor and draw upon the experience of China in particular to illustrate the potential for an orderly re-allocation of economic capital from the obsolete (ICE vehicles and oil) to the alternative (EVs and renewables).

No discussion on transportation technology and climate finance would be complete without reference to China.

There are a few reasons we highlight Asia and, more specifically, China as a focal point.

First, no discussion on transportation technology and climate finance would be complete without reference to China's role in determining global climate outcomes and long-term fossil-fuel demand. Economic growth in the country has lifted hundreds of millions of people out of poverty since the 1980s, but this has not been without costs. Political leaders face profound social, economic and environmental challenges arising from the energy- and carbon-intensive growth policies of the past. As a key party to the Paris Agreement, Beijing has taken an important first step towards a cleaner and more sustainable future.

China is already home to one in four new-energy vehicles in the world.

WE ARE INTERESTED IN IDENTIFYING LARGE-SCALE DISRUPTIONS TO OIL DEMAND THAT MAY SEND SHOCKWAVES THROUGH THE GLOBAL CAPITAL MARKETS.

An inflection point will be reached when the new technology achieves cost parity with the old.

1 MILLION b/d

We expect 1 million b/d of crude oil to be displaced in China alone in the late 2020s.

Second, the conditions are ripe for China to be at the forefront of green transportation technology. Beginning with the power generation sector (coal) and heavy industries (steel and cement), the country has demonstrated its willingness and ability to decarbonize its economy. Transportation is the next frontier. The 2020s look set to be a revolutionary decade for EVs. China is already home to one in four new-energy vehicles in the world, and the public and private sectors have worked together to lay the foundation for mass adoption of clean auto technology. We expect the EV industry to achieve a growth trajectory that is in line with a prudent climate policy.

Third, in order to make the case for responsible long-term investing, we are interested in identifying large-scale disruptions to oil demand that may send shockwaves through the global capital markets. Despite having the Asia-Pacific region's largest proven oil reserves of about 25 billion barrels, China is second only to the US as an oil-importing nation. We see strong political and economic incentives for the public and private sectors to reduce – and eventually end – China's reliance on imported oil.

An indisputable consequence of this decarbonization process is that ICE vehicles and crude oil will be displaced by EVs and renewables. As with many major transformative technology adoptions, this will start small and be supported by public subsidies. An inflection point will be reached when the new technology achieves cost parity with the old; a growing body of scientific evidence suggests that this will occur in the mid-2020s.

From a starting point of, say, 2025 when this technological breakthrough happens – and assuming that full EV adoption will be achieved between 10-20 years after – we expect 1 million b/d of crude oil to be displaced in China alone in the late 2020s. The amount of redundant oil should quickly rise to 2-4 million b/d by the mid-2030s and 4-6 million b/d by the mid-2040s. On a cumulative basis, we anticipate the total amount of oil displaced to be 70-100 million b/d in the next 35 years (Figures 1-2).

Supply and demand economics would take care of the rest. As demand for gasoline fell, so would crude oil prices (the solution to low prices is lower prices). This might keep ICE vehicles price competitive for a few more years. Conversely, an earlier-than-expected breakthrough in energy storage production might bring forward the time when cost parity is achieved. Both scenarios (very cheap oil or an early EV breakthrough) would be unfavorable outcomes for oil producers.

Figure 1

Crude-oil displacement forecast for China

Source: WWF estimates

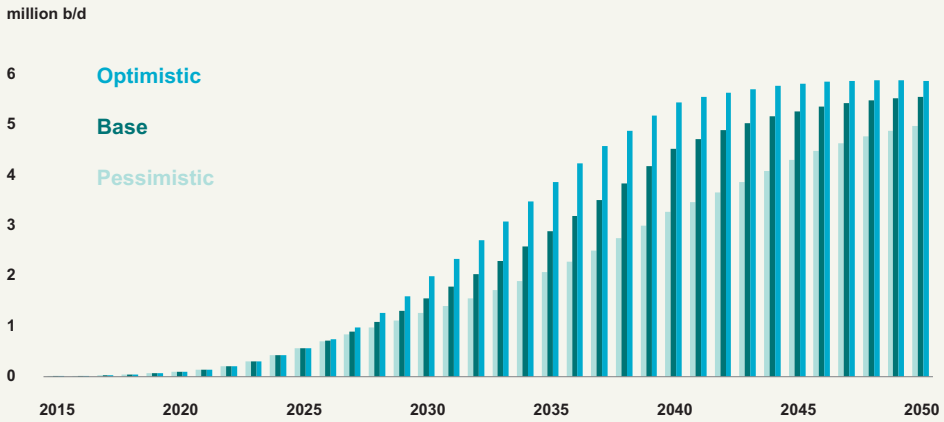
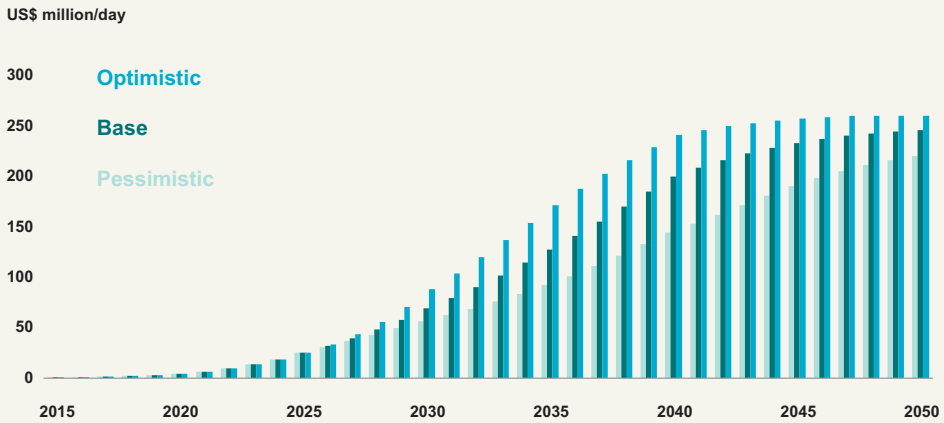


Figure 2

Crude-oil displacement forecast for China (based on US$45/barrel)

Source: WWF estimates



Fossil-fuel companies are understandably in denial about the irreversible nature of technological change.

With each successful delivery of cheaper, more reliable EV models, the risk of re-pricing increases significantly.

Unfortunately (for renewable-energy advocates), there is yet to be a consensus in the markets. Fossil-fuel companies are understandably in denial about the irreversible nature of technological change. OPEC has gone as far as to predict that the sales penetration rate for battery EVs will be just 1% globally by 2040. But fortunately (for investors), the next few years present what may be the last opportunity to re-position their portfolios for a complete dissipation of oil demand.

Our view is that asset prices will begin to adjust well before actual oil displacement occurs on a massive scale. As we progress towards the mid-2020s, the risk of permanently cheap oil should be priced in gradually. With each successful delivery of cheaper, more reliable EV models, the risk of re-pricing increases significantly.

It is also important to remember that the development of the EV industry in China will not take place in isolation. Technological transfers will make EVs more attractive globally and ICE vehicles less so over time. The rate of adoption across countries will depend mainly on governmental efforts to establish the necessary EV ecosystem and pushbacks from special interest groups in oil-producing regions.

FOR FIRMS INVOLVED IN OIL EXPLORATION AND PRODUCTION, THE DISSIPATION OF END-USER DEMAND FROM THE MID-2020S COULD MEAN THAT BOTH REVENUES AND MARGINS WILL COME UNDER TREMENDOUS PRESSURE.

THE 2020s WILL BE THE DECADE OF THE EV AND INVESTMENT PORTFOLIOS SHOULD BE RE-BALANCED TO WITHSTAND - AND TAKE ADVANTAGE OF - THE POTENTIAL CHANGES.

Perhaps more importantly, Asian asset owners have to examine their investment guidelines to ensure that their managers are properly incentivized to re-allocate capital away from risky oil exposure in equities, fixed income and commodities.

So, what would this mean for Asian oil companies?

Accepting the premise that battery technology is moving down the cost curve and that EVs will become more cost-effective than ICE vehicles in the foreseeable future, we have to accept that both EVs and cheap oil are here to stay. We illustrate the potential evolution of EV sales and oil demand for China in this report, but the underlying trends are certainly applicable to the rest of Asia and other parts of the world.

For firms involved in oil exploration and production, the dissipation of end-user demand from the mid-2020s could mean that both revenues and margins will come under tremendous pressure. To avoid being the last one with a stranded asset on their balance sheets, these companies will have an incentive to ramp up production early, which will exacerbate price pressure.

Similarly, refineries are likely to face deteriorating economics, although the impact would be mitigated by continued demand for oil products that are harder to replace than gasoline, most notably diesel, jet fuel, heating oil and petrochemicals. As for retail gas station operators, they will not only have to compete with the gas stations down the road in 5-10 years, but also with a growing number of electric charging terminals that are by their nature more economical to maintain.

And what would this mean for Asian investors?

We are not in the business of giving investment advice, but as proponents of sustainable investments as a philosophy it is clear: the 2020s will be the decade of the EV and investment portfolios should be re-balanced to withstand – and take advantage of – the potential changes. At the individual company level, we anticipate that markets will begin to question the "terminal value" that is assigned to oil companies' long-term cash flow streams as we approach EV-ICE vehicle cost parity. The value of "perpetual" cash flows – which extend beyond analysts' typical 10-15 year forecasts – may approach zero as EV adoption becomes widespread.

Perhaps more importantly, Asian asset owners have to examine their investment guidelines to ensure that their managers are properly incentivized to re-allocate capital away from risky oil exposure in equities, fixed income and commodities. This is especially relevant to funds with long-term liabilities (e.g. insurers, pension plans and endowments), because while their financial obligations will continue to exist in the next few decades, the markets for fossil-fuel assets may not.

WHY CHINA MATTERS

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Environmental progress amid economic unrest

In our search for the next technological breakthrough in climate finance that may impact investors globally, we have to start with China. The Paris Agreement, negotiated by 195 countries in 2015, has ushered in a new era for global efforts to combat climate change. It was the first time the US and China, the two largest CO2 emitters in the world [1], came together to lay out formally their plans to combat global warming in the coming decades (Figure 3).

The central aim of the Agreement is to limit the increase in global average temperatures to well below 2°C above pre-industrial levels and to pursue efforts to keep that level below 1.5°C.

Each of the Agreement's participating countries has formulated a set of Intended Nationally Determined Contributions (INDCs), which outline its long-term greenhouse gas emissions targets. While the NDCs are not legally binding, they are monitored internationally and subject to review every 5 years.

In their current form, the INDCs presented by the member states are generally believed to be insufficient to achieve the Agreement's stated 2°C target, let alone the more aggressive 1.5°C scenario. As such, even if the current NDCs are successfully implemented, a lot more needs to be done to ensure a transition towards a decarbonized world.

China's importance for the Agreement cannot be overstated. Among other things, the country has pledged to peak carbon emissions by 2030 and raise renewable energy from 10% of fuel sources in 2013 to 20% in 2030. China's commitment to the Paris Agreement was reiterated at the G20 Summit in September 2016, where issues ranging from clean energy investments and fossil-fuel subsidies to climate risk disclosures were discussed.

The Chinese government's bid to mitigate the social, financial and environmental consequences of past policies comes at a time of unprecedented economic change. While it remains to be seen how the China story will play out, it has become clear that future public policy will be heavily tilted towards a more measured pace of growth, developments in sustainable industries, and a gradual reduction in energy and emissions intensity.

Figure 3 (Left)

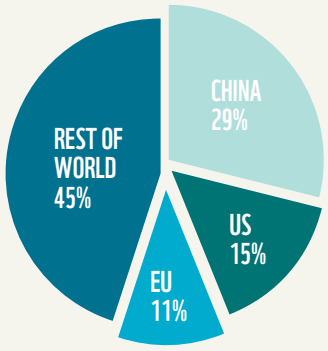
Carbon emissions by geography in gigatonnes (GT)

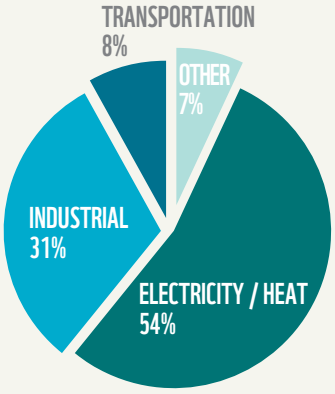
Source: EU Edgar database, WWF; As of 2013

Figure 4 (Right)

Sources of carbon emissions in China in gigatonnes (GT)

Source: World Resources Institute, WWF; As of 2012





The good news is that through the combination of public policy, innovation and a slowing economy, Beijing appears to be on track to meet its 2030 emissions targets. Of the key CO2 emitting sectors [2], power generation (coal) and heavy industries (steel and cement) have taken the biggest hits and have started a multi-year resource rationalization process, which may see many state and privately-owned enterprises struggle to stay in business. The repricing of structural risks in these assets by investors and lenders has allowed for a continued, albeit painful, redeployment of economic capital (Figure 4).

By contrast, structural changes in the transportation sector (oil) have only just started to take place. The global glut of oil has complicated the debate, as low gasoline prices are a major deterrent to clean technology adoption.

The political incentive to act has never been so strong in China, given that transportation is the only sector for which emissions are forecast to see meaningful growth over the coming decades.

Transportation: the next frontier

That said, the political incentive to act has never been so strong in China, given that transportation is the only sector for which emissions are forecast to see meaningful growth over the coming decades.

Despite accounting for less than 10% of the country's carbon emissions, there is a high level of direct human exposure to particulate pollution. Air pollution is an urgent social and public-health challenge. According to the International Energy Agency (IEA), outdoor pollution causes 1 million premature deaths a year in China. Average life expectancy is reduced by 25 months due to poor air quality. For a country of 1.3 billion people, that is a combined total of 2.7 billion years [3].

According to the Ministry of Environmental Protection, only 8 of the 74 major cities in China met the national air quality standards in 2014 [4]. A mere 3% of the Chinese population lives in areas with particulate pollution levels that comply with World Health Organization standards.

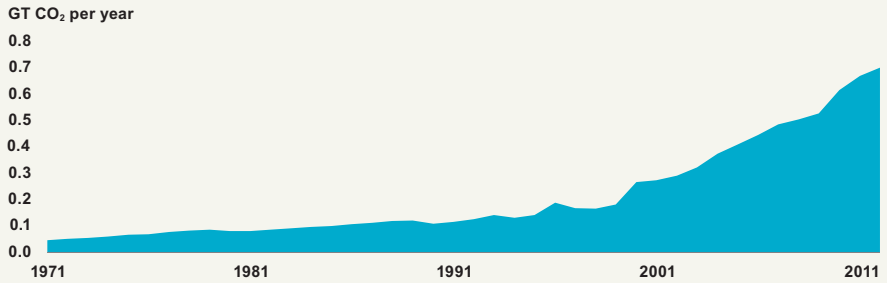
The root of the problem is the rapid industrialization and urbanization that have occurred in the past 25 years. Over this period, the urban population has doubled to 55% of the total and per-capita income has risen more than sevenfold. At the same time, energy demand is 3.5 times greater today than in 1990, with more than 90% of the increase met by fossil fuels. While coal accounts for 75% of electricity input overall, oil constitutes more than 90% of the energy consumed in the transportation sector. As a result, transportation carbon emissions have soared (Figure 5) [2].

From a policy standpoint, there are myriad mitigating factors that could ensure that transportation-related emissions will peak well below the levels seen in more developed economies. Transportation emissions currently account for a staggering 33% of the total in the US, compared with only 8% in China. Therefore, the electrification of China's vehicle fleet is critical to ensuring that the country meets its overall emissions targets as the stock of vehicles continues to grow.

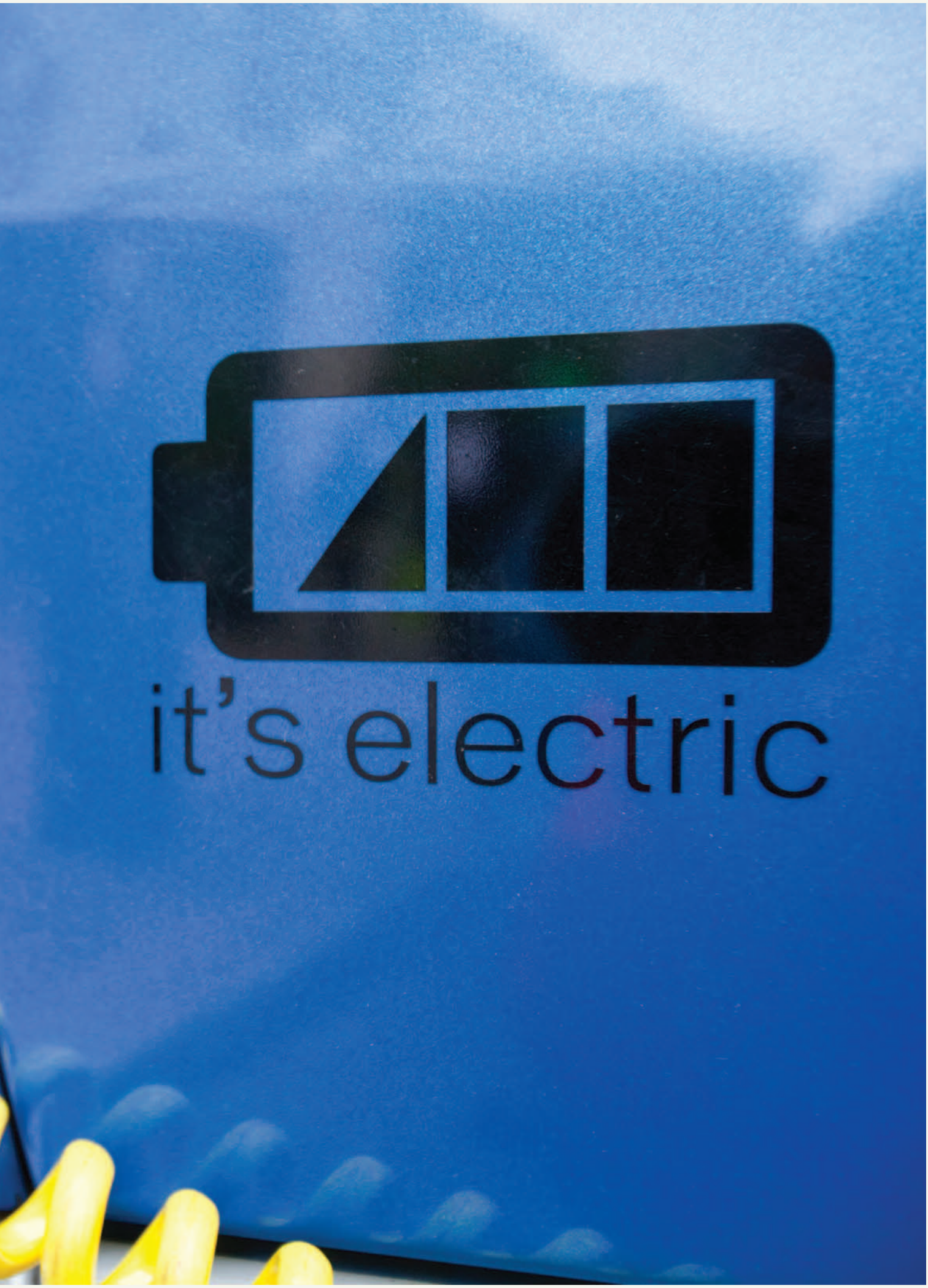
Figure 5

Transportation emissions in China in gigatonnes (GT)

Source: World Resources Institute, WWF



THE ROARING 20s: DECADE OF THE EV



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The road to the milestone of a million vehicles

Thanks to proactive public policy initiatives and significant investments by the private sector, the EV market has grown from a novel concept to a viable consumer option in many markets in just over 5 years. The number of EVs on the road globally surpassed the 1 million mark in 2015, although it is still less than 0.1% of all vehicle stock.

One in four EVs in the world is found in China. Measured by annual sales, the country is the world's largest EV market, with shipments of over 331,000 units in 2015. Another 170,000 units were delivered in the first half of 2016, a surge of more than 160% year-on-year. The strong demand for green vehicles provides a glimmer of hope for the auto industry against the backdrop of a sluggish economy.

It is worth noting that, globally, EV sales have been concentrated in a handful of markets thus far, with the US, China, Japan, the Netherlands and Norway accounting for 80% (Figure 6) [5].

A common thread for these countries is the willingness of governments to foster a positive business environment, a core component of which is the availability of financial incentives to manufacturers and consumers. As with most new technologies, the cost of early EV adoption could be inhibitive. Before battery technology matures in the 2020s, public subsidies are likely to remain a necessary impetus for the nascent EV industry.

In terms of annual sales, it should come as no surprise that EVs have the highest market penetration in West European countries, with Norway and the Netherlands boasting respective penetration rates of 23.3% and 9.7% in 2015. EVs crossed the 1% market-share milestone in China in the same year (Figure 7) [5].

Interestingly, the US and Japan are both below the 1% threshold, partially due to low gasoline prices and high switching costs. That is not to say that electric auto technology has stagnated in these advanced economies. In fact, media reports suggest that Tesla has already built an order book of 400,000 for its US$35,000 Model 3 sedan, to be released in late 2017. These pre-orders alone are almost the size of the existing EV fleet in the US today (Figure 8).

Figure 6 (Left)

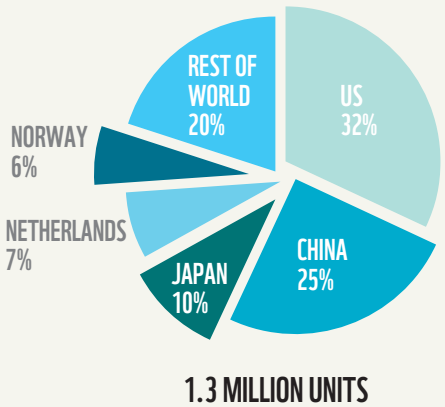
Global stock of EVs by geography in 2015

Source: IEA, WWF

Figure 7 (Right)

EV sales penetration in 2015

Source: IEA, WWF



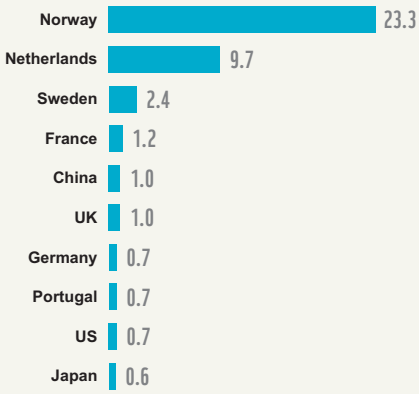
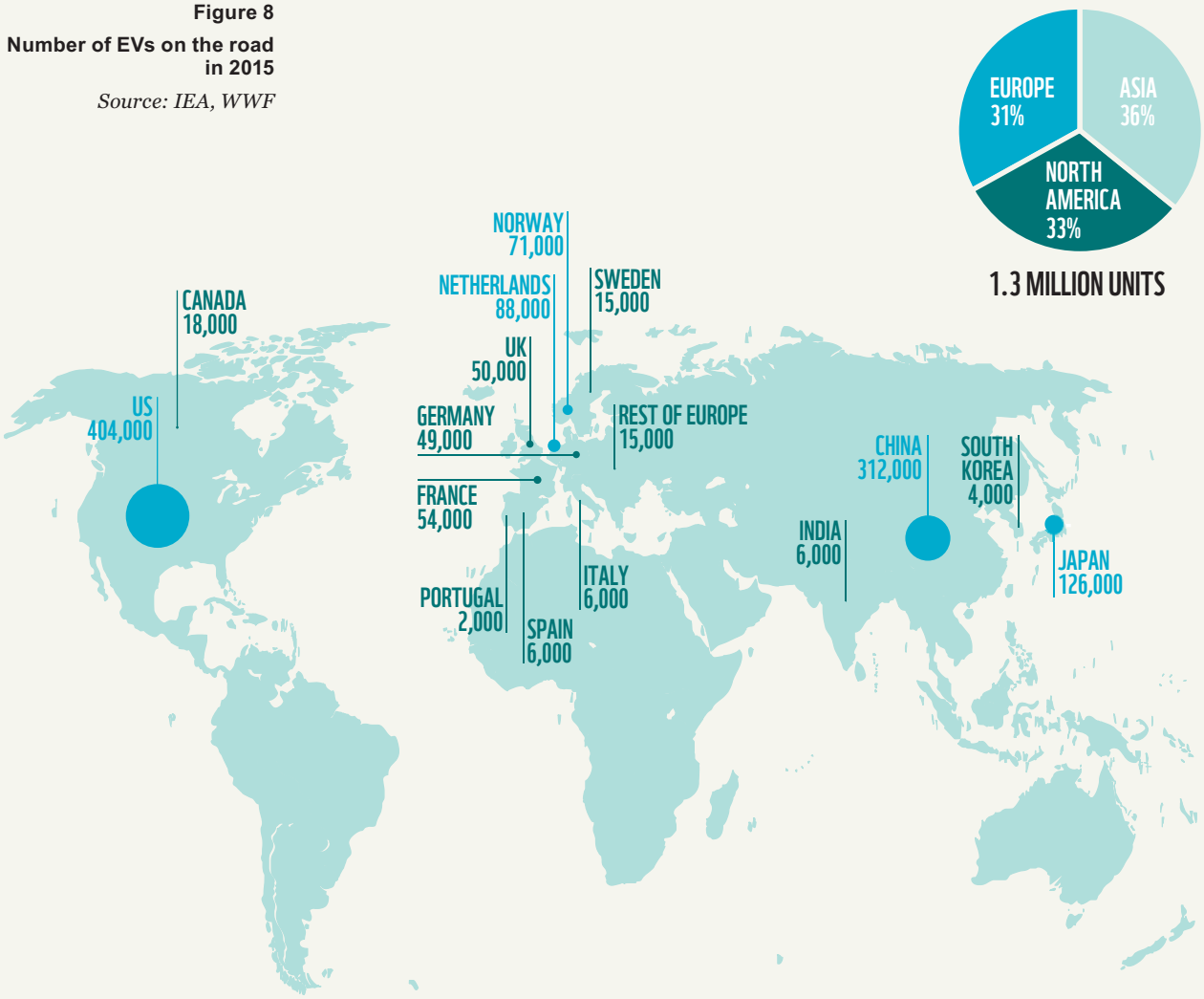


Figure 8

Number of EVs on the road in 2015

Source: IEA, WWF



CAAM EXPECTS SALES TO MORE THAN DOUBLE IN 2016, TO **700,000 UNITS.**

Early adopters in China

As for China, consumer enthusiasm for EVs has also been gaining momentum. From 2011-15, domestic EV sales rose by a CAGR of 152% and amounted to 331,000 units in 2015. The China Association of Automobile Manufacturers (CAAM) expects sales to more than double in 2016, to 700,000 units (Figure 9).

The public and business sectors are embracing new-transportation technology. About 37%, or 122,500 units, of EV sales in the country in 2015 were for commercial use (including buses, trucks and government vehicles). China is already home to the largest electric bus fleet in the world and, by 2020, policymakers aim to have 200,000 green buses on the road from 66,000 in 2015 [6].

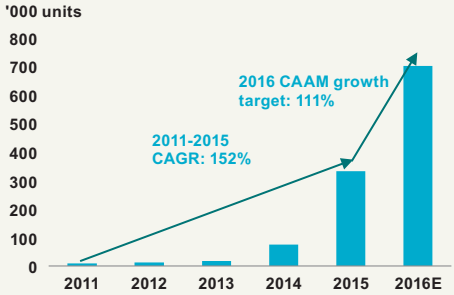
By type of technology, almost 75% of the EVs sold in China in 2015 were battery electric vehicles (BEVs), while the remaining 25% were plug-in hybrid electric vehicles (PHEVs) [5]. However, excluding commercial vehicles, the vast majority of which are BEVs, the proportion of PHEVs in the retail market is likely much higher (Figure 10).

The China EV market is dominated by domestic manufacturers, which accounted for 95% of cumulative sales from 2010-2015. This has important implications for retail price points, target customers, and battery technology. The top BEV model sold in China from 2010-15 was the Zotye Cloud 100, which has a battery range of 93 miles and retails for US$22,500 [7]. This compares with the Tesla Model S, the best-selling model in the US, which has a range of 265 miles and a US$71,000 price tag (Figures 11-13).

Based on factory battery specifications, there seems to be a distinct lack of premium models with large battery capacities in China. Battery range is a major hurdle that manufacturers will have to overcome in order for EV sales to achieve critical mass in the 2020s.

Figure 9 (Left)
Annual EV sales in China
Source: CAAM, WWF

Figure 10 (Right)
Type of EVs sold in China
Source: CAAM, WWF



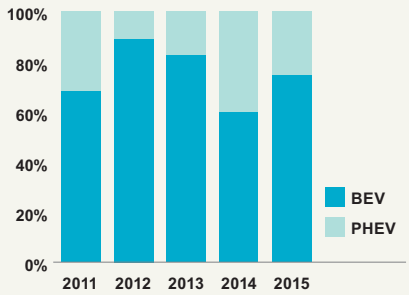
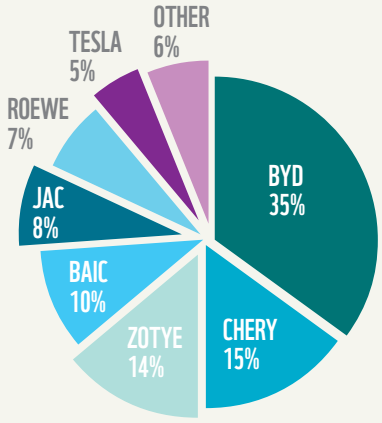
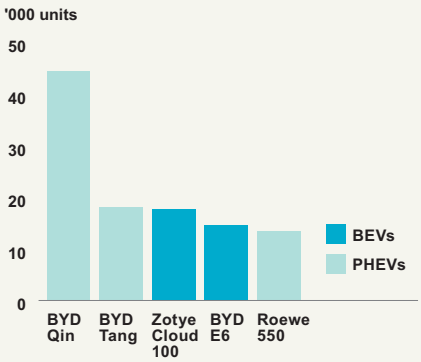


Figure 11 (Left)
China EV market share
Cumulative passenger model sales 2010-15
Source: Bloomberg, WWF

Figure 12 (Right)
Top-selling EV models in China
Cumulative passenger model sales 2010-15
Source: Bloomberg, WWF





As an example of a non-financial incentive, China has imposed quotas on new license registrations for gasoline-powered vehicles in a number of cities, most notably Beijing, Shanghai and Shenzhen.

The role of government incentives

As mentioned, governments in the largest EV markets in the world have implemented a wide range of policies to encourage early adoption of zero/low-emission automobiles. As an example of a non-financial incentive, China has imposed quotas on new license registrations for gasoline-powered vehicles in a number of cities, most notably Beijing, Shanghai and Shenzhen. This has resulted in relatively high EV penetration rates in these places.

The Chinese EV industry is also heavily subsidized. In 2015, central, provincial and municipal authorities spent US$4.5 billion on EV subsidies, according to a Reuters report, mainly in the form of sales and consumption-tax exemption, as well as waivers on registration fees [8].

Central, provincial and municipal authorities spent US$4.5 billion on EV subsidies.

The IEA estimates that the Chinese government provides incentives of about US$10,000 per BEV sold and US$6,000 for each PHEV. These amounts are in line with those offered in the US, Japan and the Netherlands, but fall short of the discounts available in Norway, which leads the world in EV penetration (Figures 14-15) [5].

Financial incentives will be phased out gradually in China. Subsidies will be reduced by 20% over 2017-18 and another 40% over 2019-20. For EV sales to take off in the 2020s, these reductions will have to be offset by cheaper battery units with larger capacities. Recent trends have been promising in this regard.

Figure 13

Retail price and battery specifications

Top three selling BEV models in China and the US

Source: China Autoweb, Statistica, Company websites, WWF

**Prices before rebates*

Model	Approximate Retail Price US$*	Battery Capacity kWh	Battery Range Miles
China			
Zotye Cloud 100	22,500	18	93
BYD E6	46,000	75	186
BAIC E150	37,500	23	87
US			
Tesla Model S	71,000	85	265
Nissan Leaf	30,000	30	107
BMW i3	39,000	22	81

Figure 14 (Left)

Estimated BEV subsidy per vehicle

Source: IEA, WWF

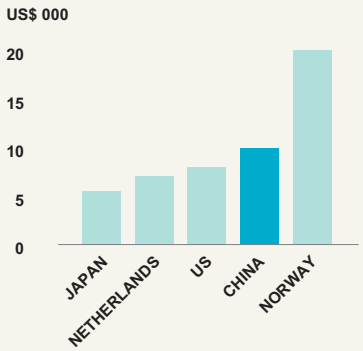
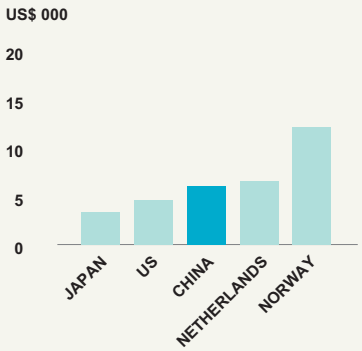


Figure 15 (Right)

Estimated PHEV subsidy per vehicle

Source: IEA, WWF



For EV sales to take off in the 2020s, these reductions will have to be offset by cheaper battery units with larger capacities.

The cost of PHEV batteries, as estimated by the US DOE, fell almost 75%, from US$1,000/kWh in 2008 to US$268/kWh in 2015.

EVS WILL BECOME CHEAPER TO OWN THAN ICE VEHICLES IN THE 2020S.

EV batteries: the key to growth

Battery units currently account for about one-third of the cost of EV production. In the space of 7 years, the cost of PHEV batteries, as estimated by the US Department of Energy (US DOE), fell almost 75%, from US$1,000/kWh in 2008 to US$268/kWh in 2015. The US DOE has a target of lowering that figure to US$125/kWh by 2022, which is equivalent to a 10% annual decline from 2016. Auto manufacturers are generally more optimistic about the potential for cost reduction, with Tesla forecasting that its batteries will cost US$100/kWh by 2020 (Figure 16) [7].

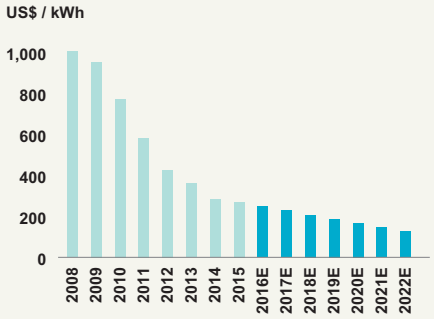
As batteries become cheaper, they will also be longer-lasting, addressing range-limitation concerns. PHEV battery energy intensity (the amount of energy stored per unit of space) increased by almost 400%, from 60 Wh/L in 2008 to 295 Wh/L in 2015, according to US DOE estimates. The government agency's target is to raise that number to 400 Wh/L by 2022. This would significantly increase the distance an EV can travel on a single charge (Figure 17) [7].

The US DOE's projections are consistent with Bloomberg New Energy Finance's (BNEF) assessment that, on an unsubsidized basis, EVs will become cheaper to own than ICE vehicles in the 2020s (Figure 18) [7].

The BNEF analysis considers the total cost of ownership of ICE vehicles and EVs, accounting for, on an unsubsidized basis, purchase and financing costs, insurance, maintenance and fuel expenses. It assumes that average ICE vehicles will cost 1% more each year (inflation), while EVs will become cheaper over time (battery technology). The projections further assume that the price of crude oil will rise from US$50/barrel in 2015 to US$75/barrel in 2040.

Figure 16 (Left)
PHEV battery cost
Source: BNEF, US DOE, WWF

Figure 17 (Right)
PHEV battery energy density
Source: BNEF, US DOE, WWF



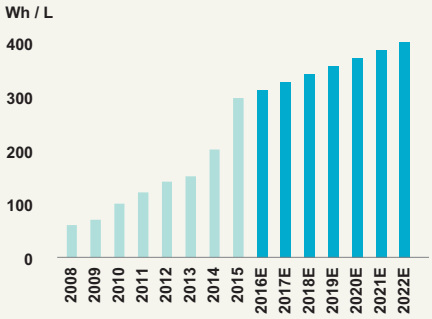
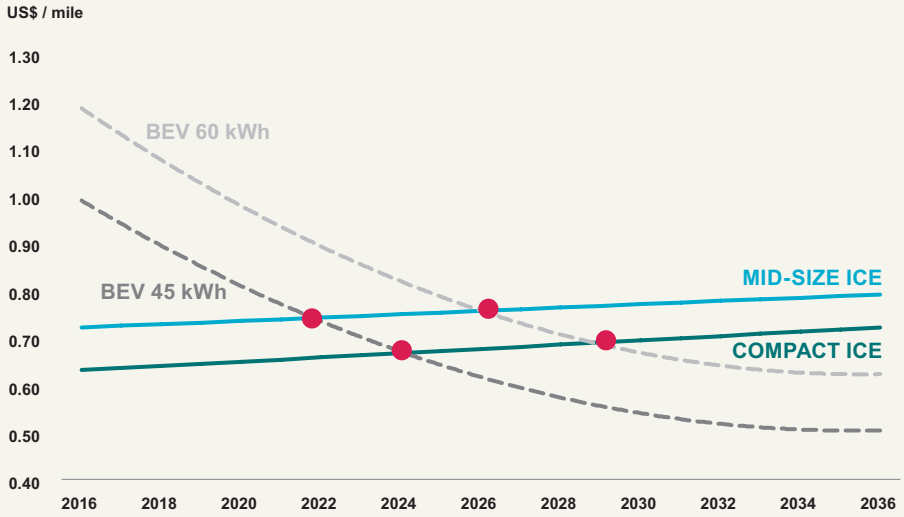


Figure 18
EV-ICE vehicle costs
Estimated by BNEF
Source: BNEF, WWF



Based on these key assumptions, BNEF concludes that a BEV with a 45kWh battery will cost the same as a mid-size ICE vehicle in 2022 and a compact ICE model in 2024. For a BEV running on a 60kWh battery, cost parity will be reached in 2026 and 2029 for the two vehicle classes, respectively.

These projections inform our EV sales and oil displacement analyses.

The EV ecosystem: service stations

Another critical component in building a clean transportation ecosystem is accessibility to a public charging infrastructure. In 2015, there were 1.3 million private and 190,000 public charging outlets globally. In line with the stock of EVs on the road, 25% of private outlets and 31% of public stations were located in China. This suggests that overall development of the EV service infrastructure has been keeping pace with demand. In fact, China has one of the lowest ratios of EVs to charging stations in the world (Figures 19-22) [7].

This data obviously does not account for the fact that China is a vast country and that the existing EV infrastructure tends to be concentrated geographically. Accessibility is further constrained by the scarcity of charging ports in residential neighborhoods, where the majority of EV owners live in apartment buildings.

Local governments have been tasked with building service infrastructure sufficient to handle 5 million EVs by 2020. There also exist opportunities for public-private partnerships that allow corporations to invest in the country's charging network, which is currently dominated by state-owned utilities.

Figure 19 (Left)

Private charging outlets in 2015

Source: IEA, WWF

Figure 20 (Right)

Public charging outlets in 2015

Source: IEA, WWF

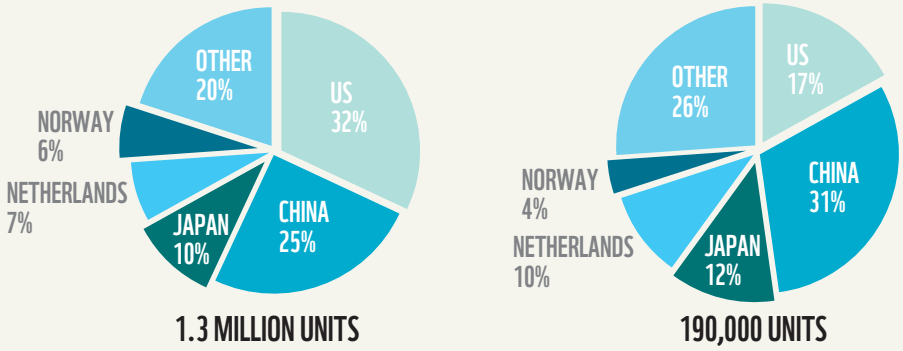


Figure 21 (Left)

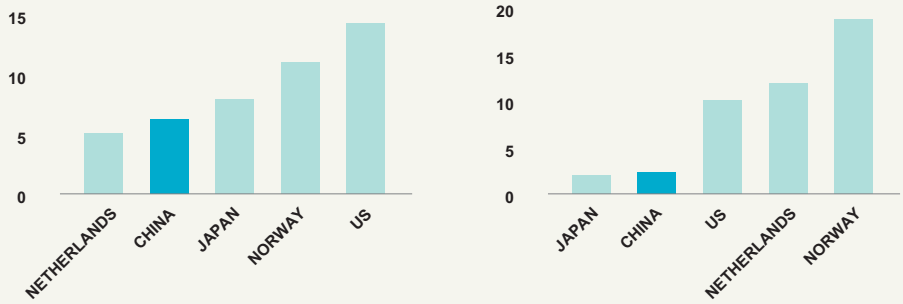
Ratio of EVs to slow charging outlets in 2015

Source: US DOE, WWF

Figure 22 (Right)

Ratio of EVs to fast charging outlets in 2015

Source: IEA, WWF



NO MIDDLE ROAD

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Forecasting EV sales growth

Having examined the current state of the EV industry, we now consider the opportunities for growth in China. In forecasting EV sales, our first point of reference is the S-curve, which depicts the typical relationship between market penetration and time for technology adoption. It should come as no surprise that the adoption cycles of more recent technologies (e.g. the smartphone) have been significantly shorter than those of earlier inventions (e.g. the TV) (Figure 23).

10 YEARS

We assume that it will take 10 years for EVs to have a sales penetration rate of 100% in our optimistic scenario.

Granted, automobiles, electric or not, have longer useful lives than electronic devices and to expect entire fleets of ICE vehicles to be replaced in a matter of years would be wishful thinking. Having said that, one important aspect of the S-curve will undoubtedly apply to EV adoption: there will be an inflection point at which the cost differential between EVs and ICE vehicles will become so compelling that mass adoption will be inevitable.

Based on improvements in battery costs, the tipping point should come in the mid-2020s: we pick 2025 as the starting date. As depicted by the typical S-curve, what follows the inflection point will be a period of rapid growth. We assume that it will take 10 years for EVs to have a sales penetration rate of 100% in our optimistic scenario, 15 years in our base case, and 20 years in our pessimistic projections.

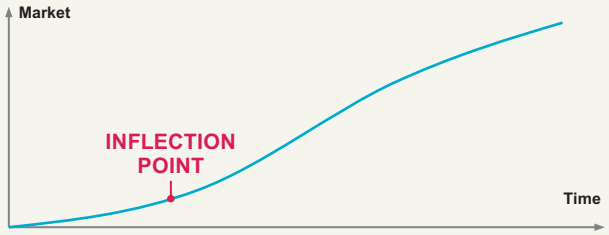
The underlying assumption for these is the World Bank forecast that China's population peaks in the mid-2020s at about 1.4 billion. In addition, as the population will age rapidly up to that time, vehicle use in general may never reach the penetration rates seen in developed economies such as the US, where socio-demographic factors will remain vastly different in the future.

For the overall vehicle fleet, we factor in 5% sales growth from 2016-20, fading to 0% in 2035, before turning negative thereafter. In addition, we assume that, initially, 4.5% of the total fleet is replaced annually and that the ratio will increase to 10% over time. This implies that vehicle ownership in China will level off at about 30%, which compares with close to 80% in the US. Our view is supported by trends in urban planning (densely populated urban centers inter-connected by public transportation networks), consumer behavior, and technology (increased use of car-sharing services).

Figure 23

The typical technology adoption S-curve

Source: WWF



Our forecasts are presented in Figures 24-28.

Figure 24

Overall vehicle stock forecast for China 2016-50

Source: WWF estimates

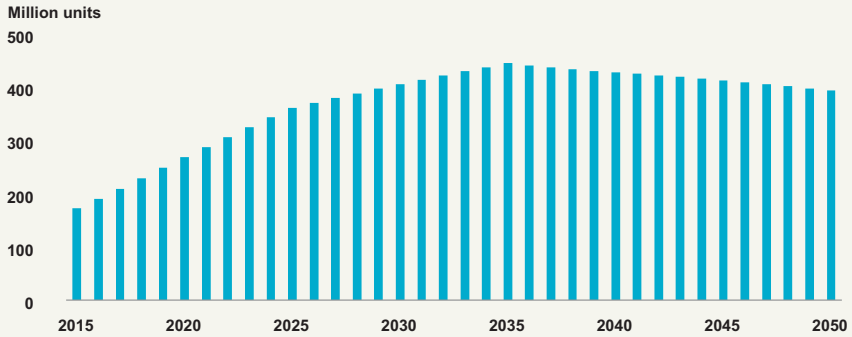


Figure 25

EV sales forecasts for China 2016-50

Source: WWF estimates

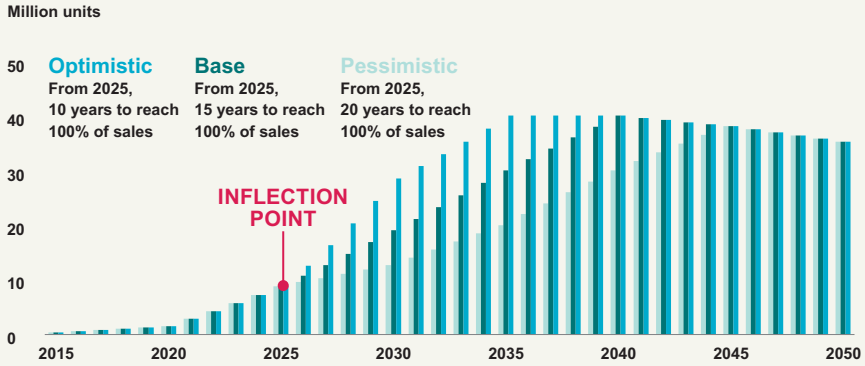


Figure 26

EV stock forecasts for China 2016-50

Source: WWF estimates

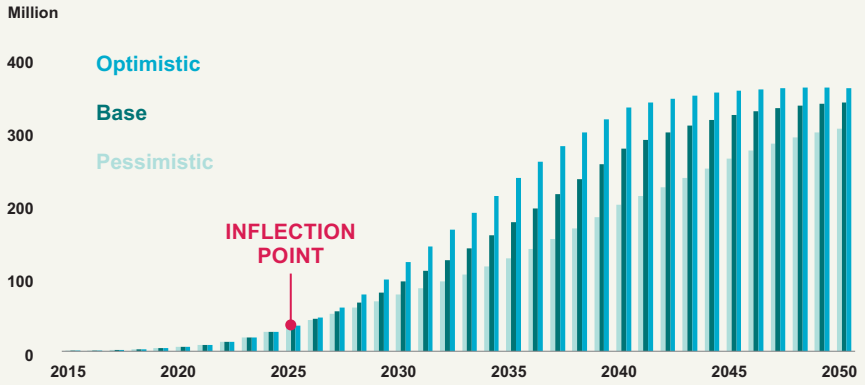


Figure 27

EV sales penetration forecasts for China 2016-50

Source: WWF estimates

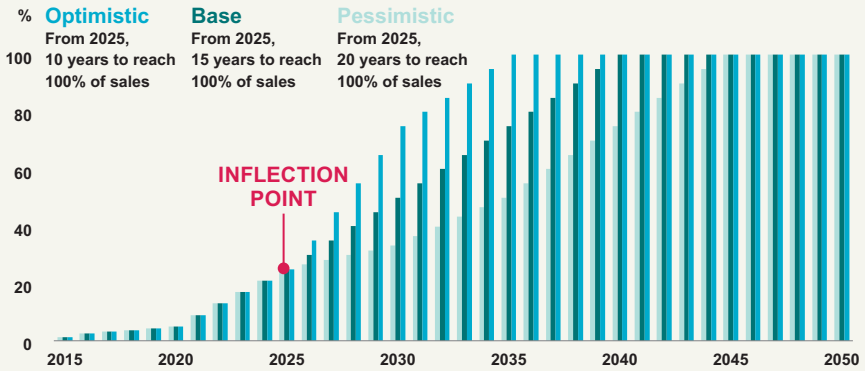
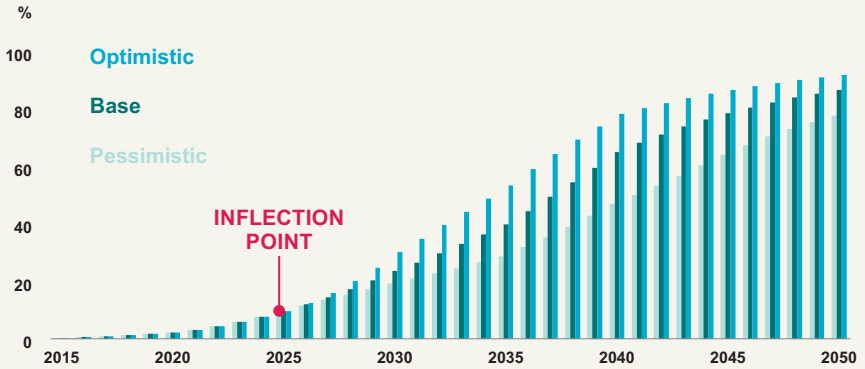


Figure 28

EV stock penetration forecasts for China 2016-50

Source: WWF estimates



Our views on the periods over our forecast horizon from 2016-50 are summarized in the following paragraphs.

Subsidized growth: 2016-20

Over the next few years, EV manufacturing operations in China (and globally, for that matter) will remain sub-scale and their products will be uncompetitive before subsidies. From a low base, however, the percentage growth should still be remarkable. Across our three scenarios, we expect EV sales in the country to grow from 331,000 to just over 1.5 million units. This represents a CAGR of 37%.

Emergence: 2021-25

As public subsidies are reduced, 2021-25 will be a crucial period for our hypothesis. The cumulative investments in energy storage should pay off in the form of cheaper EV batteries with larger capacities. The cost improvements over this period do not have to take a quantum leap; the 10% annual cost decline that the US DOE forecasts for 2016-22 should be sufficient to result in EV/ICE vehicle cost parity. We choose 2025 as the inflection point in our analysis. That date may be 2-3 years earlier (steeper cost reductions) or later (very cheap oil). Either case would be an unfavorable outcome for oil producers. For all three of our scenarios, we expect an EV sales CAGR of 41% over this period of technological change.

Mass adoption: 2026-35/2026-40/2026-45

From the inflection point in 2025, we illustrate three possible paths EV sales could take. In our optimistic scenario, we assume that it will take 10 years for EVs to reach a 100% share of car sales. Our more conservative base-case scenario assumes that it will take China 15 years to see full sales penetration (compared with the average car replacement cycle of, say, 12-13 years). In our pessimistic case, this period would last a full 20 years.

We believe there is simply no middle road beyond the timeframes we consider.

It is difficult for us to imagine a world where mass adoption would occur over a materially shorter horizon, given the average useful lives of vehicles in general. Likewise, it would be hard to argue that it would take longer than 20 years before car dealers stop carrying ICE vehicles altogether. In view of the divergence in service infrastructure availability (gas/charging stations and spare parts), we believe there is simply no middle road beyond the timeframes we consider.

Maturity: 2045-50 and beyond

It is, of course, conceivable that there will be some ICE vehicles left in the fleet, considering that our forecasts include commercial and industrial vehicles. But they should be in the minority and increasingly costly to service (think steam locomotives today). By 2050, we forecast EV fleet penetration rates to be 78-92% in our three scenarios.

Over the very long-term, we cannot forecast trends in technologies that are far from being commercially viable now. One such technology is the autonomous vehicle, which could increase car ownership by removing age limits on vehicle operation. At the same time, self-driving cars can encourage car-sharing, which could reduce car ownership, but increase the average distances travelled each year. In any case, the vast majority of these emerging technologies seem to work in favor and complement the EV industry rather than against it. For instance, there are a lot fewer moving parts in EVs, making autonomous driving technology easier to implement. Re-charging is also safer and more convenient.

The proliferation of EVs is arguably one of the timeliest subjects of discussion in the realm of climate change.

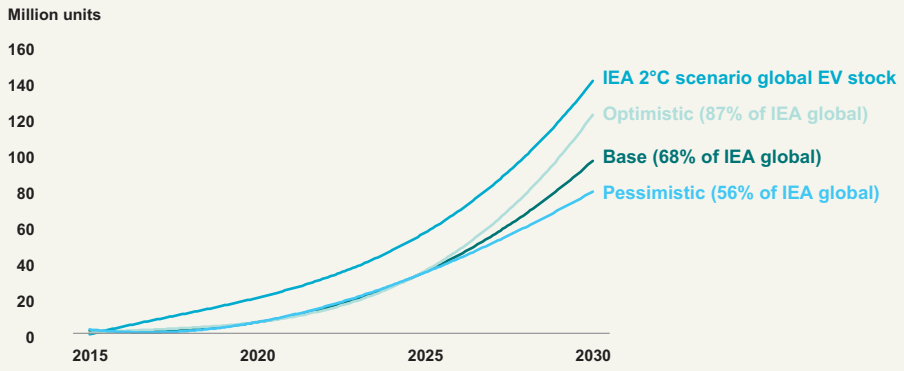
Relevance to climate change

The proliferation of EVs is arguably one of the timeliest subjects of discussion in the realm of climate change. The predictions we have made for the China market are relevant to any other Asian country, although the evolution may be different in scale (Hong Kong and Singapore), stages of technological leadership (Japan and Korea), and infrastructure challenges (India and across emerging ASEAN nations).

In that context, we believe it is instructive to cross-reference our findings with the levels of carbon-emission reductions required to achieve a globally acceptable climate outcome.

For that, we turn to the IEA's global EV forecasts, which suggest that by 2030, the global EV stock has to be about 140 million units in order for CO2 reductions to be consistent with a 2°C scenario. Our forecasts for China alone compare favorably with what we consider to be the IEA's minimum requirements for a marginally acceptable climate outcome (Figure 29) [5].

Figure 29
EV stock forecasts 2016-30
Source: IEA, WWF estimates



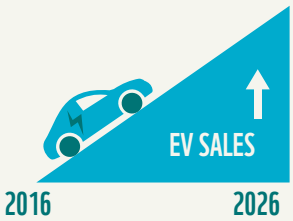
For 2030, our optimistic, base and pessimistic cases for China are respectively 87%, 68% and 56% of the IEA's global EV stock forecast. This implies that, should China succeed in decarbonizing its road transportation system, there is a strong likelihood that global tailpipe emissions will be reigned in.

At the other extreme of the climate finance debate, oil producers are understandably much less enthusiastic about the prospects for the EV industry. OPEC forecasts a 1% sales penetration rate for battery-powered EVs by 2040. This would mean the world remained heavily dependent on fossil fuels over the next 25 years, and that the substantial investments in green auto technology were worthless. In light of the current rate of technological innovation, we consider this to be highly unlikely.

AN OIL CRISIS IN THE MAKING?

© PETER CHADWICK / WWF

Geopolitical factors and supply-side economics in general have tended to dominate discussions on oil in the past. As China and other growth engines slow, the demand side of the equation has become more relevant than ever. EV innovation can only make the focus on demand more pertinent. We are not suggesting there is no money to be made from oil and oil-related assets; near- term cyclical drivers are almost impossible to predict anyway. But as there is a strong likelihood that EV sales will take off in the next 10 years, we must accept that cheap oil, and, by extension, cheap commodities (for which oil is a major cost factor) are here to stay.



As there is a strong likelihood that EV sales will take off in the next 10 years, we must accept that cheap oil, and, by extension, cheap commodities (for which oil is a major cost factor) are here to stay.

First, the caveats

Before looking at the potential impact of EV adoption in China on global oil demand, we start with the caveats.

EV technology: BEV vs PHEV

About 75% of EVs sold in China in 2015 were BEVs but, as noted earlier, that percentage is a lot lower if we exclude commercial vehicles such as public buses. PHEVs operate on a combination of gasoline and battery power and could become a preferred choice for consumers in the next 3-5 years before battery range limitations are resolved.

For simplicity, we assume that all of the EVs sold in China over the forecast period are BEVs. This means we are likely over-estimating oil displacement and under- estimating oil demand in the early years of our projections. We expect BEVs to become increasingly price- and performance-competitive in the mid-2020s. At that point, there will be a strong incentive for consumers to choose pure electric models over hybrids. Given that overall EV growth is back-loaded in our forecasts, the net impact of our assumption should be negligible.

Average gasoline consumption per vehicle

We assume that the average car in China consumes 250 gallons of gasoline a year and that it stays constant over time. This is close to the 2015 national average and substantially lower than the levels seen in the US. There are two other issues at play here.

First, fuel economy for ICE vehicles should improve over our forecast period. This would lower the relative cost of owning conventional vehicles, reduce the initial demand for EVs and therefore the amount of oil displaced. We would, again, be over-estimating oil displacement and under-estimating oil demand in early years. This impact is moderated by the reduced oil consumption of ICE vehicles from fuel- economy upgrades.

Second, while recent global trends have pointed to a drop in average mileage travelled, we believe car-sharing services and automated driving have the potential to substantially raise the distance travelled per vehicle over the forecast period. We can only re-visit this assumption once the technologies in question become commercially viable.

Forecasting oil displacement from EV adoption

Using our EV sales forecasts in the previous section and the assumptions above, we can estimate the amount of crude oil likely to be displaced by the adoption of clean auto technology (Figures 30-32).

Figure 30

Crude-oil displacement forecasts for China

Source: WWF estimates

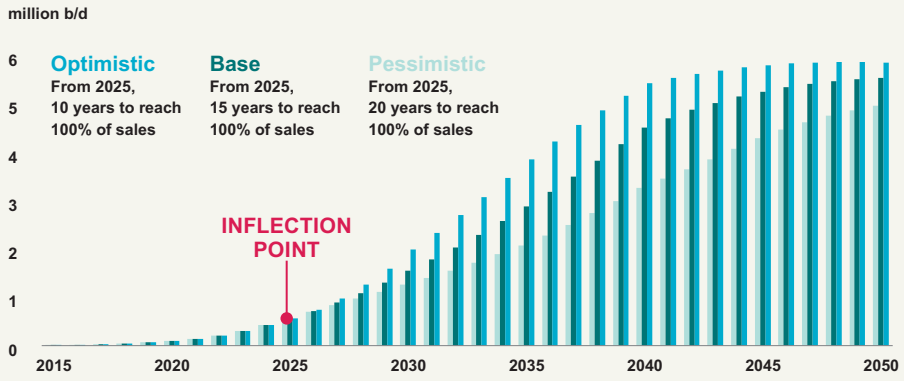


Figure 31

Crude-oil displacement forecasts for China
At US$45/barrel

Source: WWF estimates

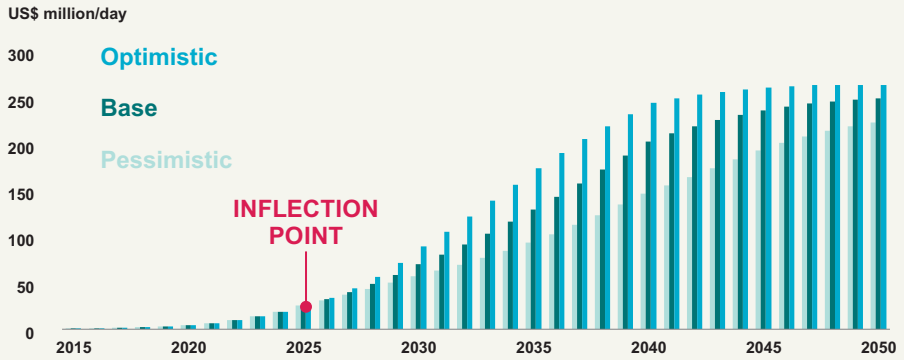
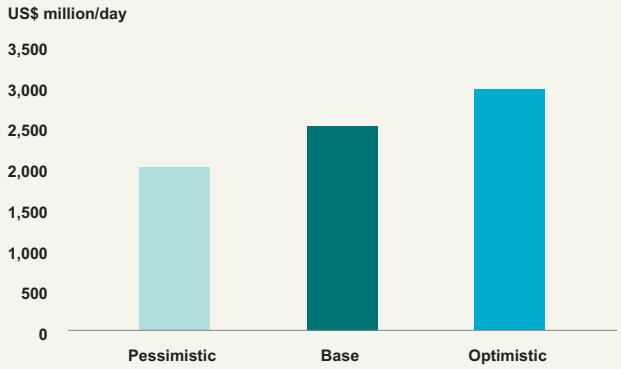


Figure 32

Present value of crude-oil displacement forecasts for China
At US$45/barrel and a 2% discount rate

Source: WWF estimates



BY 2020, WE EXPECT **96,000 BARRELS OF OIL A DAY TO BE DISPLACED.**

The direct positive relationship between the rate of EV adoption and crude-oil displacement is described below.

Subsidized growth: 2016-20

As may be expected, the oil displacement effect in the subsidized growth stage is immaterial, as ICE vehicles and oil remain a more cost-effective combination than EV and electric batteries. By 2020, we expect 96,000 barrels of oil a day to be displaced in China across our three scenarios. At US$45/barrel, that is equivalent to a foregone value of about US$4 million/day.

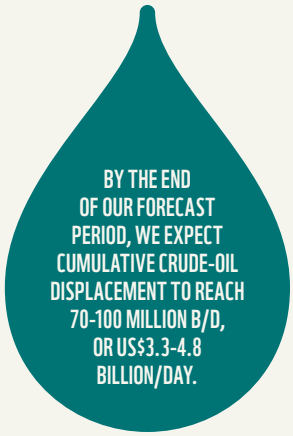
The numbers become meaningful soon after 2025, the year in which we assume economics will tilt decidedly in the favor of EVs.

Emergence: 2021-25

We believe oil displacement will grow in line with EV sales over 2021-25, with more than 570,000 barrels being redundant each day in all three of our scenarios. The monetary value of that oil is about US$26 million/day at US$45/barrel. Oil producers may begin to face a dilemma in this phase of EV industry development. From a purely competitive standpoint, the rational response from oil companies may be to keep prices low (by increasing supply) to discourage consumers from switching from ICE vehicles.

Mass adoption: 2026-35/2026-40/2026-45

The numbers become meaningful soon after 2025, the year in which we assume economics will tilt decidedly in the favor of EVs. We expect oil displacement to reach 1 million b/d in the latter part of the decade (2028-29). By 2035, this should reach 2-4 million b/d, for a value of US$93-174 million/day at US$45/barrel, and by 2045, 4-6 million b/d and US$193-262 million/day.



Maturity: 2045-50 and beyond

By the end of our forecast period, we expect *cumulative* crude-oil displacement to reach 70-100 million b/d, or US$3.3-4.8 billion/day. In present value terms (at a 2% discount rate), beyond 2050 the use of crude oil is likely to be limited to non-gasoline fuels and petrochemicals, assuming no viable alternatives are been discovered.

What does this all mean for oil producers globally?

To recap, we have now established that:

- The cost of EVs is likely to fall, due to continued improvements in battery technology.
- We believe that that EV-ICE vehicle cost parity will be achieved in the mid- 2020s. Between 2025-45, EV sales will rise gradually to account for 100% of all vehicle sales.
- As a direct consequence of EV proliferation, 1 million b/d of crude oil will be displaced by the late 2020s, rising to 2-4 million b/d by 2035 and 4-6 million b/d by 2045.

We now examine what this means for China and global oil producers. China was the world's second-largest oil-importing country in the world in 2015, behind the US. Total oil consumption was about 12 million b/d, of which 4 million b/d were produced domestically. The other 8 million b/d were sourced from OPEC (60%) and non-OPEC nations (40%) (Figure 33).

Currently, only about 25% of China's oil consumption is for the production of gasoline, compared with nearly 50% in the US. In China, the other three quarters of oil consumed are used for diesel, jet fuel, other fuel types, and petrochemicals. In other words, current oil demand from gasoline users in the country is about 2.75 million b/d (25% x 11 million b/d) [9].

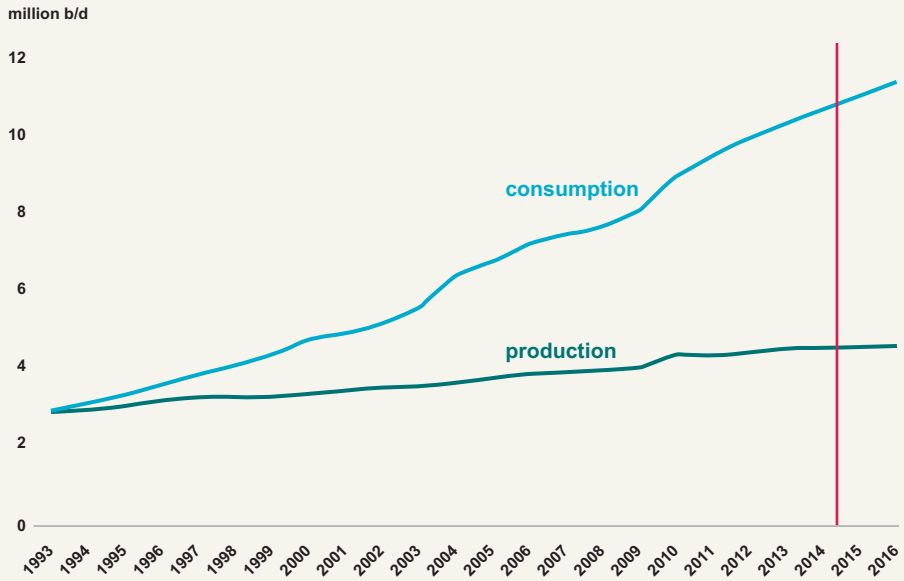
The 1 million b/d of oil displacement that we expect in the late 2020s is, therefore, about 9% of *current* oil demand (1 million b/d/11 million b/d), but 36% of gasoline demand (1 million b/d/2.75 million b/d). From a supply perspective, 1 million b/d is equivalent to 22% of *current* domestic production, or 15% of imports.

This may not seem to be a catastrophic outcome for oil producers. After all, 1 million b/d appear to be a small compared with global oil demand 95 million b/d. But it is important to remember that marginal changes in supply and demand – and the speed of change – determine commodity prices.

Figure 33

China oil consumption and production

Source: EIA, WWF



To illustrate the relative scale of 1 million b/d of incremental change, we refer to OPEC's spare capacity and global unplanned supply disruptions. Both of these indicators reflect marginal changes in supply, the former being planned and the latter unexpected (Figures 34-35).

OPEC's spare capacity is a measure that shows the organization's supply management. A period of low spare capacity, coupled with high economic growth and oil demand, is associated with rising prices, as was the case from 2003-08. As at the end-1Q16, OPEC's spare capacity was just shy of 2 million b/d [10].

OPEC unplanned supply disruptions measure the production volume lost due to unexpected supply outages. Disruptions cost 2.3 million b/d of oil in September 2016 [10].

Next to these data points, a 1 million b/d fall in demand is not insignificant.

Figure 34

OPEC spare capacity and WTI crude oil prices

Source: EIA, WWF

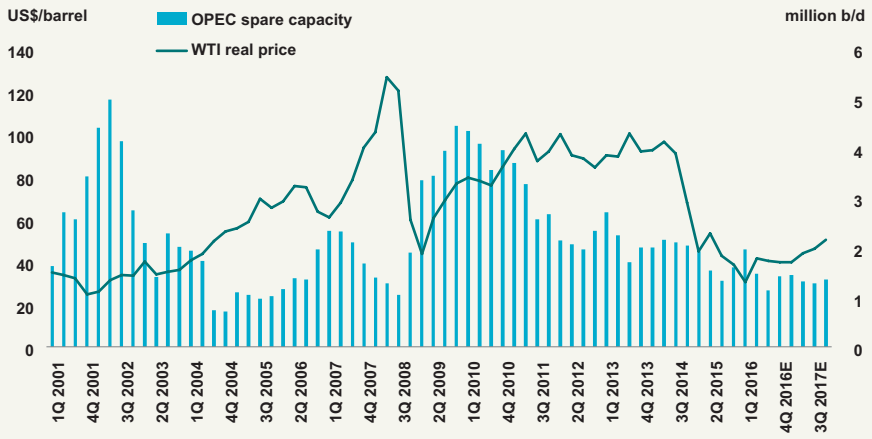
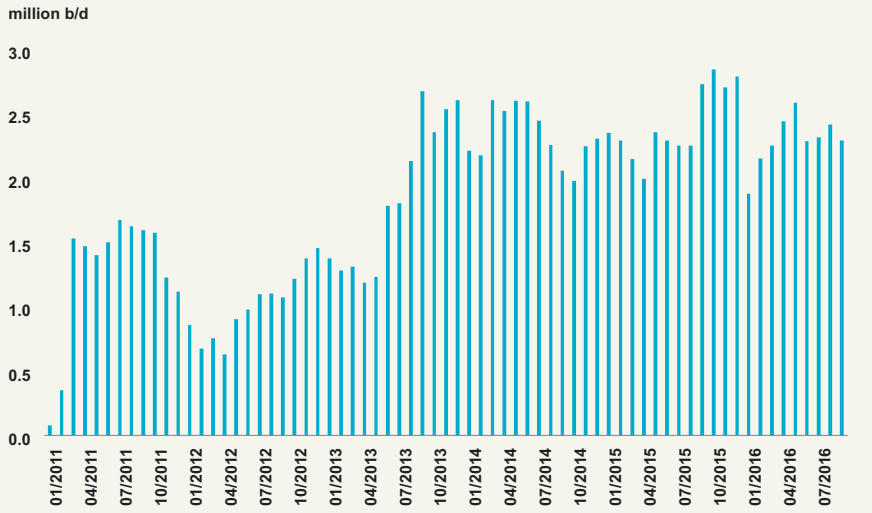


Figure 35

OPEC unplanned supply disruptions

Source: EIA, WWF

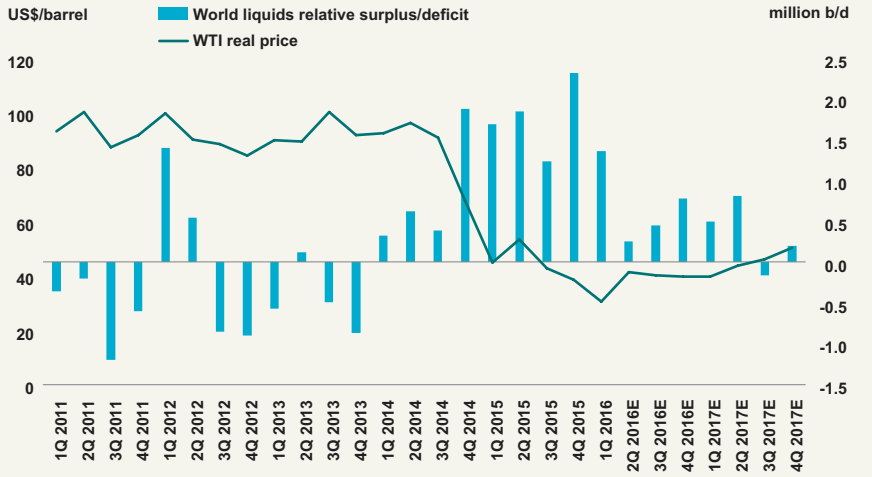


In fact, global over/under-supply of oil has rarely been over 3 million b/d in either direction. The price collapse in 2014 happened when there was a supply surplus of less than 2 million b/d (Figure 36) [11].

Figure 36

Over/under-supply vs WTI crude oil prices

Source: EIA, WWF



The most common pushback on the EV/oil debate is that we are still 10 years away from even a 1-million b/d displacement scenario in China. The potential for a demand decline, however significant, would therefore not be considered a shock to the oil markets. Suppliers have plenty of time to postpone extraction activities, reduce supply, and manage down inventories to ensure that a new equilibrium can be reached.

That may be true for most other commodities.

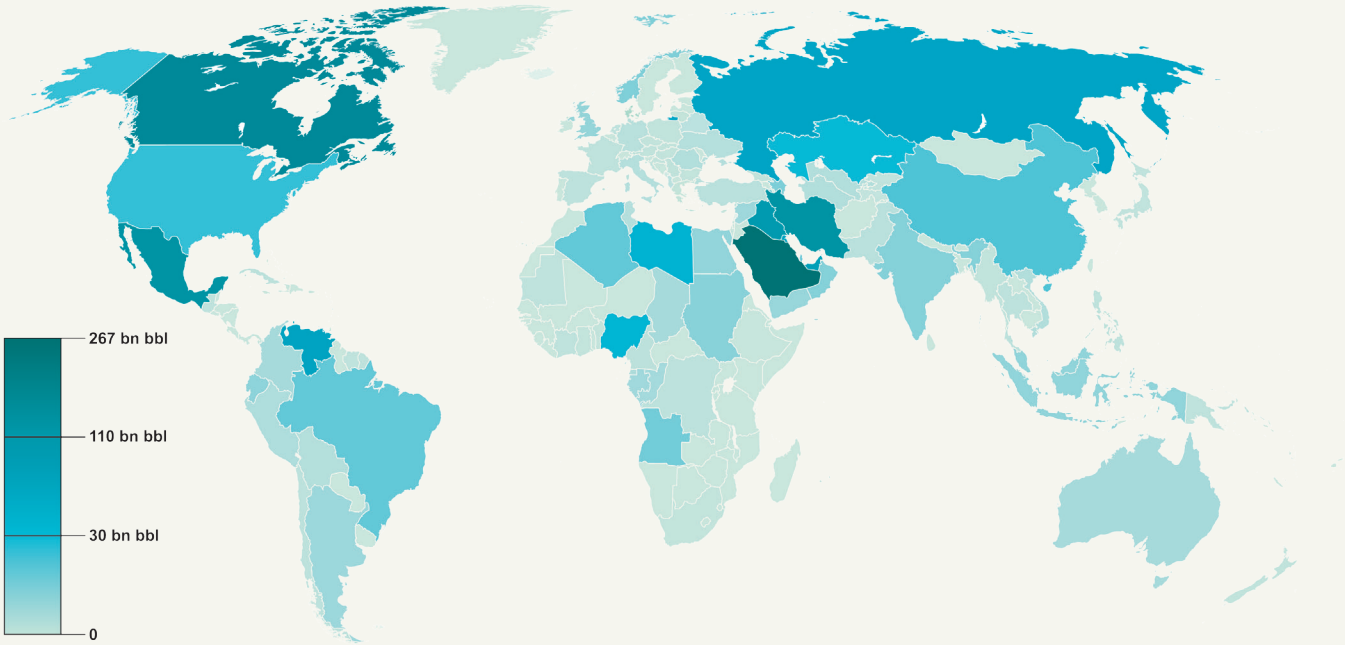
The problem with that argument with respect to oil is that if and when oil displacement from EV adoption approaches 1 million b/d (and that is just for China), the risk of ICE vehicles and gasoline becoming obsolete would have risen significantly. From our earlier analysis, we expect that when we arrive at the 1 million b/d threshold in China in the late 2020s, EV sales penetration will already be about 40%.

Facing the risk of holding a permanently impaired asset, rational oil producers – whether they remain in denial or not – would have no choice but to offload their oil reserves as quickly as possible. The resulting excess supply would drive prices down further, resulting in a downward spiral.

Who will emerge as the winners depends largely on the size of the oil reserves likely to be stranded. Luckily for China – which holds only 25 billion barrels or less than 2% of the world's proven reserves [12] – we estimate that even if all of its domestic oil stockpile were used for gasoline, there would still be a 15-year window for it to consume all of its inventories internally (Figure 37).

Figure 37
Proven oil reserves in the world in 2015

Source: EIA, WWF



RECOMMENDATIONS

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In this report, we have shown that the global EV industry will reach an inflection point. As public and private initiatives to form a clean transportation ecosystem gain traction, we may see strong demand for new-energy vehicles from the 2020s onwards. This shift in consumer preference is of significance to China, but could have similarly profound effects elsewhere. Should our EV growth thesis pan out, oil may well be the next asset class on investors' de-risking agenda (Figure 38).

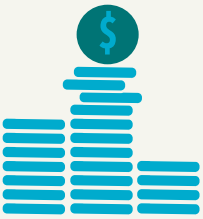
Oil may well be the next asset class on investors' de-risking agenda.

However, the re-allocation of capital away from fossil-fuel assets could be a complicated and nuanced process for long-term asset owners (e.g. pension funds, endowments, insurers), the vast majority of which have passive investment mandates.

The performance of these investors is typically measured against established benchmarks. For equity mandates in Asia, a relevant benchmark is the MSCI AC Asia index, in which energy, utilities and materials companies account for about 10.5% (compared with close to 13.8% for MSCI USA and 18.8% for MSCI Europe). In addition, there are non-fossil-fuel names in the industrials and financials space that may be exposed to the risk of permanently cheap oil to varying degrees (Figure 39).

This presents a major challenge to investors looking to decarbonize their portfolios.

Simply maintaining underweight positions in carbon-exposed assets could lead to material underperformance over the near term. In our view, capital markets have yet to properly price in carbon risk (stranded assets) and climate policy risk (regulations and public incentives). This is due to the perception that the financial implications of climate-related risks will only materialize far in the future. Consequently, there is a degree of uncertainty over the timing of carbon asset re-pricing.



ONE SOLUTION IS FOR INSTITUTIONAL INVESTORS TO DYNAMICALLY HEDGE THEIR CARBON EXPOSURE.

The solution is for institutional investors to dynamically hedge their carbon exposure by constructing a low-carbon, or decarbonized, market index that seeks to reduce climate risks, while minimizing their portfolios' performance deviation from their respective benchmarks. The empirical evidence on the effectiveness of this simple, yet practical, hedging strategy was recently presented by Andersson, Bolton and Samama in the *Financial Analysts Journal* [13].

The decarbonized index approach is based on the premise that, as of now, markets are inefficient in pricing carbon and climate policy risks. While discussions on climate-related risks have been receiving increasing attention, the general lack of explicit mandates to decarbonize suggests to us that these risks have yet to be fully priced in, if at all. The hedging framework further assumes that capital markets will price in carbon risks gradually as we reach various tipping points in clean technologies (the year 2025 in our earlier EV example).

Figure 38

Notable global fossil-fuel divestments

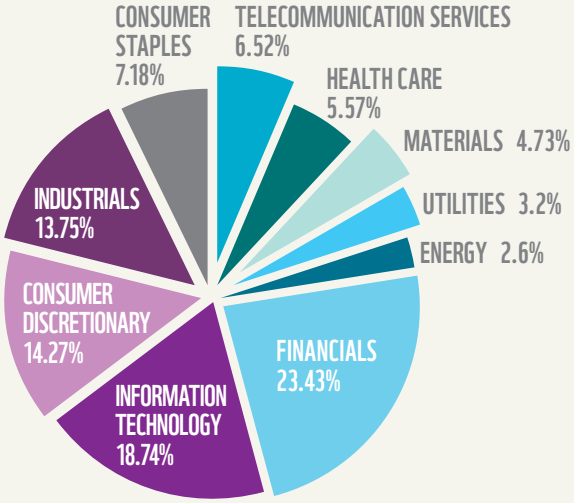
Source: Bloomberg, WWF

Institution	Country	Type	Divested asset	Divestment Amount (US$ bn)
Norges Bank Investment Management	Norway	Pension Fund	Coal	8.00
Allianz	Germany	For Profit	Coal	4.25
Axa	France	For Profit	Coal	0.58
Lund University	Sweden	Education	Coal, oil and gas extraction	0.21
California Public Employees' Retirement System	USA	Pension Fund	Coal mining	0.21

Figure 39

MSCI AC Asia Index
Sector weightings

Source: MSCI, WWF; As of June 30, 2016



By minimizing index-tracking error, the decarbonized portfolio will perform largely in line with its relevant benchmark before the effects of climate risks are adequately appreciated by the market. Once carbon risks are priced (or expected to be priced), the portfolio should outperform. As such, the portfolio is akin to a "free option on carbon", and the worst possible outcome for investors is to achieve market performance.

The actual construction of a carbon-risk proof equity index is a three-step process for institutional investors.

First, establish a prudent carbon-exposure policy consistent with global commitments to tackle climate change

Compared with their European counterparts, very few Asian asset owners have developed an explicit risk policy that sets forth their portfolios' maximum exposure to carbon-related assets. This is partially a function of the scarcity of publicly available ESG disclosures. In particular, the Task Force on Climate-related Financial Disclosures cites inconsistencies in disclosure practices, a lack of context for information, and incomparable reporting as major obstacles to incorporating carbon risks into investment decisions.

A more holistic approach would be to calculate a composite score for each invested entity based on its direct and indirect exposure to carbon and climate-policy risks.

The construction of an investable decarbonized index hinges upon the availability of data on individual firms' carbon footprint (the variable investors seek to minimize). A more holistic approach would be to calculate a composite score for each invested entity based on its direct and indirect exposure to carbon and climate-policy risks. This would, for instance, account for a bank's loan exposure to fossil-fuel companies, which is not conventionally considered part of the lender's carbon footprint.

The Blackrock Climate Score, which measures the carbon exposure of US companies, is an example of how an explicit risk policy would work in practice. The Blackrock framework evaluates a company's carbon risk by measuring the absolute level of (and the annual rate of change in) a range of metrics in three categories: resource efficiency (prefer more sales with less carbon), climate risks (impact of carbon taxes and extreme weather events), and climate opportunities (green technologies) (Figure 40) [14].

Figure 40

Blackrock Climate Score
The criteria

Source: Blackrock, WWF

Climate-risk policies could also take the form of asset-exclusion rules based on quantitative factors, such as fossil-fuel reserves, emissions intensity, coal revenues, and forestry commitments. Conversely, assets that benefit from green-technology adoption could be explicitly favored as an investment policy (Figure 41).

Figure 41

Hypothetical climate-friendly investment policy

Source: Blackrock, WWF

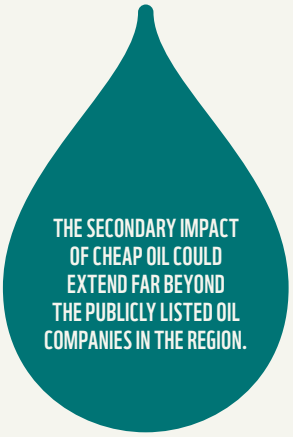
Exclusions	Rule	Reasoning
Fossil fuel reserves	Companies reporting fossil fuel reserves as assets – unless 25% or more of their revenues are from renewables.	Reduces risks from the transition to a less carbon-intensive world and from stranded assets.
Carbon emissions intensity	Energy, materials, utilities and industrial companies with a carbon intensity greater than their subsector's average.	Screens out the worst performers in four sectors that account for the majority of CO2 emissions.
Coal revenue or generation	Companies that receive 30% of revenue from extracting coal or using it for power generation.	Companies relying on coal face high regulatory, technological and energy transition risks.
Water withdrawal intensity	The top 50% most water-intensive companies in the materials and mining, beverage and utility sectors.	Companies that use the most water are most exposed to scarcity and regulatory risks.
Toxic emissions	The bottom 50% of companies that have toxic emissions as an environmental key performance indicator.	Reduces toxic emissions to limit damage to the environment and air pollution.
Forestry commitments	Companies failing to address deforestation risks in their supply chains, including retailers and food producers.	Deforestation and forest degradation contribute to 10%-20% of global CO2 emissions.
Additions	**Rule**	**Reasoning**
Green bonds	Green bonds with similar maturities and risk profiles. They can be of excluded companies as proceeds are ring-fenced.	Uses debt capital markets to finance projects that have a positive impact on the environment.
Clean tech or green companies	Companies deriving 50%-100% of revenues from clean technologies such as renewables and energy efficiency.	Increases exposure to climate change solutions and sustainability initiatives.

For firms involved in exploration and production, the dissipation of end-user demand from the mid-2020s could mean that both revenues and margins will come under tremendous pressure.

Second, make the case for de-risking or engaging if appropriate

Institutional investors have a fiduciary duty to optimize returns. Re-visiting our thesis that EV proliferation could lead to permanently cheap oil, we see an overwhelming case for a substantial reduction in exposure to oil and oil-related assets. This demonstrates that prudent climate and investment policies are not necessarily in conflict.

For firms involved in exploration and production, the dissipation of end-user demand from the mid-2020s could mean that both revenues and margins will come under tremendous pressure. To avoid being the last one with a stranded asset on their balance sheets, these companies will have an incentive to ramp up production early, which will exacerbate price pressures.



Similarly, refineries are likely to face deteriorating economics, although the impact should be moderated by continued demand for oil products that are harder to replace than gasoline, most notably diesel, heating oil, jet fuel and petrochemicals. As for retail gas station operators, they will have to compete with a growing number of electric charging terminals that are more economical to maintain.

Firms that are not directly oil-related may also be affected (utilities), to the extent the EV ecosystem will expedite public and private commitments to switch from fossil fuels to renewables as a source of power generation. As we have recently seen with the Singaporean banks' exposure to offshore service companies, the secondary impact of cheap oil could extend far beyond the publicly listed oil companies in the region.

At the individual company level, we anticipate that markets will begin to question the "terminal value" that is assigned to oil companies' long-term cash flow streams as we approach EV-ICE vehicle cost parity. The value of "perpetual" cash flows – which extend beyond analysts' typical 10-15 year forecasts – may approach zero as EV adoption becomes widespread.

THE "PERPETUAL" CASH FLOWS - WHICH EXTEND BEYOND ANALYSTS' TYPICAL 10-15 YEAR FORECASTS - MAY APPROACH ZERO AS EV VALUE OF ADOPTION BECOMES WIDESPREAD.

We also question the premise that fossil-fuel firms are too big or too important to fail. We often hear that Asian fossil-fuel companies are quasi-sovereign agencies, in that they are either directly/indirectly government-owned or a regulatory monopoly. The implicit sovereign support they are perceived to enjoy could lead to lower borrowing costs and more relaxed loan underwriting standards. From a pure economic perspective, Asian governments should be fiscally capable of facilitating an orderly exit of capital from fossil-fuel industries. China's commitment to restructuring the coal, steel and cement industries is a case in point.

There may also be a case to engage with companies if it is possible for them to transform their business to be compatible with a low-carbon economy. For example, to help a utility to transform its fossil fuel driven production of energy to one that sources its energy from sustainable sources.

Beta strategies seeks to eliminate as much of the portfolio's carbon exposure as possible without sacrificing financial returns.

Third, construct a dynamic hedging strategy

The more common category is pure-play indices that focus on renewable energy and clean technologies. These "alpha" strategies seek to identify individual assets that could benefit from carbon-reduction efforts. From the perspective of institutional investors with sizable assets under management, pure-play indices may have limited applications due to the paucity of liquid investments in the space. Many of these assets could also be highly risky, due to the substantial capital expenditure on unproven technologies. In fact, many pure-play index products in the green space have significantly underperformed market benchmarks since January 2007 (Figure 42).

The less-common type of green index is a "beta" strategy that seeks to eliminate as much of the portfolio's carbon exposure as possible without sacrificing financial returns. Without going into the mathematics, the decarbonized index methodology we are interested in takes a universe of market index constituents (e.g. the MSCI Europe Index) and produces a portfolio weighting that maximizes carbon intensity reduction for any given level of tracking error.

It is important to note that while we highly recommend a strong carbon risk policy and a de-risking approach, we also recognize that in certain circumstances this may not be feasible in the immediate term. Therefore a dynamic hedging strategy can be utilized.

THE DECARBONIZED INDEX IS EFFECTIVELY A "FREE OPTION ON CARBON."

Figure 43 illustrates the "carbon frontier" on the MSCI Europe Index. It is noteworthy that if we accept an index tracking error of 0.5%, it is possible to construct a portfolio with a 75% reduction in carbon intensity. Essentially, investors in this particular decarbonized portfolio are predicted by the model to achieve the same returns as the MSCI Europe +/- 0.5% per annum before carbon risks are properly priced in by the market. After carbon risks are recognized in the future, the decarbonized portfolio should outperform (it will only have 25% of the carbon intensity of the MSCI Europe Index).

Figure 42

Performance of select green pure-play indices vs benchmarks
January 5, 2007-September 1, 2015

Source: Amundi, Bloomberg, WWF

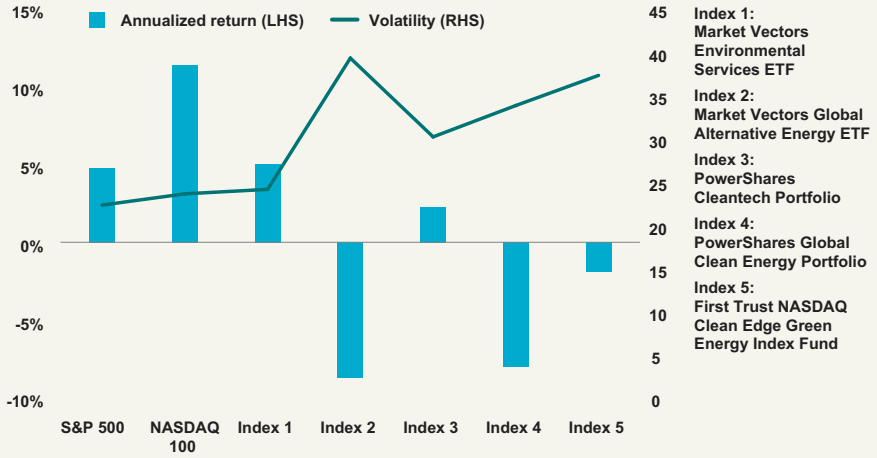
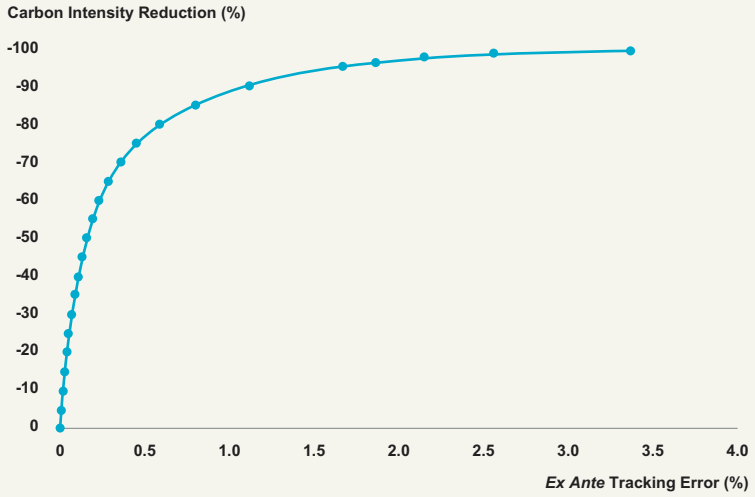


Figure 43

Carbon Frontier on the MSCI Europe Index

Source: Amundi, WWF



As a result, the decarbonized index is effectively a "free option on carbon", allowing investors to substantially reduce their exposure to carbon risks while maintaining a very similar risk-reward profile to their benchmark index. This significant reduction in carbon intensity is largely due to the fact that climate-related risks tend to be heavily concentrated in a small number of index constituents. Recall that the sectors most at risk (energy, utilities and materials) represent 10.5%, 13.8% and 18.8% of the MSCI Asia, USA and Europe Indices, respectively. The low weighting of carbon-exposed assets in Asia supports the case that these beta strategies can be replicated in an Asia portfolio management setting.

Figure 44

Performance of the MSCI Europe Low Carbon Leaders Index
November 30, 2010-February 29, 2016

Source: MSCI, WWF

Key Metrics	MSCI Europe Index	MSCI Europe Low Carbon Leaders Index
Total return[a]	7.8%	8.7%
Total risk[a]	13.2%	13.2%
Return / risk	0.59	0.65
Sharpe ratio	0.57	0.63
Active return[a]	0%	0.9%
Tracking error[a]	0%	0.7%
Information ratio	NA	1.16
Historical beta	1.00	1.16
Turnover[b]	1.8%	9.9%
Securities excluded	NA	93
Market cap excluded	NA	21.4%
Reduction in carbon emissions intensity (*t*CO2/US$ millions)	NA	52%
Reduction in carbon reserves intensity (*t*CO2/US$ millions)	NA	66%

Figure 44 further illustrates the portfolio characteristics of the MSCI Europe Low Carbon Leaders Index, constructed using the principles described above. Looking at back-tested data from November 2010-February 2016, the green index outperformed MSCI Europe by an impressive 90bps, with a similar volatility and a tracking error of 0.7%. In the meantime, the portfolio achieved a 52% reduction in emissions intensity and a 66% decline in carbon reserves intensity.

In our opinion, the next few years present what may be the last window of opportunity for Asian investors to address the potential risks arising from EV proliferation and the resulting oil displacement. Asian asset owners have to examine their investment guidelines to ensure that their managers are properly incentivized to re-allocate capital away from risky oil exposure in equities, fixed income and commodities. A decarbonized beta strategy is an evolving, but increasingly relevant, performance-management solution. Decarbonized indices are especially pertinent to funds with long-term liabilities (e.g. insurers, pension plans and endowments), because while their financial obligations will continue to exist in the next few decades, the markets for fossil-fuel assets may not.

Conclusion

Despite uncertainties in technology, consumer behavior and oil prices, it should be apparent that many energy companies are grossly underestimating the risk of widespread EV adoption. The 1% BEV penetration rate in 2040 that OPEC predicts not only seems inconsistent with the political will to adhere to the 2°C target, but also appears to contradict the tremendous improvements in battery technology in recent years.

Investment managers and asset owners can play a vital role in global efforts to mitigate climate change by reallocating financial resources from polluting, low-return assets to more sustainable alternatives. A number of international investors have begun to divest their interests in coal assets, which have been plagued by over-capacity and the risk that renewable energy sources may soon diminish their importance. Divestment activities have so far occurred in an orderly manner, allowing investors to de-risk their portfolios at a steady pace.

Although it is difficult to predict when the adoption of EVs will cause a structural decline in oil demand, the likelihood of this happening from continued breakthroughs in technology is growing by the day. It is, therefore, in the interests of investors to act early and to position themselves for the age of clean transportation technology.

APPENDIX

How much electricity will EVs use in China?

When we consider the environmental impact of EVs, oil displacement from ICE vehicles is only part of the equation. An equally important consideration is the strain EVs put on electricity production and the types of fuel used to produce the incremental electricity.

If we assume that EVs consume, on average, 0.3 kWh of electricity per mile travelled and that each EV travels 10,000 miles a year, our EV sales forecasts for China suggest that by 2050, the incremental power demand will be 914 to 1,079 TWh a year (Figure 43).

To put this into context, the US Energy Information Administration forecasts that by 2040, China's electricity generation will reach almost 10,000 TWh a year [15]. The incremental demand from EVs will, therefore, be less than 10% of total power output, a level which we consider to be manageable given that China is now the largest investor in renewable energy (Figure 44).

Figure 43

Incremental electricity demand from EVs in China (TWh)

Source: WWF estimates

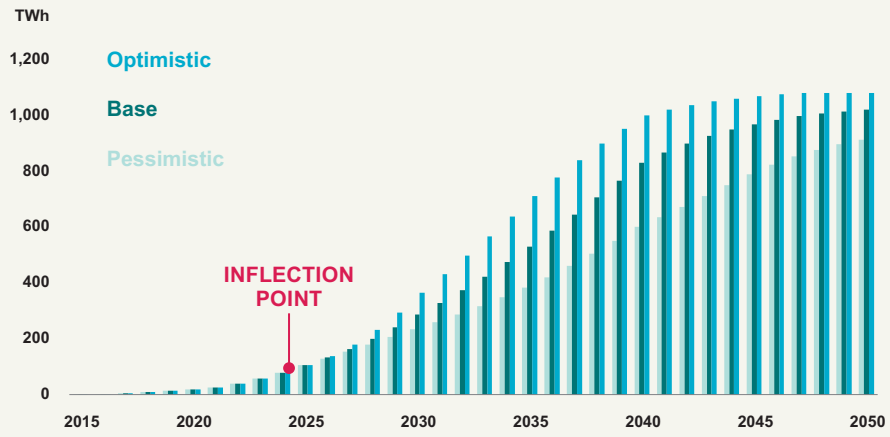
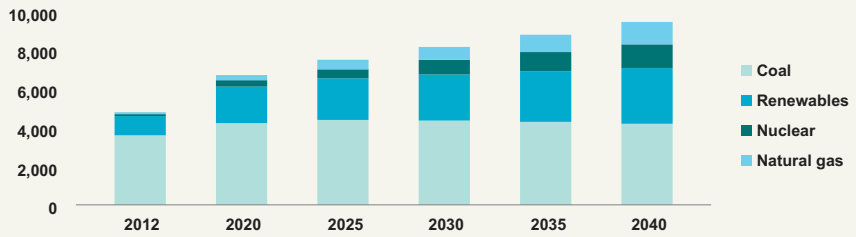


Figure 44

Incremental electricity demand from EVs in China (TWh)

Source: EIA, WWF

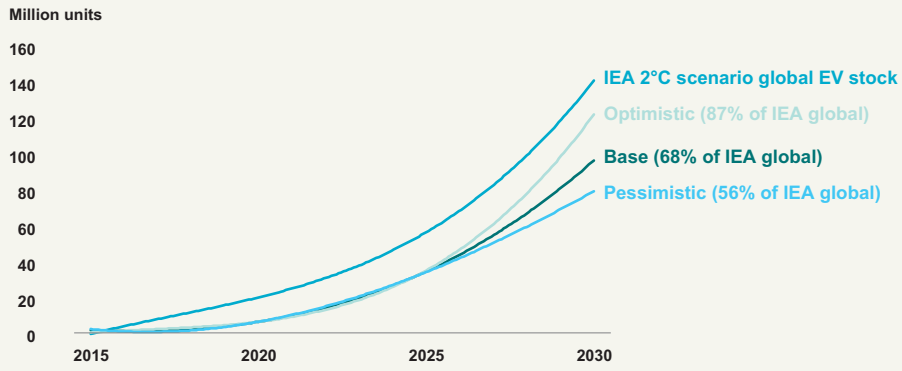


The net benefit of EVs to the environment is largely predicated upon the types of fuel used in power generation. We note that, under China's Energy Development Strategy Action Plan:

- China will target a reduction of coal in the primary energy mix to under 62% by 2020, to the advantage of non-fossil fuels (15% by 2020 and 20% by 2030, from about 10% in 2013) and gas (10% by 2020);
- By 2020, the installed nuclear power capacity is expected to reach 58 GW, with an additional 30 GW under construction;
- China targets an installed hydropower capacity of 350 GW by 2020, with wind and solar capacities reaching 200 GW and 100 GW respectively.

In a more global context, we compare our China EV forecasts with those produced by the IEA below (Figure 45).

Figure 45
EV stock forecasts 2016-30
Source: IEA, WWF estimates



The IEA's global EV forecasts suggest that by 2030, the global EV stock has to be about 140 million units in order for CO2 reductions to be consistent with a 2°C scenario. Our forecasts for China alone compare favorably with what we consider to be the IEA's minimum requirements for a marginally acceptable climate outcome.

For 2030, our optimistic, base and pessimistic cases for China are respectively 87%, 68% and 56% of the IEA's global EV stock forecast. This implies that, should China succeed in decarbonizing its road transportation system, there is a strong likelihood that global tailpipe emissions will be reined in.

METHODOLOGY

This section summarizes the methodology we use in arriving at our EV sales and stock forecasts for China and the resulting oil displacement estimates.

Total vehicle sales and stock

To establish a base-line forecast for all vehicle sales and stock in China, we assume annual sales growth of 5% from 2016-2020, trending down to 2.5% from 2021-2025, 1.5% from 2026-2030, 1.0% from 2031-2035, 0% from 2036-2040, -1.0% from 2041-2045 and -1.5% from 2046-2050.

We further assume that 4.5% of all vehicles are replaced annually from 2016-2020, rising to 5.0% from 2021-2025, 7.5% from 2026-2035 and 10% from 2036-2050.

EV sales and stock

Across our base, bull and bear scenarios, we assume that EV sales penetration rate will rise from 2.5% to 5.0% from 2016-2020 and from 5.0% to 25.0% from 2021-2025. From 2025 onwards, we assume that EV sales penetration will steadily climb to 100% by 2035, 2040 and 2045 in our bull, base and bear scenarios, respectively.

To arrive at our EV stock estimates, we assume that 0% of EVs on the road will be replaced from 2016-2025, rising to 5.0% from 2026-2030, 7.5% from 2031-2040 and 10% from 2041-2050.

Oil displacement forecasts

For simplicity, we assume that all of the EVs sold in China over the forecast period are BEVs. This means we are likely over-estimating oil displacement and under-estimating oil demand in the early years of our projections. We expect BEVs to become increasingly price- and performance-competitive in the mid-2020s. At that point, there will be a strong incentive for consumers to choose pure electric models over hybrids. Given that overall EV growth is back-loaded in our forecasts, the net impact of our assumption should be negligible.

We assume that the average car in China consumes 250 gallons of gasoline a year and that it stays constant over time. This is close to the 2015 national average and substantially lower than the levels seen in the US. There are two other issues at play here.

First, fuel economy for ICE vehicles should improve over our forecast period. This would lower the relative cost of owning conventional vehicles, reduce the initial demand for EVs and therefore the amount of oil displaced. We would, again, be over-estimating oil displacement and under-estimating oil demand in early years. This impact is moderated by the reduced oil consumption of ICE vehicles from fuel-economy upgrades.

Second, while recent global trends have pointed to a drop in average mileage travelled, we believe car-sharing services and automated driving have the potential to substantially raise the distance travelled per vehicle over the forecast period. We can only re-visit this assumption once the technologies in question become commercially viable.

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THE GROWTH OF ELECTRIC VEHICLES AND THEIR IMPACT ON OIL

100% RECYCLED

2025

Electric vehicles will be cheaper to own

1.3m

Electric vehicles on the road in 2015 globally

1m

Barrels of oil displaced per day in China in late 2020s

100%

Electric vehicles' penetration rate in China in 2045

Working to sustain the natural world for people and wildlife

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