The background of the entire page is a photograph of an oil rig at sunset. The sun is a large, bright yellow circle in the center, partially obscured by the rig's structure. The sky is filled with orange and yellow clouds. The rig is a complex of dark silhouettes against the bright sky. The water in the foreground is dark and calm.

FORECASTING FAILURE

WHY INVESTORS SHOULD TREAT OIL COMPANY ENERGY FORECASTS WITH CAUTION

Overview

Leading investors are increasingly asking international oil companies about how their strategy reflects climate change.¹ Are the companies taking seriously the need to cut emissions and undergo a transition to clean energy? Are their investments robust to the anticipated global decline in fossil fuel use? Are the companies playing a constructive or an obstructive role in policy development for the transition?

In response, companies often point to their models of the world energy system, which forecast that fossil fuels will continue to dominate the energy mix for the coming decades. So, the companies argue, high-carbon and high-cost investments will be safe. The models also predict that limiting climate change to internationally-agreed levels is unlikely. For an investor with holdings in climate-vulnerable sectors, such as property or food, this is not good news.

A POOR TRACK RECORD

So how plausible are their forecasts? Their track record has not been good, especially when it comes to energy sources that compete with their core products. For example:

- ExxonMobil's first published Outlook in 2005 projected that wind and solar would account for 1% of total world energy production by 2030. Wind and solar achieved this share in 2012, after seven years rather than 25.
- Every year since its first published forecast in 2011, BP has predicted a sudden slowing of renewable energy growth, although every year the prediction has been wrong.

Forecasts cannot be expected to get everything right. But to be useful, they should demonstrate thinking about a range

of realistically possible futures. In reality, oil company forecasts are systematically skewed, resting on often unlikely assumptions. In this report, we focus on the forecasts regularly published by ExxonMobil, Shell and BP, though most of the criticisms apply also to how other oil companies think about the future, and often also to the International Energy Agency (IEA) and the US Energy Information Administration (EIA).

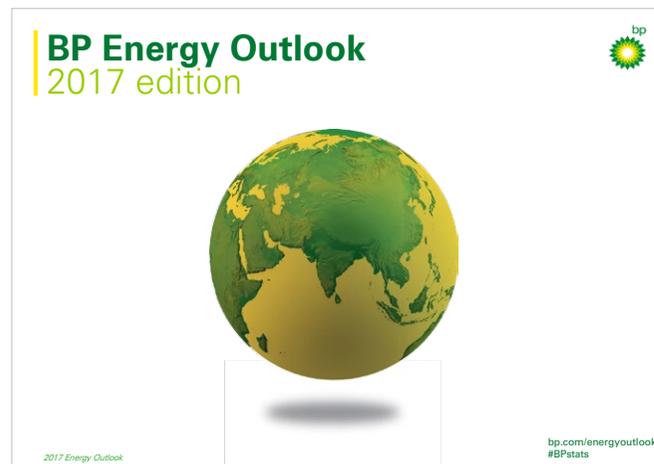
SELECTIVE SCEPTICISM ON TECHNOLOGY

The companies have a selective scepticism about technologies that challenge oil and gas, contrasted with an optimism about technologies that advance oil and gas:

- Over the last five years, forecast publications by ExxonMobil, Shell and BP have highlighted obstacles to renewable energy 35 times, and challenges for oil and gas just four times.

- Shell considers two possible futures, one of which involves technological and economic breakthroughs in new unconventional oil (including tar sands and kerogen), the other in new unconventional gas (including shale, coal-bed methane and methane hydrates).
- BP and ExxonMobil estimate costs of renewable energy and electric vehicles well above mainstream industry estimates; BP's forecast for solar costs in the United States in 2050 is higher than the actual average cost in 2016.
- The companies assume that electric cars will remain marginal – a view not shared by the car industry, nor by industry experts.

In this report, we reveal how energy models are constructed, and highlight their central weakness: by extrapolating existing trends, they tend to predict that the future will be just like the present, while masking underlying potential for disruption.



ANALYSIS OR ADVOCACY?

The credibility of oil company forecasts is weakened by their purpose being muddled between informing investment decisions and influencing policymakers. In the advocacy role, they often reflect what the companies want decision-makers to believe, rather than being a genuine exploration of possible futures. Indeed, the first publication of forecasts in their current form was driven by ExxonMobil's public affairs department, targeting what it called "informed influentials", including investors and policymakers.

Most oil companies oppose regulation to address climate change, preferring market-based approaches. Government action (other than carbon pricing) is also generally absent from the companies' forecasts. Yet however much they want governments to refrain from regulating, no plausible forecast would ignore policy as a key driver of change.

- ExxonMobil, Shell and BP assume there will be no significant climate or energy regulation by governments, not just now but for the coming decades, as climate impacts intensify.²
- When considering possible climate action, Shell assumes that solutions will be limited to natural gas and carbon capture and storage (CCS) – and so necessarily good for Shell.
- Neither ExxonMobil nor BP significantly changed their forecast of emissions after the Paris Agreement of December 2015. (Shell has not published a forecast since Paris.)

A WAY FORWARD

The Task Force on Climate-Related Financial Disclosures, reporting to the Financial Stability Board, recommends a more robust approach to planning which uses "scenarios" to consider more than one possible future.

Drawing on best practice, we propose that for effective use of scenario analysis:

- Companies should consider multiple possible futures, shaped by the most impactful and uncertain drivers.
- Scenarios should be plausible and internally consistent, and avoid focusing on what is considered "likely", as that is subject to psychological biases.
- Companies should stress-test a business in conditions that are actually stressful, not best-case assumptions.

For shareholders, it's essential that allocations of capital made by companies to multi-decade, high-cost projects are based on robust judgments about the future. ExxonMobil, Shell and BP alone are expected to invest US \$250bn of capital in the next five years.³ In this paper we outline a comparative analysis of the oil majors' current approaches to thinking about energy futures, and identify strengths and weaknesses. We also suggest a number of questions shareholders should ask oil companies to determine whether portfolio companies are following best practice in developing planning scenarios.



QUESTIONS FOR COMPANIES

- 🔍 To what extent does the company use its published forecasts as the basis for investment decisions? Does the company consider other scenarios privately, beyond those it publishes?
- 🔍 Does the company believe its published forecasts present an adequate range of credible future technological and policy developments that could reasonably be expected to affect the business?
- 🔍 If different scenarios are used internally, what is the purpose of publishing only particular forecasts? Is there a risk their publication might mislead investors or others (eg policymakers)?
- 🔍 What temperature rise would the company's forecast entail, with what probability?
- 🔍 How does the company's forecast factor in the negative macroeconomic implications associated with that amount of temperature rise?
- 🔍 In the company's planning, what range of ultimate penetration levels for wind and solar in power generation, and of electric vehicles in transportation, does the company consider? And what range of timescales?
- 🔍 What is the company's strategy for the eventuality that the more ambitious end of the range occurs?
- 🔍 What signposts does the company monitor to gauge whether technological change is moving faster than anticipated by its scenarios?
- 🔍 How do the company's cost forecasts compare with those of other organisations?
- 🔍 How do the company's forecasts of future costs compare with actual current costs?
- 🔍 Will the company disclose to which government departments and officials (in all countries) it has presented its energy forecasts?
- 🔍 Will the company comply with all of the Task Force on Climate-Related Financial Disclosures' recommendations regarding scenario analysis?
 - In particular, will the company disclose "the key assumptions and considerations underlying each scenario, and whether scenarios with major disruptions (positive and negative) from business-as-usual (breakthroughs, breakdowns) were considered"?
- 🔍 How many scenarios does the company consider in its business planning, where governments achieve the Paris goals of keeping warming well below 2°C, and/or keeping it to 1.5°C? For example, does the company consider different scenarios for a disruptive technology-driven transition vs a policy/regulatory-driven transition?
- 🔍 Which of these scenarios is most challenging for the business? For example, do they include scenarios where demand for the company's core products falls?
- 🔍 If the company relies on the IEA 450S (see page 17), what steps is the company taking either internally or with the IEA to explore the assumptions in that scenario?
- 🔍 Are company portfolios robust to:
 - Zero net global emissions by 2050 (the median IPCC scenario for achieving 1.5°C)?
Zero net emissions by 2070 (the median for likely staying below 2°C)?
 - No new petrol or diesel car sales from 2025 or 2030 (assuming the current trend spreads to all major countries)?
 - No new gas power stations built after 2020, with all new power investments going into zero-carbon sources?

Why Forecasts Matter

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Abbreviations

450 Scenario	(450S)
Bloomberg New Energy Finance	(BNEF)
carbon capture and storage	(CCS)
electric vehicles	(EVs)
Intergovernmental Panel on Climate Change	(IPCC)
internal combustion engine	(ICE)
International Energy Agency	(IEA)
US Energy Information Administration	(EIA)



Flawed Forecasts Put Capital at Risk

In August 2015, Shell responded to intensifying investor concern about its plans to drill in the Alaskan offshore by pointing to its forecasts of the future of energy. “Hydrocarbons are going to be needed for an awfully long time,” said Shell’s executive vice president for the Arctic. “That’s where Alaska fits into the picture.”⁴

Shell’s Arctic adventure may now be over – at a cost of at least \$7bn to shareholders⁵ – but Shell and other international oil companies continue to pursue high-cost, high-risk investments in other frontier oil provinces, such as Australia’s Great Bight, Brazil’s ultra-deepwater, and Canada’s tar sands. These investments can succeed only if oil demand continues to grow, and if efforts to limit climate change fail. The companies confidently assert that both conditions will be met, based on forecasts such as ExxonMobil’s Outlook for Energy, BP’s Energy Outlook and Shell’s New Lens Scenarios.⁶

Yet the history of technological change is littered with companies who confidently but mistakenly believed there would be ever-growing demand for their product. Think of Kodak, or Blockbuster.

The oil companies argue that action to limit climate change is unlikely within the 12-16 year period of their reserves/production ratios, so they will be able to shift capital later.⁷ In reality, companies are today investing shareholders’ money in projects that aim to break even in 15, 20 or 25 years’ time.⁸ Even a relatively small decrease in demand could translate into falling prices during that period, and delay breakeven or reduce returns. For example, Bloomberg estimates that at current growth rates, electric vehicles could reduce oil demand by 2 million barrels per day by 2023, the same amount as the supply glut that triggered the 2014 oil price collapse.⁹

Recent analysis by Oil Change International found that the extractable oil, gas and coal in already-developed fields and mines (as estimated by Rystad Energy and the IEA) exceeds what the Intergovernmental Panel on Climate Change (IPCC) says can be burned while likely staying below 2°C of warming.¹⁰ The implication is that any investment in new extraction could take the world beyond 2°C, or alternatively lead to assets being stranded (in the absence of a technological miracle in CCS¹¹). Climate change is not an issue for the distant future: it relates to capital expenditure decisions being made right now. This is why it is vital that investors engage with companies on their energy forecasts.

Forecasts are Used to Justify High-Cost Projects such as in the Arctic



©The United States Coast Guard / Greenpeace

QUESTIONS FOR COMPANIES

- ➊ To what extent does the company use its published forecasts as the basis for investment decisions? Does the company consider other scenarios privately, beyond those it publishes?
- ➋ Does the company believe its published forecasts present an adequate range of credible future technological and policy developments that could reasonably be expected to affect the business?
- ➌ If different scenarios are used internally, what is the purpose of publishing only particular forecasts? Is there a risk their publication might mislead investors or others (eg policymakers)?

Company Forecasts Undermine Climate Action

Oil company forecasts not only describe the future, they influence it. By portraying the achievement of climate goals as unlikely, they can discourage action by policymakers or investors, and undermine confidence in alternatives. They can create a fatalism that fossil fuels will necessarily dominate the energy mix for decades to come.

Oil companies have generally said they do not believe that limiting warming to 2°C is a realistic possibility (see below). As the graph shows, their forecasts of emissions substantially exceed IPCC scenarios that would be consistent with the Paris Agreement goals of limiting warming to well below 2°C above pre-industrial levels, and aiming for 1.5°C. The companies are not just judging today's climate politics, they are assuming no progress for decades to come.

We have noted the risk of wasted shareholder capital. However, climate change creates the greater risk to investment portfolios: The Economist Intelligence Unit estimates that

warming of 5°C could result in US\$7tn in losses, more than the total capitalisation of the London Stock Exchange.¹² Accordingly, investors have become more vocal in calling for effective policy measures to address climate change.

Once carbon-intensive investments are made, they tend to lock in future production and emissions, due to their high capital costs and low operating costs.¹³ It also becomes more politically difficult to make decisions that would strand those assets, due to the real capital and jobs associated with them, and indeed the lobbying power of their owners.

Investors face a potential lose-lose situation. If the forecasts are wrong, investors stand to lose on their oil investments. But if they are right, long-term investors stand to lose on the rest of their portfolio. This is why it is vital that investors engage with companies on their energy forecasts.

The Oil Companies do not Believe Achieving Climate Goals is Plausible

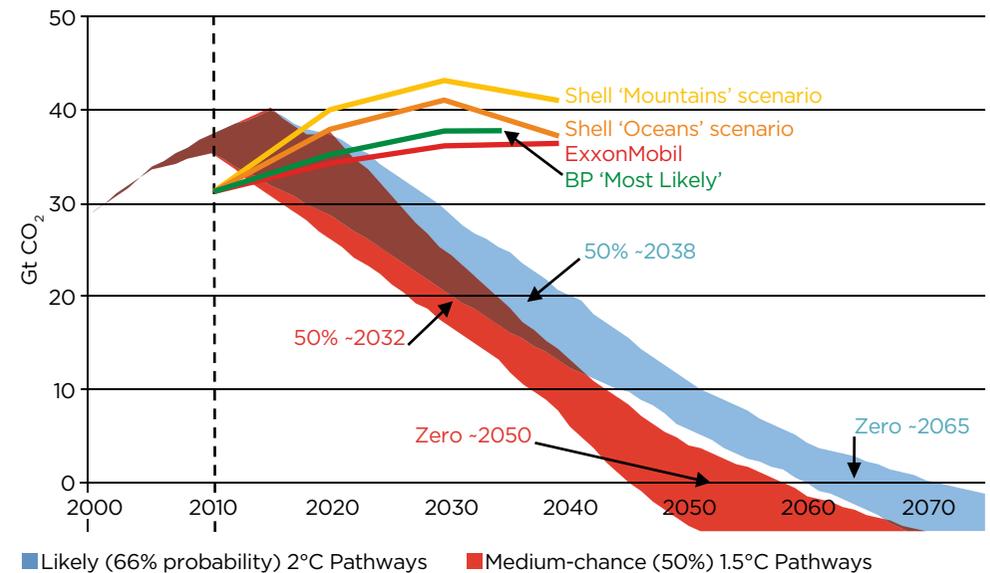
"While the risk of regulation where GHG emissions are capped to the extent contemplated in the low carbon scenario during the Outlook period [to 2040] is always possible, it is difficult to envision governments choosing this path in light of the negative implications for economic growth and prosperity that such a course poses" – ExxonMobil¹⁴

"We also do not see governments taking the steps now that are consistent with the 2°C scenario" – Shell¹⁵

"Achieving anything close to the IEA's 450 Scenario by 2035¹⁶ would require an unprecedented pace of improvement in both global energy intensity and carbon intensity" – BP¹⁷

The Oil Companies Forecast Emissions Going Well Beyond the Paris Goals¹⁸

Range of IPCC global CO₂ emissions scenarios (from all sources) consistent with Paris goals vs oil company forecasts (from fossil fuel sources only)



Sources: IPCC Scenarios Database; Rogelj et al / Nature Climate Change 2015; ExxonMobil; Shell; BP

QUESTIONS FOR COMPANIES

- What temperature rise would the company's forecast entail, with what probability?
- How does the company's forecast factor in the negative macroeconomic implications associated with that amount of temperature rise?

Systematic Bias in Renewable Energy Forecasts: Oil Companies Keep Getting it Wrong

Forecasts are not expected to get everything right. But to be useful, they should demonstrate corporate thinking about realistic futures, based on plausible assumptions.

The companies have repeatedly underestimated growth in renewable energy. For example, ExxonMobil's Outlook in 2005 projected that wind and solar would account for 1% of total world energy production by 2030. Wind and solar achieved this share in 2012, after seven years rather than 25.¹⁹ In 2010, as this underestimate had become clear, ExxonMobil predicted that wind and solar would then reach 1.5% in about 2022, a level that was in fact reached in 2016.²⁰

The first graph shows BP's predictions of renewable energy consumption, from its annual forecasts since 2011, and compares them with actual development. Every year, BP predicted a slow-down in the growth rate; every year it got the prediction wrong but then repeated the prediction the following year (simply lifting the start point to the new actual level).

The oil companies do provide technological, economic or political reasons for their scepticism about the future of renewable energy. However, they are not sceptical of technologies that would boost their business, such as fracking, petrol/diesel engine efficiency or CCS. Of Shell's two

main scenarios, one predicts technological and economic breakthroughs in new unconventional oil (including tar sands and kerogen); the other in new unconventional gas (including shale, coal-bed methane and methane hydrates).²¹ The companies' scepticism is selective.

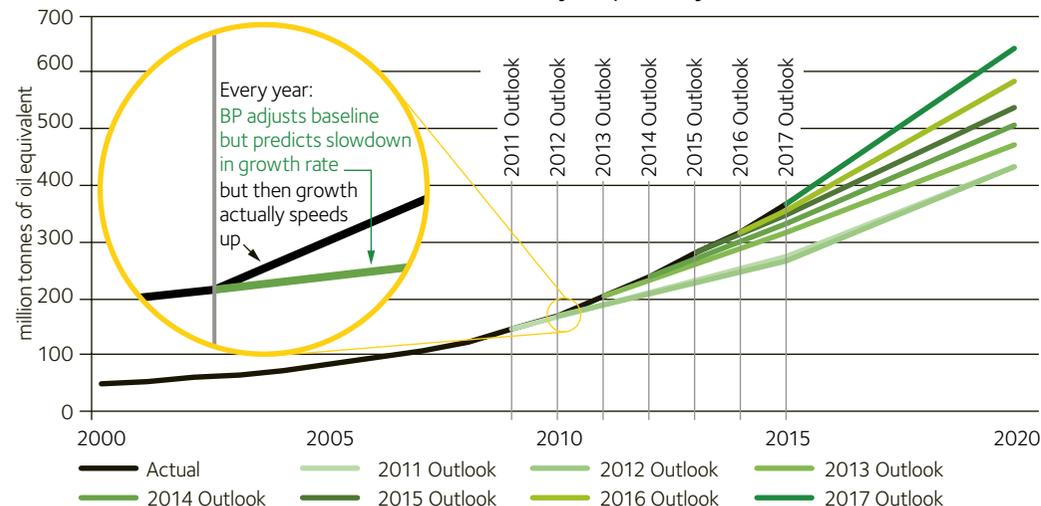
The continued growth of oil and gas faces structural challenges,²² but these are glossed over or (more often) ignored, in contrast to the challenges for clean energy technologies, as the second graph illustrates. In their forecast publications of the last five years, ExxonMobil, BP and Shell mentioned the high cost or intermittency of renewables 35

times; they mentioned challenges for oil and gas only four times.

This skewed treatment suggests either that the companies suffer from confirmation bias (unwittingly interpreting evidence so as to support pre-existing beliefs), or that the outlooks are slipping from analysis to advocacy (page 15).

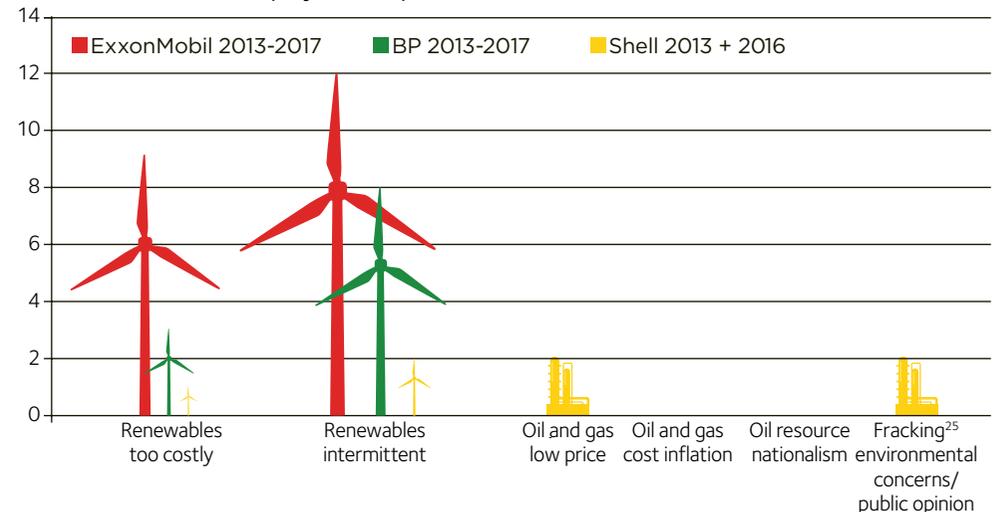
Every Year, BP Wrongly Predicts Renewable Energy Growth Will Slow Down²³

Renewable energy consumption: BP forecasts vs what actually happened
(NB for each forecast, most recent historic data was from 2 years previously)



Oil Companies See Structural Obstacles to Clean Energy... But Almost Never to Oil and Gas²⁴

Number of mentions in company forecast publications, 2013-2017



How Technology Changes

From fridges to smartphones, when new technologies are introduced, their growth generally follows a common pattern: the 'S'-curve. Initially, take-up is slow but rises exponentially as new customers want the product. In a second phase, growth becomes rapid but linear. Finally, the growth starts to slow down as the technology approaches saturation level within its market.²⁶ The two variable elements are the level at which saturation occurs, and how quickly the technology gets there.



The important question for new energy technologies is: in which innovation phase are we? The answer will have a huge impact on energy futures. For instance, if renewables sustained their current exponential growth rates, they'd catch up with oil within about 18 years. At current linear rates it would take over 80 years.²⁷

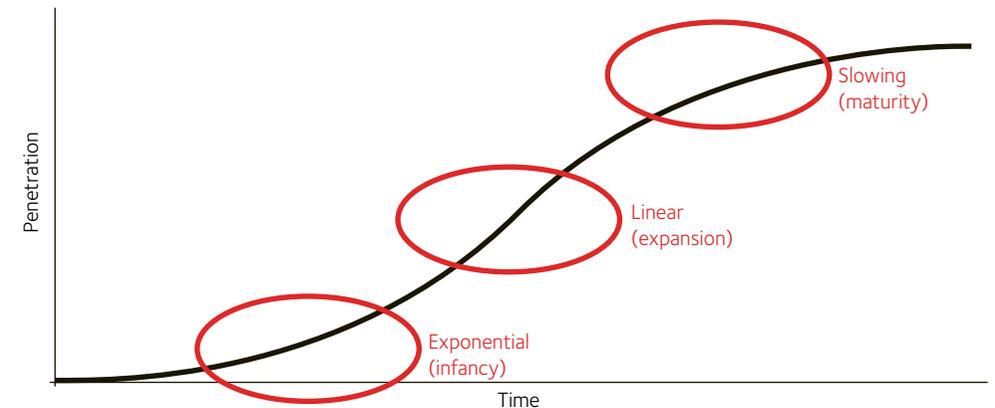
BP appears to believe that renewable energy consumption – which has so far shown a clear exponential trend – is moving into a linear phase, as of today. The linear phase implies

that the renewable energy industry – from manufacturing to installation – stops growing significantly. That is not an impossible future, but it seems an unlikely one. The graph contrasts this with Bloomberg New Energy Finance's (BNEF) forecast, which sees continued exponential growth in renewable generation, and continued expansion of the renewable energy industry.

QUESTIONS FOR COMPANIES

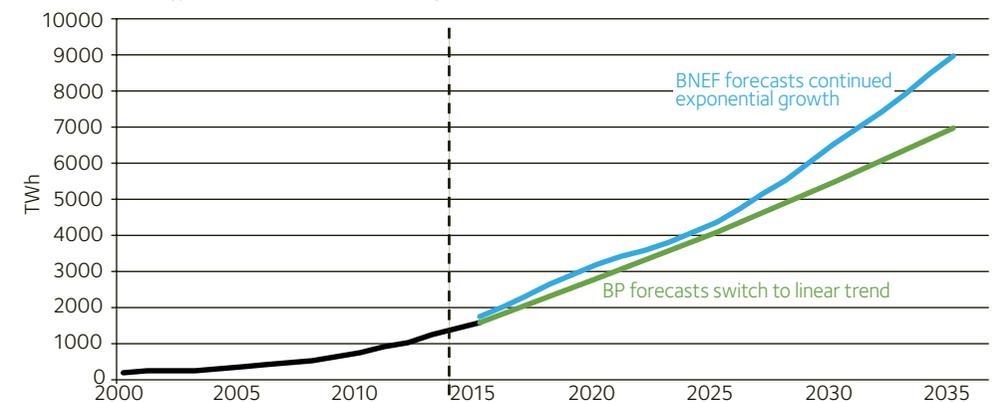
- ☪ In the company's planning, what range of ultimate penetration levels for wind and solar in power generation, and of electric vehicles in transportation, does the company consider? And what range of timescales?
- ☪ What is the company's strategy for the eventuality that the more ambitious end of the range occurs??
- ☪ What signposts does the company monitor to gauge whether technological change is moving faster than anticipated by its scenarios?

New Technology Adoption Follows an S-Curve. Where on the Curve are Renewables?



BP Believes Renewables Growth is Moving to Linear Phase²⁸

Renewable energy consumption (wind, solar, geothermal, biomass): BP vs BNEF forecasts



Electric Vehicles: Oil Companies More Sceptical than the Car Industry

While the companies' gas businesses are threatened by wind and solar power, oil is primarily used in transport, where the competing technology is electrification.

Electric vehicles (EVs) are certainly in the exponential phase of the S-curve, and so far have just less than 1% of sales.²⁹ There is therefore considerable uncertainty about how fast they will grow. Cars remain on the road for 10-15 years,³⁰ compared to the 40-year lifetime of power plants, so the whole market could shift much more quickly.

BP forecasts that only 6% of the global car fleet will be electric by 2035,³¹ and ExxonMobil about 6% by 2040.³² For comparison, Carbon Tracker Initiative and Imperial College modelled potential EV penetration using up-to-date cost estimates (see page 11), with no regulatory change, and projected EVs would account for 55% of passenger vehicles by 2040.³³

The car industry itself sees electrification as a much more important trend.³⁴ "The future is electric," says GM, the world's third largest car manufacturer.³⁵ VW, the equal largest, aims for 20-25% of its production to be all-electric by 2025.³⁶



"Electrification will be bigger than expected," predicts Deutsche Bank's auto analyst Rod Lache, forecasting an inflection in demand in the early 2020s.³⁷ Ratings agency Fitch goes further: EVs could create an "investor death spiral" for the oil companies.³⁸

A recent study by BNEF and McKinsey considered scenarios where nearly 100% of car sales are electric by 2025 (regulatory-driven scenario) or by 2030 (technology-driven scenario), as shown in the graph. It is not a question of whose forecast is correct. The problem is that the oil companies do not even consider scenarios of EV growth. Indeed, even if technological progress is only slightly above the oil company projections it is still likely to affect oil pricing, and thereby the companies' financial performance. As noted on page 6, another study by Bloomberg found that EVs need only reach 3% of the world's car fleet to reduce oil demand by an amount equivalent to the supply glut that led to the dramatic fall in oil prices from 2014-2016.

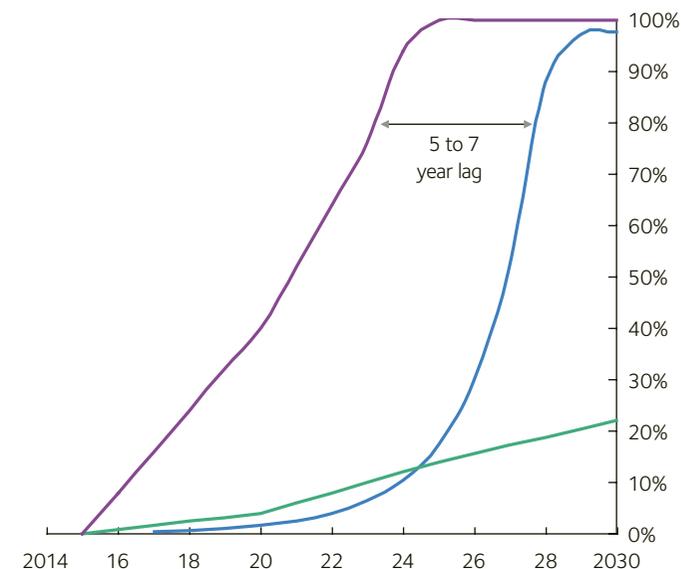
EV Growth Could Be a Lot Faster Than Oil Companies Think: Scenarios³⁹

Different possible adoption curves

- Base case curve
 - Meets general fleet emission targets
- Regulatory-driven curve
 - 100% of light vehicle sales to be electric by 2025 (e.g., Seamless Mobility)
 - Based on Norway's intentions
- Innovation and imitation curve
 - Assuming early adopter and imitation effect
 - Speed of adoption and imitation based on historic sales, and the relative cost of ICE versus EVs

Source: BNEF/McKinsey

Electric vehicle as share of car sales
Percent



Implausible Forecasts of Technology Costs

While oil companies' models largely ignore political drivers of change (page 14), the relative cost of different fuels is key to the prediction of the energy mix. Yet the companies appear to have unusually high estimates and forecasts of clean energy costs.

The graph shows BP's 2012 estimate and 2050 forecast of the average levelised cost of energy for three power generation technologies in North America, compared with the current costs estimated by financial adviser Lazard, an authority on the relative costs of energy. Lazard finds that onshore wind and utility-scale solar are already cheaper on average than combined cycle gas. BP forecasts that even in 2050, utility-scale solar will cost more than combined cycle gas. Remarkably, BP's forecast of the average solar cost in 2050 is higher than Lazard's estimate of the cost today.⁴⁰

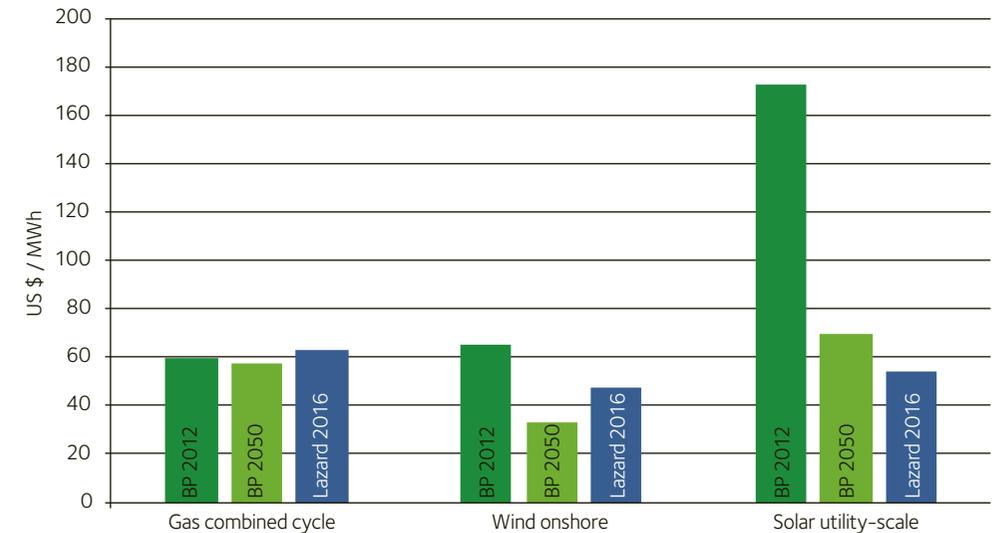
ExxonMobil is similar: it estimates that removing a ton of carbon costs on average nearly five times as much for wind as for gas (compared to coal).⁴¹ Lazard estimates that gas and wind both generate savings compared to coal, and both at the same level.⁴²



It is the same story with EVs. BP predicts that, as late as 2050, EVs will still be more expensive than petrol and diesel cars, including vehicle cost, fuel cost and carbon price.⁴³ ExxonMobil predicts that for small, short-range cars, "high cost differentials begin to narrow versus conventional cars" by around 2040.⁴⁴ In contrast, most commentators anticipate EVs achieving cost parity with petrol and diesel by the mid-2020s. UBS goes further: it predicts that, by the early 2020s, the purchase price of an EV will be only very slightly higher than a petroleum-fueled car, with only a small fraction of the fuel and maintenance costs.⁴⁵ This may imply that BP is using out-of-date information.

BP's 2050 Solar Cost Prediction Higher Than Current Levels⁴⁰

Levelised cost of electricity: BP vs Lazard



Source: BP; Lazard

QUESTIONS FOR COMPANIES

- How do the company's cost forecasts compare with those of other organisations?
- How do the company's forecasts of future costs compare with actual current costs?

Forecasts Give False Confidence, While Masking Underlying Trends

Energy models, from which the companies' forecasts are derived, are inherently analytical. They break the world into regions, and each region into energy demand sectors. For each, they project total energy demand, based on extrapolation of either general drivers or specific ones (eg Car fuel demand = Population x Car ownership rate x Average distance travelled x Average fuel efficiency). The models assume that energy supply will meet this demand, and extrapolate the existing mix to project each fuel's contribution.

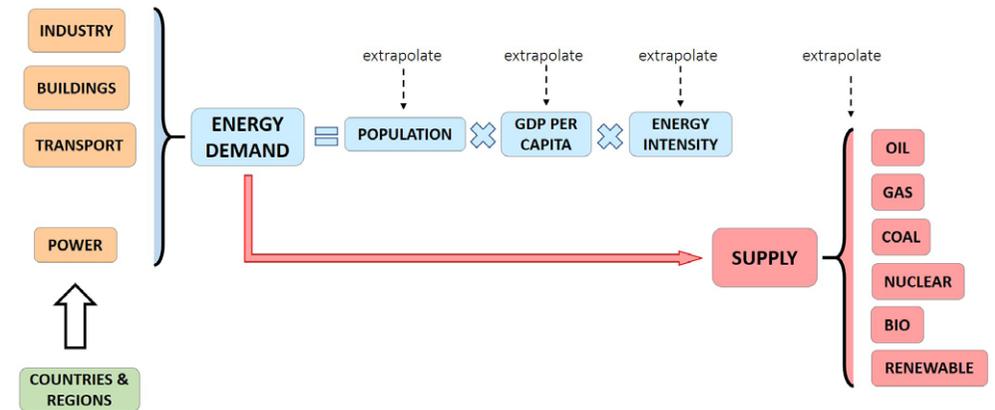
All of this requires an impressive amount of work, and on face value is a sophisticated approach: it gives an integrated view of a large system in which the elements are clearly interdependent. The quantitative approach is attractive to a company, because it allows investments to be modelled and measured. But herein lie forecasts' weaknesses too: they give a false feeling of predictive rigour. By relying on extrapolation, they must make (often subjective) assumptions about which trends will wither, persist or accelerate, while the inertia of the whole system – expressed in slow-changing aggregate numbers – may mask important underlying trends.

"Forecasts are not always wrong; more often than not, they can be reasonably accurate. And that is what makes them so dangerous... They often work because the world does not always change. But sooner or later forecasts will fail when they are needed most: in anticipating major shifts in the business environment that make whole strategies obsolete."
Pierre Wack, leader of Shell's first scenarios team, from 1971⁴⁷

The problem is seen in the graph. In 2004, ExxonMobil's prediction extrapolated trends in the energy mix (with a small boost for gas). In the event, the market shares of coal and oil shares changed significantly. This was a forecast over only 13 years, in a period where there was no major disruption.

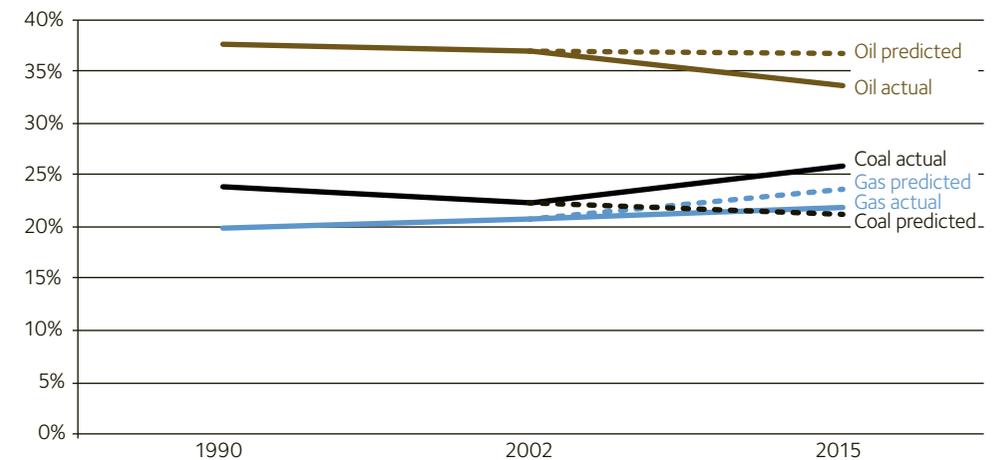
The masking of underlying trends can be fatal. Clayton M Christensen, the Harvard professor of business administration who coined the term "disruptive innovation", explains the mechanism of disruption in his classic book *The Innovator's Dilemma*. Companies ignore new technologies which at first offer lower margins and lower performance than the companies' own products. The new technologies are deployed in niche markets, where experience leads to improved performance and lower costs. Eventually, the new technologies reach the point where they can win in mainstream markets; at this point it is too late for the incumbents to catch up.⁴⁶

How the Oil Companies' Energy Models Work



ExxonMobil Predicted That Things Would Stay the Same, But They Didn't⁴⁸

Shares of world primary energy: ExxonMobil 2004 forecast vs actual



Source: ExxonMobil

Oil Companies Assume the Future Will be Like the Present

When it comes to the wider energy mix, oil companies see the future being very like the present. In spite of climate policy, and in spite of potentially rapid technological change, they believe fossil fuels' share of world energy will fall only slightly, from around 85% now to 75-80% in 2040, as shown in the graph.

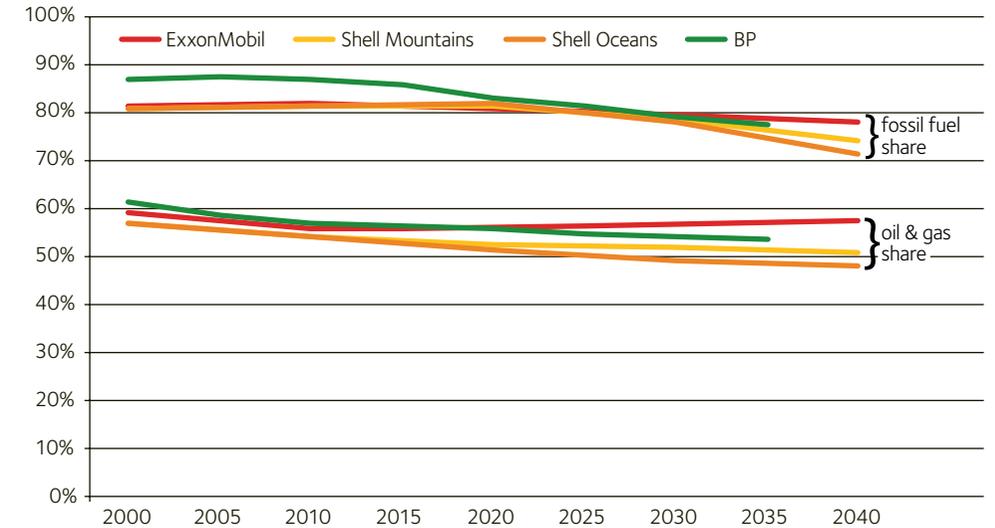
There are two factors that can make the future very unlike the present: technology and politics. Both are notoriously hard to predict – yet both will be fundamental to

the future shape of energy. In the previous section we saw that the one area where the companies appear not to extrapolate existing trends is in technologies that threaten their core business of oil and gas. When it comes to political change too, new trends – such as the Paris Agreement – may be at an early stage, but could be the start of a more profound transformation.

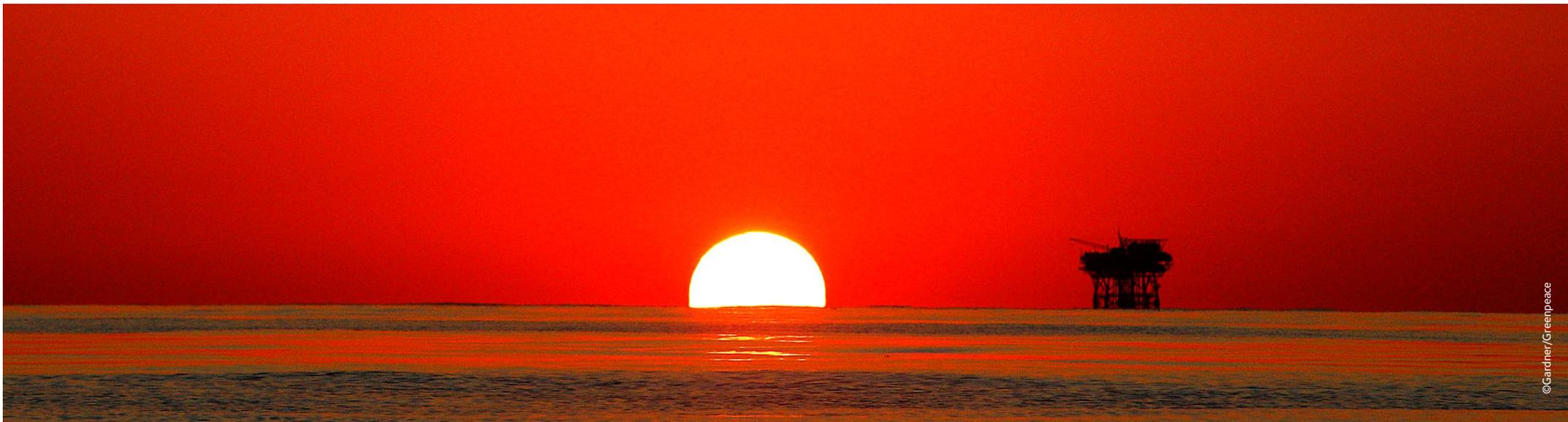
In these respects, assuming continuation of the status quo leaves the companies potentially vulnerable to disruption.

Oil Companies Believe Fossil Fuels Will Continue to Dominate the Future

Shares of world primary energy: oil company forecasts of fossil fuel share and oil & gas share⁴⁹



Source: ExxonMobil; Shell; BP



Oil Companies Ignore Political Drivers of Energy Change

Oil companies often argue that energy transitions are slow, pointing to the historical shifts from wood to coal, or coal to oil and gas.⁵⁰ However, this is not always true. Benjamin Sovacool of Aarhus University highlights transformations that took place within a decade or two.⁵¹ The common feature was a concerted effort by government to facilitate the transition: through subsidies, establishing pilot programs, retraining workers, providing investment, and regulation. For example:

- When the Netherlands government “strategically steered” a transition away from coal, natural gas’ share of energy supply grew from 2% in 1959 to 50% in 1971.
- In France, the government decided after the 1974 oil crisis to shift to nuclear, which grew from 4% of electricity supply in 1970 to 40% in 1982.
- After Ontario decided in 2003 to phase out coal power, coal’s share of generation fell from 25% in 2003 to 0% in 2014.

Government action will be an important factor in the transition to clean energy. Major cities from Paris to Mexico City plan to ban diesel cars and vans from their roads

from 2025.⁵² The Netherlands parliament is considering legislation to ban sales of internal combustion engine (ICE) cars from 2025,⁵³ with similar proposals being considered in several European countries.⁵⁴ Germany’s Bundesrat has passed a resolution calling on the EU to ban sales of ICE cars across Europe from 2030.⁵⁵ The Indian government aims to achieve 100% electric cars sales by 2030, through incentives and innovative financing.⁵⁶

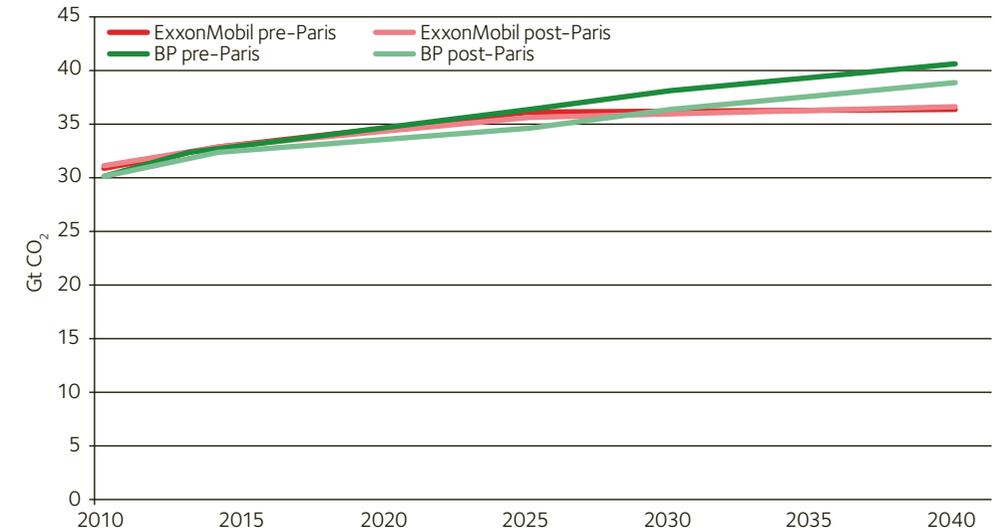
This appears to be a blind spot in oil company forecasts:

- BP’s Energy Outlook 2017 lists four factors that could influence electric car uptake: battery costs, subsidies, conventional engines’ competitive cost, and consumer preference. The obvious omission from that list is government action (other than subsidies).
- BP’s forecasts of emissions barely changed in response to the Paris Agreement, and ExxonMobil’s didn’t change at all, as the graph shows.

This undermines their credibility, as no plausible forecast would ignore regulation as a key driver of change.

BP and ExxonMobil Emissions Forecasts Unchanged Following Paris Agreement

CO₂ emissions from fossil fuel sources: ExxonMobil and BP forecasts before and after Paris Agreement



Source: ExxonMobil, BP

Company Forecasts are More Advocacy than Analysis

While generally presented as objective, expert analysis, the publication of forecasts was originally conceived as an advocacy exercise. ExxonMobil started publishing its forecast in 2004, as an initiative of the company's public affairs department, which identified as its target audience a group it labelled "informed influentials": investors, policymakers, economists and commentators.⁵⁷ Throughout the year, ExxonMobil presents its forecasts in universities, think tanks, private meetings and the media.

In 2008, Shell shifted its existing scenario exercises from exploring wider societal trends to focusing more closely on energy futures. BP began publishing energy forecasts in 2011.

We have seen that the companies have consistently under-forecast renewable energy growth, and are now highly sceptical of electric vehicles. The fact that ExxonMobil and BP have an interest in decision-makers believing these propositions means one should be cautious of treating their view as an objective picture of the future.

Much in the forecasts indeed has the tone of advocacy. For example, ExxonMobil's latest Outlook for Energy states that "societies should adopt policies targeting

CO₂ emissions that will minimize the related costs that are ultimately borne by consumers and taxpayers; the best policy options to achieve that goal will be market-based." The accompanying chart specifies which mitigation options the company believes are cheapest, starting with negative costs for improved gasoline vehicles and low costs for gas power, and then escalating costs for nuclear, hybrid vehicles, carbon capture and storage, wind, solar and electric cars (with electric cars costing more than three times as much as even the most expensive of the other options).⁵⁸ This order of preference reflects the most beneficial options for ExxonMobil's business.

Conversely, companies' advocacy positions appear to influence the forecasts. Launching BP's Energy Outlook 2017, chief economist Spencer Dale argued strongly against climate regulation.⁵⁹ This may be a reason BP's forecasts ignore regulation as a driver (see page 14).

In 2015, BP's chief executive said of climate change, "The challenge ahead is to make the case for the necessary role of fossil fuels."⁶⁰ How much is making that case – of the inevitability of fossil fuel dominance for decades ahead – part of the purpose of BP's Energy Outlook?



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QUESTIONS FOR COMPANIES

- Will the company disclose to which government departments and officials (in all countries) it has presented its energy forecasts?

Be Prepared for More Than One Future

Perhaps it is as hard for BP, Shell or ExxonMobil to imagine the demise of oil and gas as it was for transportation companies in the late 19th century to foresee reduced demand for horses. Still, decisions must be made – on investments or policies – that require some view on what the future might hold. So how should we think about the future of energy?

The first step is to recognise that the future is necessarily uncertain. For example, the EIA now routinely publishes its energy outlooks with a health warning: they are projections, based on a given set of assumptions, not predictions of what will actually happen.⁶¹

Second, decision-makers should consider more than one possible future. Rather than relying on a single forecast, they should use “scenarios” to explore different possible futures. This is the recommendation of the Task Force on Climate-Related Financial Disclosures, reporting to the Financial Stability Board in December 2016.⁶² It further recommends that scenarios should be plausible, distinctive, consistent, relevant and challenging.⁶³

Ironically, the organisation that has done most to teach the world how to prepare for

Scenario checklist

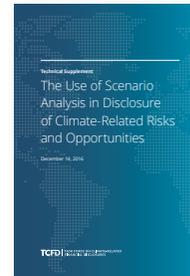
- ✓ Multiple, significantly-different scenarios
- ✓ Plausible and internally consistent, rather than “likely”: don’t assume the future will be like the present
- ✓ Identify key underlying drivers, reflecting:
 - greatest uncertainties (eg technology, political action), and
 - greatest impacts on the business
- ✓ If a scenario is not difficult for the company, it’s not a stress test
- ✓ Challenge psychological biases; beware of groupthink

an uncertain future is Shell. Shell’s Scenario Team at one time emphasised that scenarios need only be plausible, not necessarily what managers considered “most likely”.⁶⁴ Part of the reason was that managers were subject to psychological biases, which prevented them from seeing parts of the picture. New scenarios were developed in conversation with diverse people outside the industry to obtain a range of perspectives. Shell’s scenario practice was once the best in the world; however today the company has dropped most of it in favour of a more closed forecasting approach (see page 19).

Scenarios are not simply a multi-branch version of prediction (where the future is assumed to necessarily reflect one of the scenarios, or a combination of them). Rather they are intended to illustrate possible aspects of the future, to stretch the imagination of planners and expose unfounded assumptions.

Drawing on best practice, we propose that for effective use of scenario analysis companies should follow the guiding principles below.

Resources on Scenario Planning



Details in references⁶⁵

QUESTIONS FOR COMPANIES

- ☉ Will the company comply with all of the Task Force on Climate-Related Financial Disclosures’ recommendations regarding scenario analysis?
 - In particular, will the company disclose “the key assumptions and considerations underlying each scenario, and whether scenarios with major disruptions (positive and negative) from business-as-usual (breakthroughs, breakdowns) were considered”?
- ☉ How many scenarios does the company consider in its business planning, where governments achieve the Paris goals of keeping warming well below 2°C, and/or keeping it to 1.5°C? For example, does the company consider different scenarios for a disruptive technology-driven transition vs a policy/regulatory-driven transition?
- ☉ Which of these scenarios is most challenging for the business? For example, do they include scenarios where demand for the company’s core products falls?
- ☉ If the company relies on the IEA 450S (see page 17), what steps is the company taking either internally or with the IEA to explore the assumptions in that scenario?
- ☉ Are company portfolios robust to:
 - Zero net global emissions by 2050 (the median IPCC scenario for achieving 1.5°C)?
 - Zero net emissions by 2070 (the median for likely staying below 2°C)?
 - No new petrol or diesel car sales from 2025 or 2030 (assuming the current trend spreads to all major countries)?
 - No new gas power stations built after 2020, with all new power investments going into zero-carbon sources?

The IEA 450 Scenario

Since the oil companies' forecasts do not provide it, what can companies, investors and policy makers use as a guide for determining the likely level of energy demand and the energy mix in a climate-constrained world?

The most commonly cited climate scenario is the IEA's 450 Scenario (450S).⁶⁶ However, this scenario gives only a 50% probability of keeping temperatures below 2°C.⁶⁷ As such it does not match current scientific or political reality, as contained in the Paris Agreement goals of staying *well below* 2°C and striving for 1.5°C. First published in 2009, the 450S reflects the then aim of limiting warming to 2°C.⁶⁸ Since then, new findings on climate change impacts have indicated that 2°C can no longer be considered an adequate target, but rather the absolute maximum that can be tolerated.⁶⁹ The IEA is currently working on two new scenarios: one that would give a higher probability of staying below 2°C, and one that would aim for 1.5°C.

Like any projection, the 450S tells us only about one possible future in which its assumptions turn out to be correct. It is not *the* 2°C future. Three important assumptions in the 450S may lead to understating the decline of oil and gas production:

- ☹ It makes generous assumptions about technological success in CCS.⁷⁰ This may be a dangerous assumption: progress to date on the technology has been described by the Financial Times as “woeful”, and today several governments and companies are pulling back from CCS projects.⁷¹
- ☹ It assumes an overshoot of the climate target,⁷² where negative emissions are expected to later bring down atmospheric concentrations – another unproven technology. The IEA also does not disclose the rate at which emissions are expected to fall after the outlook period to 2040: it may be that deeper cuts are assumed, which understate the required cuts during the period being examined.
- ☹ It assumes the majority of emissions reduction will occur in developing countries⁷³ – an unlikely outcome, given both climate politics and basic fairness. Since poorer countries rely disproportionately on coal for their energy, compared to oil and gas,⁷⁴ a consequence of this assumption is that it may understate the degree of reductions in oil and gas.

Combined with the low probability of success, the result is that the 450S projects oil production would have to fall by just 17% between 2013 and 2040 (and coal by only 38%); while gas production could actually increase by 16%.⁷⁵ For comparison, according to an analysis of the IPCC Scenarios Database published in the journal *Nature Climate Change* (graph, page 7), to achieve a likely (66%) chance of staying below 2°C requires total emissions to be halved by the late 2030s; for a 50% chance of 1.5°C, they would have to be halved by the early 2030s.⁷⁶

It remains to be seen whether the new scenarios the IEA is working on will share these assumptions. Investors should scrutinise the assumptions of any new climate scenario.

In light of the recommendations of the Task Force on Climate-Related Financial Disclosures⁷⁷, more companies are likely to turn to the IEA's outputs for scenario planning purposes. To ensure robust corporate scenario planning, the IEA must produce a forecast aligned with the goals of the Paris Agreement, and which provides insight into multiple pathways to achieving those goals. We recommend that investors consider engaging with the IEA to request:

- ☹ Replacing the 450S with a full scenario in line with the Paris goals: a high probability of staying below 2°C, and aiming for 1.5°C.
- ☹ Greater transparency about assumptions – especially on CCS, negative emissions, post-2040 emissions and international effort-sharing – and about how the picture would change with different assumptions.

Company	Number of scenarios considered	Published analysis of energy futures?	Number of 2°C (50% probability) scenarios	Strengths of Approach	Weaknesses of Approach
	1	Annually	0	<ul style="list-style-type: none"> None 	<ul style="list-style-type: none"> Considers single possible future Emissions peak in the 2030s is solely due to reduction in coal Assumes demand for oil and gas will inevitably grow Assumes renewables growth slows down; renewables/EVs have limited technological progress Strongly driven by advocacy
	2	Every few years, plus supplements	(1 partial)	<ul style="list-style-type: none"> 2 distinct scenarios; transparent about assumptions Considers a climate scenario in a supplement, albeit without specifics Explicitly recognises falling costs of renewables and the potential of electric vehicles⁷⁸ Scenario publications foresee a peak in oil demand in the 2030s or 2040s⁷⁹ 	<ul style="list-style-type: none"> Neither scenario anticipates disruption to fossil fuels' dominance Assumes climate action focused on shift from coal to gas – ie inherently beneficial to Shell Believes renewables and EVs will still grow relatively slowly; disproportionate optimism on CCS
	2 (partially)	Ad hoc	(1 partial)	<ul style="list-style-type: none"> None 	<ul style="list-style-type: none"> Assumes demand for oil and gas will inevitably grow, even if there is action on emissions Stress test is limited to 450S price forecasts
	1 (+ 5 variations)	Annually	(1 partial)	<ul style="list-style-type: none"> In 2016 began introducing brief overviews of alternative scenarios: in 2017 this included "Even Faster Transition" scenario, with emissions aligned with the IEA 450 Scenario (450S) More transparent than others about revisions each year, and about comparison with other organisations' outlooks Recognises that some high-cost resources may not get extracted,⁸¹ but asserts this will affect governments rather than oil companies⁸² 	<ul style="list-style-type: none"> Assumes renewable energy slows down; EVs remain marginal Believes both oil consumption and emissions will rise until at least 2035 Strongly driven by advocacy; dismisses possibility of regulation
	1	Ad hoc	1	<ul style="list-style-type: none"> Uses IEA 450S as central (not just alternative) scenario Recognises need to adjust energy production, not just process emissions Recognises some reserves cannot be extracted and high-cost projects may be vulnerable 	<ul style="list-style-type: none"> Does not consider weaknesses of 450S eg need for greater confidence of staying below 2°C Ignores climate limitations of natural gas; too little analysis of more restricted oil pathways High confidence in CCS breakthrough
	3	Annually	1	<ul style="list-style-type: none"> 3 scenarios, considered equally likely. Scenario drivers reflect fundamental challenges to the energy industry, notably climate policy: 1 scenario reflects Nationally Determined Contributions and 1 reflects 50% chance of 2°C Recognises potential of EVs to reduce oil demand, with potential peak in 2025; also price sensitivity to Middle East producers' depletion strategies Open-minded discussion, rather than emphasis on favoured messages; consideration of multiple potentially disruptive factors Healthier degree of scepticism about CCS, based on performance to date 	<ul style="list-style-type: none"> Does not consider need for greater than 50-50 confidence of staying below 2°C Weak reflection of energy scenarios in investment strategy: limited to testing portfolio against prices in IEA 450S and very slow expansion of investment in renewables (15-20% of capex by 2030)⁸⁴
	7	No	3	<ul style="list-style-type: none"> Recognises there is more than one way of reaching 2°C, 3 climate scenarios: based on regulation, on technological advance and a combination. 	<ul style="list-style-type: none"> Does not publish its forecasts – so cannot evaluate specifics

The Demise of Shell Scenarios

In the early 1970s, Shell pioneered a scenario approach. Today most best-practice forecasting has its origins in the techniques that Shell developed.

The company's first scenarios considered what was then unthinkable: that governments of major Middle Eastern oil-producing countries would force up the price companies paid for their oil. As a result, Shell was better able than its peers to anticipate the 1970s oil price spikes and nationalisations. Subsequent scenarios helped prepare Shell for the 1980s price crash, the Soviet breakup and the rise of environmentalism.⁸⁶

Shell still has a Scenarios Team, but today its approach is closer to that of the other companies: a highly quantitative analysis of the kind that the team's founder Pierre Wack criticised so strongly (page 12). A key change occurred around ten years ago, when Shell developed a world energy model.⁸⁷ Whereas many of the earlier scenarios presented possibilities that were challenging to oil companies, Shell's last two rounds of scenarios, in 2008 and 2013, have presented different versions of the future in which oil companies remain dominant. While society and politics are quite different between the scenarios, the broad shape of the energy system is not significantly different – perhaps because of the aggregating effect of the model.

The extent of the change in Shell's practice is illustrated by its 2015 publication of a 2°C scenario.⁸⁸ In it, Shell argued that in the unlikely event that warming was limited to 2°C, it would be by luck more than deliberate action (a "goldilocks scenario", where economic growth was neither too fast nor too slow). Emissions would be reduced by greater use of gas and CCS, in both of which the company has a leading position. So, Shell concluded, the company could only thrive in a climate scenario. In reality, as we have seen in this report, there are many ways energy change could happen, as some of Shell's peers now recognise.

Like other oil and gas companies, Shell highlights its investments in gas as a climate solution. Yet there are increasing indications that new investment in gas is not consistent with achieving the Paris goals: remaining atmospheric space is so depleted that the switch now must be to renewable energy.⁸⁹

The 2016 Shell climate scenario contains the final lesson for companies considering the future: if you are stress-testing your business, test it against situations that are actually stressful. If you look only at scenarios that are good for the company, you do not reveal any risks.

- 1 See, for example: IIGCC et al, Investor Expectations of Oil and Gas Companies: Transition to a lower carbon future, November 2016, <http://www.iigcc.org/publications/publication/updated-guide-of-investor-expectations-of-oil-and-gas-companies-2016> CERES et al, Carbon Asset Risk: From Rhetoric To Action, September 2015, <https://www.ceres.org/resources/reports/carbon-asset-risk-from-rhetoric-to-action/view>
- 2 The companies do commonly factor a shadow carbon price into their investment decisions, but not at a high enough level to impact oil and gas demand, nor to limit warming to 2°C (see page 7).
- 3 Capital expenditure 2017–2021: respectively US \$84 bn, \$95 bn and \$69 bn (2017 dollars). Rystad Energy UCube database
- 4 Paul Barrett & Benjamin Elgin, "Inside Shell's Extreme Plan to Drill for Oil in the Arctic", Bloomberg Businessweek, 5 August 2015, <https://www.bloomberg.com/news/features/2015-08-05/inside-shell-s-extreme-plan-to-drill-for-oil-in-the-arctic>
- 5 Karolin Schaps, "Royal Dutch Shell pulls plug on Arctic exploration", Reuters, 28 September 2015, <http://uk.reuters.com/article/shell-alaska-idUKL3N11Y1720150928>
- 6 BP and ExxonMobil forecast that oil consumption will consistently rise throughout the forecast period (to 2035 for BP, to 2040 for ExxonMobil). Shell publications anticipate an oil demand peak in either the 2030s or 2040s, though its chief financial officer Simon Henry recently said it could occur in the 2020s. All three companies say they do not believe warming will be kept below 2°C (see page 7). Rakteem Katakay, "Energy Giant Shell Says Oil Demand Could Peak in Just Five Years", Bloomberg, 2 November 2016, <https://www.bloomberg.com/news/articles/2016-11-02/europe-s-biggest-oil-company-thinks-demand-may-peak-in-5-years>
- 7 ExxonMobil, "Energy and Carbon -- Managing the Risks", April 2014, p.12, <http://cdn.exxonmobil.com/-/media/global/files/energy-and-environment/report---energy-and-carbon---managing-the-risks.pdf>; BP, Sustainability Report 2014, p.16, http://www.bp.com/content/dam/bp/pdf/sustainability/group-reports/Sustainability_Report_2014.pdf On the other hand, Shell recognises that reserves' life tells only part of the story, and asserts that commodity prices are unlikely to be affected by climate policy within the lifetime of projects. Shell, letter to investors re carbon asset risk, 16 May 2014, p.16, <https://s02.static-shell.com/content/dam/shell-new/local/corporate/corporate/downloads/pdf/investor/presentations/2014/sri-web-response-climate-change-may14.pdf>
- 8 For example, Shell made a decision in late 2013 to proceed with its Carmon Creek in situ tar sands project in Canada. According to Oil Change International cashflow analysis, assuming the US EIA's 2013 price forecast, it would have been expected to break even (discounted at 10% – ie expected to achieve 10% internal rate of return) in 2030. However, the fall in oil price expectations pushed this back significantly: assuming EIA's 2015 price forecast, the breakeven year became 2060. When combined with a market access constraint due to export pipelines not being built, the project would never break even. In October 2015, Shell cancelled the half-built project, taking a \$2bn impairment. Sources: Rystad Energy, Oil Change International Analysis. Shell press release, "Shell to halt Carmon Creek in situ project", 27 October 2015, <http://www.shell.com/media/news-and-media-releases/2015/shell-to-halt-carmon-creek-in-situ-project.html>; Oil Change International & Greenpeace, Flawed Fundamentals: Shell's and BP's Stalled Tar Sands Ambitions, p.32 (p.34 of pdf), <http://www.greenpeace.org/uk/document/flawed-fundamentals> See also Carbon Tracker Initiative, "Responding to Shell – An Analytical Perspective", 9 July 2014, <http://www.carbontracker.org/report/responding-to-shell-an-analytical-perspective/> and "Responding to Exxon – A Strategic Perspective", September 2014, <https://www.carbontracker.org/wp-content/uploads/2014/09/Exxonresponse-Full-110914.pdf>
- 9 Tom Randall, "Here's How Electric Cars Will Cause the Next Oil Crisis", Bloomberg, 25 February 2016, <https://www.bloomberg.com/features/2016-ev-oil-crisis/>
- 10 Greg Muttitt, The Sky's Limit: Why the Paris Climate Goals Require A Managed Decline of Fossil Fuel Production, Oil Change International, 22 September 2016, <http://priceofoil.org/2016/09/22/the-sky-limit-report/>
- 11 See note 71
- 12 The Economist Intelligence Unit, The Cost of Inaction: Recognising the Value at Risk from Climate Change, p.2, https://www.eiuperspectives.economist.com/sites/default/files/The%20cost%20of%20inaction_0.pdf
- 13 Peter Erickson, Michael Lazarus and Kevin Tempest, "Carbon lock-in from fossil fuel supply infrastructure", Stockholm Environment Institute discussion brief, 2015, <https://www.sei-international.org/mediamanager/documents/Publications/Climate/SEI-DB-2015-Carbon-lock-in-supply-side.pdf>; Greg Muttitt, op. cit., pp.33–35
- 14 ExxonMobil, "Energy and Carbon – Managing the Risks", April 2014, p.11, <http://cdn.exxonmobil.com/-/media/global/files/energy-and-environment/report---energy-and-carbon---managing-the-risks.pdf>
- 15 Shell, letter to investors re carbon asset risk, 16 May 2014, p.6, <https://s02.static-shell.com/content/dam/shell-new/local/corporate/corporate/downloads/pdf/investor/presentations/2014/sri-web-response-climate-change-may14.pdf>
- 16 see page 17
- 17 BP, Energy Outlook 2016, p.51 (p.53 of pdf)
- 18 IPCC Scenarios Database, <https://tntcat.iiasa.ac.at/AR5DB/>; Joeri Rogelj et al, "Energy system transformations for limiting end-of-century warming to below 1.5°C", Nature Climate Change, Vol.5, June 2015, Fig.1a, p.520 & pers. comm.; ExxonMobil, Outlook for Energy 2017; Shell, New Lens Scenarios, 2013; BP, Energy Outlook 2017. Given uncertainties in the climate system, atmospheric concentrations of GHGs (and hence emissions pathways) are probabilistically correlated with temperature targets. For given temperature targets, the IPCC considers scenarios that would give 33%, 50% or 66% probabilities of not exceeding that target. Since 2°C is considered an absolute limit beyond which severe dangers occur, this chart uses the budget for delivering a 66% chance ("likely" in IPCC parlance) of avoiding those dangers. However, we use a 50% chance of reaching 1.5°C because it has been set as an aspirational goal in the Paris Agreement, rather than an absolute maximum.
- 19 ExxonMobil The Outlook for Energy: A View to 2030, presentation, 12 September 2005, slide 13. Actuals interpolated linearly from Outlook for Energy 2014, p. 52 ("other renewables" minus biofuels).
- 20 ExxonMobil The Outlook for Energy: A View to 2030, December 2010, p.53. Actuals from Outlook for Energy 2017 Excel data tables. Both interpolated linearly. "Other renewables" minus biofuels.
- 21 Shell, New Lens Scenarios, 2013, p.66 (p.35 of pdf)
- 22 See for example Paul Stevens, International Oil Companies: The Death of the Old Business Model, Chatham House, May 2016, <https://www.chathamhouse.org/sites/files/chathamhouse/publications/research/2016-05-05-international-oil-companies-stevens.pdf>
- 23 BP, Energy Outlooks 2011–2017; Statistical Review of World Energy 2016
- 24 ExxonMobil Outlooks for Energy 2013–2016; BP Energy Outlooks 2013–2017; Shell New Lens Scenarios, 2013; Shell A Better Life with a Healthy Planet, 2016
- 25 We haven't counted one obscure reference to fracking by BP: "Varying assessments of above ground issues are another driver of divergent forecasts" – BP, Energy Outlook 2013, p.73
- 26 For a graph showing S-curves for various technologies, see BlackRock Investment Institute, Interpreting Innovation: Impact on Productivity, Inflation & Investing, September 2014, <https://www.blackrock.com/corporate/en-us/literature/whitepaper/bii-interpreting-innovation-us-version.pdf>; For an introduction to the concept of S-curves, see Gal's Insights, "The Innovation S-Curve", 25 July 2015, <http://www.galsinsights.com/the-innovation-s-curve>
- 27 According to BP, renewable energy consumption is currently 364 mtoe per year; oil is around 4,500. Linear growth rate of renewables is about 50 mtoe per year; CAGR is around 15%. BP, Statistical Review of World Energy 2016.
- 28 BP, Energy Outlook 2017; Statistical Review of World Energy 2016; Bloomberg New Energy Finance, New Energy Outlook 2016, Fig.65, p.44
- 29 EVvolumes.com, "Global Plug-in Sales for 2016", <http://www.ev-volumes.com/country/total-world-plug-in-vehicle-volumes/>
- 30 The average age of a UK car at scrappage is 13.9 years. Society of Motor Manufacturers & Traders web page, "Average Vehicle Age", <https://www.smmt.co.uk/industry-topics/sustainable/vehicle-end-of-life/average-vehicle-age/> Average lifespan of US cars is 13–17 years. Berla web page, "Average Lifespan for U.S. Vehicles", <https://berla.com/average-us-vehicle-lifespan/> Average age of US cars currently on the road is 11.4 years. IHSMarket News Release, "Average Age of Vehicles on the Road Remains Steady at 11.4 years", 9 June 2014, <http://news.ihsmarket.com/press-release/automotive/average-age-vehicles-road-remains-steady-11-4-years-according-ihs-automotive>
- 31 BP, Energy Outlook 2017, p.47 (p.48 of pdf)
- 32 ExxonMobil, Outlook for Energy 2017, p.18
- 33 Carbon Tracker Initiative & Grantham Institute, Expect the Unexpected: The Disruptive Power of Low-carbon Technology, February 2017, p.22, http://www.carbontracker.org/wp-content/uploads/2017/02/Expect-the-Unexpected_CTI_Imperial.pdf
- 34 Tom Bergin, "Factbox: Why the shift to electric cars may surprise oil groups", Reuters, 6 December 2016, <http://uk.reuters.com/article/us-oil-autos-projections-factbox-idUKKBN13V18D>
- 35 GM press release, "GM Employees on Mission to Transform Transportation", 7 May 2015, http://media.gm.com/media/us/en/gm/company_info/facilities/assembly/orion_detail.html/content/Pages/news/us/en/2015/may/0507-sustainability-report.html
- 36 Dave Guilford, "The next wave of electric vehicles", Automotive News, 3 October 2016, <http://www.autonews.com/article/20161003/OEM05/310039967/the-next-wave-of-electric-vehicles>; BBC News, "VW plans huge investment to become electric cars leader", 16 June 2016, <http://www.bbc.co.uk/news/business-36548893>
- 37 Rod Lache et al, Global Auto Outlook, 15 December 2014, Deutsche Bank Markets Research, p.4
- 38 Brian Parkin, "Batteries May Trip 'Death Spiral' in \$3.4 Trillion Credit Market", Bloomberg, 18 October 2016, <https://www.bloomberg.com/news/articles/2016-10-18/batteries-may-trip-death-spiral-in-3-4-trillion-credit-market>
- 39 McKinsey&Company and Bloomberg New Energy Finance, An Integrated Perspective on the Future of Mobility, October 2016, p.38, https://data.bloomberglp.com/bnef/sites/14/2016/10/BNEF_McKinsey_The-Future-of-Mobility_11-10-16.pdf
- 40 BP, Technology Outlook 2016, p.18 (p.19 of pdf). Lazard, Levelized Cost of Energy Analysis – Version 10.0, December 2016, p.6 (p.7 of pdf)
- 41 ExxonMobil estimates abatement costs at about US \$10–35 per tonne of CO₂ equivalent for gas, and \$55–160/t for wind. ExxonMobil, Outlook for Energy 2017, p.31.
- 42 Lazard estimates both gas and wind deliver savings of \$31/t. Lazard, Levelized Cost of Energy Analysis – Version 10.0, December 2016, p.6 (p.7 of pdf)
- 43 BP, Technology Outlook 2016, p.22 (p.23 of pdf)
- 44 ExxonMobil, Outlook for Energy 2017, p.17
- 45 Patrick Hummel et al, Will solar, batteries and electric cars re-shape the electricity system? UBS Global Research, 20 August 2014, p.4
- 46 Clayton M. Christensen, The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail, Harvard Business School Press, 1997, pp.11–12, 28–34
- 47 Pierre Wack, "Scenarios: Uncharted Waters Ahead", Harvard Business Review, September 1985, <https://hbr.org/1985/09/scenarios-uncharted-waters-ahead>
- 48 ExxonMobil A Report on Energy Trends, Greenhouse Gas Emissions and Alternative Energy, February 2004, p.4 (p.6 of pdf); Outlook for Energy 2017 data tables. For simplicity, the only data points shown in the graph are 1990, 2002 and 2015
- 49 ExxonMobil, Outlook for Energy 2017; Shell, New Lens Scenarios, 2013; BP, Energy Outlook 2017. Note that historical figures differ because of definitional differences, primarily whether traditional biomass is counted in the total
- 50 For example: ExxonMobil, Outlook for Energy 2013, p.48 (p.50 of pdf); Shell: Energy Transitions and Portfolio Resilience, p.2 (p.6 of pdf), <https://s02.static-shell.com/content/dam/shell-new/local/corporate/corporate/downloads/pdf/investor/presentations/2014/sri-web-response-climate-change-may14.pdf>; BP Energy Outlook 2017, p.21 (p.22 of pdf)
- 51 Benjamin Sovacool, "How long will it take? Conceptualizing the temporal dynamics of energy transitions," Energy Research & Social Science 13 (2016), pp.202–215
- 52 Fiona Harvey, "Four of world's biggest cities to ban diesel cars from their centres", Guardian, 2 December 2016, <https://www.theguardian.com/environment/2016/dec/02/four-of-worlds-biggest-cities-to-ban-diesel-cars-from-their-centres>
- 53 Jess Staufenberg, "Netherlands on brink of banning sale of petrol-fuelled cars", Independent, 18 August 2016, <http://www.independent.co.uk/environment/climate-change/netherlands-petrol-car-ban-law-bill-to-be-passed-reduce-climate-change-emissions-a7197136.html>
- 54 Pedestrian Observations, "Several European Countries to Follow Norway's Lead, Ban Fuel-Powered Cars", 1 April 2016, <https://pedestrianobservations.wordpress.com/2016/04/01/several-european-countries-to-follow-norways-lead-ban-fuel-powered-cars/>
- 55 Bertel Schmitt, "Germany's Bundesrat Resolves End Of Internal Combustion Engine", Forbes, 8 October 2016, <http://www.forbes.com/sites/bertelschmitt/2016/10/08/germanys-bundesrat-resolves-end-of-internal-combustion-engine/#3bb0523d31d9>
- 56 Economic Times, "India aims to become 100% e-vehicle nation by 2030: Piyush Goyal", 26 March 2016, <http://economictimes.indiatimes.com/industry/auto/news/industry/india-aims-to-become-100-e-vehicle-nation-by-2030-piyush-goyal/articleshow/51551706.cms>
- 57 Steve Coll, Private Empire – ExxonMobil and American Power, Penguin, 2012, pp.302–5, 309–10
- 58 ExxonMobil, Outlook for Energy 2017, p.31
- 59 "A carbon price incentives [sic] provides incentives for businesses, markets and consumers to seek out the most efficient path as technologies and behaviors evolve. In contrast, a regulation-based approach essentially requires governments and policymakers to try to guess in advance the best path and then mandate that path by rules and regulations. I used to be a policymaker. I know which one I think is likely to be the most efficient. It's hard for any government to pick winners and losers." Spencer Dale, speaking at launch of BP Energy Outlook 2017, 25 January 2017
- 60 Bob Dudley, speaking at BP annual general meeting, 16 April 2015, <http://www.bp.com/en/global/corporate/press/speeches/2015-annual-general-meeting-group-chief-executive.html>
- 61 EIA web site, "EIA's Annual Energy Outlook is a projection, not a prediction", <http://www.eia.gov/todayinenergy/detail.php?id=26272> Shell's forecasts contain a similar disclaimer in the small print – "Scenarios, therefore, are not intended to be predictions of likely future events or outcomes, and investors should not rely on them when making an investment decision. The oil company forecasts contain legal disclaimers" – but does not draw attention to it through a web page, unlike the EIA. ExxonMobil and BP publications contain a standard legal disclaimer about forward-looking statements. In BP's launch of its outlook, chief economist Spencer Dale commented that all forecasts are inherently uncertain, but this does not show in the general presentation of the outlook's predictions, in particular the focus on a "most likely" case.
- 62 Task Force on Climate-related Financial Disclosures, Recommendations, 14 December 2016, pp.27–32 (pp.34–39 of pdf), https://www.fsb-tcfd.org/wp-content/uploads/2016/12/16_1221_TCDF_Report_Letter.pdf

- 63 Task Force on Climate-related Financial Disclosures, Technical Supplement on the Use of Scenario Analysis in Disclosure of Climate-Related Risks and Opportunities, 14 December 2016, p.3 (p.5 of pdf), <https://www.fsb-tcfd.org/wp-content/uploads/2016/11/TCFD-Technical-Supplement-A4-14-Dec-2016.pdf>
- 64 Angela Wilkinson & Roland Kupers, The Essence of Scenarios: Learning from the Shell Experience, Amsterdam University Press, 2014, pp.80-84
- 65 Task Force on Climate-related Financial Disclosures, Technical Supplement on the Use of Scenario Analysis in Disclosure of Climate-Related Risks and Opportunities, op. cit, p.3 (p.5 of pdf) Amy Myers Jaffe, A Framework for 2 Degrees Scenario Analysis: A Guide for Oil and Gas Companies and Investors for Navigating the Energy Transition, CERES, December 2016, <https://www.ceres.org/resources/reports/a-framework-for-2-degree-scenario-analysis/view> Peter Schwartz, The Art of the Long View: Planning for the Future in an Uncertain World, Wiley, 1996
- 66 Its name refers to greenhouse gas concentrations ultimately settling at 450 parts per million.
- 67 The IEA's annual World Energy Outlook contains three scenarios, intended to illustrate three levels of climate action: no further action (Current Policies Scenario), emissions pledges met (New Policies Scenario) and long-term goal met (450 Scenario). The problem is that the 450 Scenario uses the wrong long-term goal.
- 68 The 2°C goal was proposed by the UNFCCC in Copenhagen in 2009 and formally adopted the following year at Cancún.
- 69 eg "The 'guardrail' concept, in which up to 2°C of warming is considered safe, is inadequate and would therefore be better seen as an upper limit, a defense line that needs to be stringently defended, while less warming would be preferable" - UNFCCC Subsidiary Body for Scientific and Technological Advice, Forty-second session, Bonn, 1-11 June 2015, Report on the structured expert dialogue on the 2013-2015 review, p.18, <http://unfccc.int/resource/docs/2015/sb/eng/inf01.pdf> For analysis of the difference in impacts between 1.5°C and 2°C, see Carl-Friedrich Schlessner et al, "Differential climate impacts for policy-relevant limits to global warming: the case of 1.5°C and 2°C," Earth System Dynamics #7, 2016, pp.327-351, <http://www.earth-syst-dynam.net/7/327/2016/esd-7-327-2016.pdf>
- 70 The CCS assumption was reduced in the 2016 World Energy Outlook, but still assumes about 3 Gt of CO2 per year are captured by 2040. IEA, World Energy Outlook 2016, Fig.8.6, p.327
- 71 For example, in 2015 the United Kingdom cancelled its competition for commercial-scale CCS projects and the United States terminated funding for the FutureGen CCS retrofitting demonstration project. Earlier in 2015, four leading European utilities pulled out of the European Union's Zero Emission Platform. For a discussion, see Greg Muttitt, op. cit, p.48
- 72 IEA, World Energy Model Documentation, 2016 Version, p.5, http://www.worldenergyoutlook.org/media/weowebsite/2016/WEM_Documentation_WEO2016.pdf
- 73 IEA, World Energy Outlook 2014, Fig.2.21, p.91
- 74 Coal accounts for 19% of primary energy in industrialized countries in OECD countries, but 37% of primary energy in non-OECD countries. IEA, World Energy Outlook 2015 data tables
- 75 IEA, World Energy Outlook 2015, p.583
- 76 Joeri Rogelj et al, "Energy system transformations for limiting end-of-century warming to below 1.5°C," Nature Climate Change, Vol.5, June 2015, p.520; and pers. comm.
- 77 Task Force on Climate-related Financial Disclosures, Technical Supplement on the Use of Scenario Analysis in Disclosure of Climate-Related Risks and Opportunities, December 14, 2016, pp.10, 13-15
- 78 For example, Shell's Mountains scenario forecasts EVs providing 20% of passenger miles by 2040, and 60% by 2060.
- 79 Chief Financial Officer Simon Henry recently suggested the peak could come in the next 5-15 years. Rakteem Katakey, "Energy Giant Shell Says Oil Demand Could Peak in Just Five Years", Bloomberg, 2 November 2016, <https://www.bloomberg.com/news/articles/2016-11-02/europe-s-biggest-oil-company-thinks-demand-may-peak-in-5-years>
- 80 Chevron, Managing Climate Change Risks - A Perspective for Investors, March 2017, <https://www.chevron.com/-/media/chevron/shared/documents/climate-risk-perspective.pdf>
- 81 Andrew Ward, "BP warns of price pressures from long-term oil glut", 25 January 2017, https://www.ft.com/content/28607ed2-e305-11e6-8405-9e5580d6e5fb7ftcamp-published_links%2Frss%2Fcompanies_energy%2Ffeed%2F%2Fproduct
- 82 "I think sort of the biggest challenges that poses are for the owners of that [sic] resources. So for the countries who own those low cost -- own the higher cost resource. A company like BP, our capital is mobile. If the production levels shift from one part of the world to another part of the world, we can reallocate our capital to where that production growth is moving to. So I perceive that as sort of really as largely an opportunity because we've got the mobility of our capital to shift around. And the real challenge in terms of that production is to the owners of the resource rather than to us." Spencer Dale, speaking at launch of BP Energy Outlook 2017, 25 January 2017
- 83 Total, Integrating Climate into our Strategy, May 2016
- 84 Statoil, Statoil's Climate Roadmap - Creating a Low Carbon Advantage, March 2017, <https://www.statoil.com/content/dam/statoil/image/how-and-why/climate/A5-climate-roadmap.pdf>
- 85 ConocoPhillips website, "Carbon Scenarios", <http://www.conocophillips.com/sustainable-development/environment/climate-change/climate-change-strategy/Pages/carbon-scenarios.aspx>
- 86 Shell, 40 Years of Scenarios, November 2012, <http://s03.static-shell.com/content/dam/shell/static/future-energy/downloads/shell-scenarios/shell-scenarios-40yearsbook061112.pdf> Peter Schwartz, The Art of the Long View: Planning for the Future in an Uncertain World, Wiley, 1996, especially pp.7-9, 44-45, 54-55.
- 87 Angela Wilkinson & Roland Kupers, The Essence of Scenarios: Learning from the Shell Experience, Amsterdam University Press, 2014, p.68.
- 88 Shell, A Better Life With a Healthy Planet, June 2016, http://www.shell.com/energy-and-innovation/the-energy-future/scenarios/a-better-life-with-a-healthy-planet/_jcr_content/par/textimage.stream/1475857466913/a1aa5660d50ab-79942f7e4a629fcb37ab93d021afb308b92c1b77696ce6b2ba6/scenarios-nze-brochure-interactive-afwv9-interactive.pdf
- 89 For example, researchers at Oxford University have found that the world's stock of power stations, if operated for their full economic lives, would exhaust the carbon budget for even a 50% chance of limiting warming to 2°C. New gas expansion is possible only if coal plants are shut down prematurely. Alexander Pfeiffer et al, "The '2°C capital stock' for electricity generation: Committed cumulative carbon emissions from the electricity generation sector and the transition to a green economy," Applied Energy, 2016, <http://dx.doi.org/10.1016/j.apenergy.2016.02.093> Studies in the United States suggest that recent and projected growth in natural gas is not leading to reductions in emissions, because it is competing with renewable energy more than with coal. Energy Modeling Forum, "Changing the Game? Emissions and Market Implications of New Natural Gas Supplies," EMF Report 26, September 2013, Vol. I. C. Shearer et al, "The effect of natural gas supply on US renewable energy and CO2 emissions," Environ. Res. Lett., 24 September 2014. Vol. 9 A study by Oil Change International found that the 2040 gas consumption projected by the Energy Information Administration would on its own - with zero coal, oil or cement - cause more emissions than the US target of 83% below 2005 levels by 2050. Lorne Stockman, A Bridge Too Far: How Appalachian Basin Gas Pipeline Expansion Will Undermine U.S. Climate Goals, Oil Change International, <http://priceofoil.org/2016/07/22/a-bridge-too-far-report/>

This report was researched and written by Greg Muttitt.

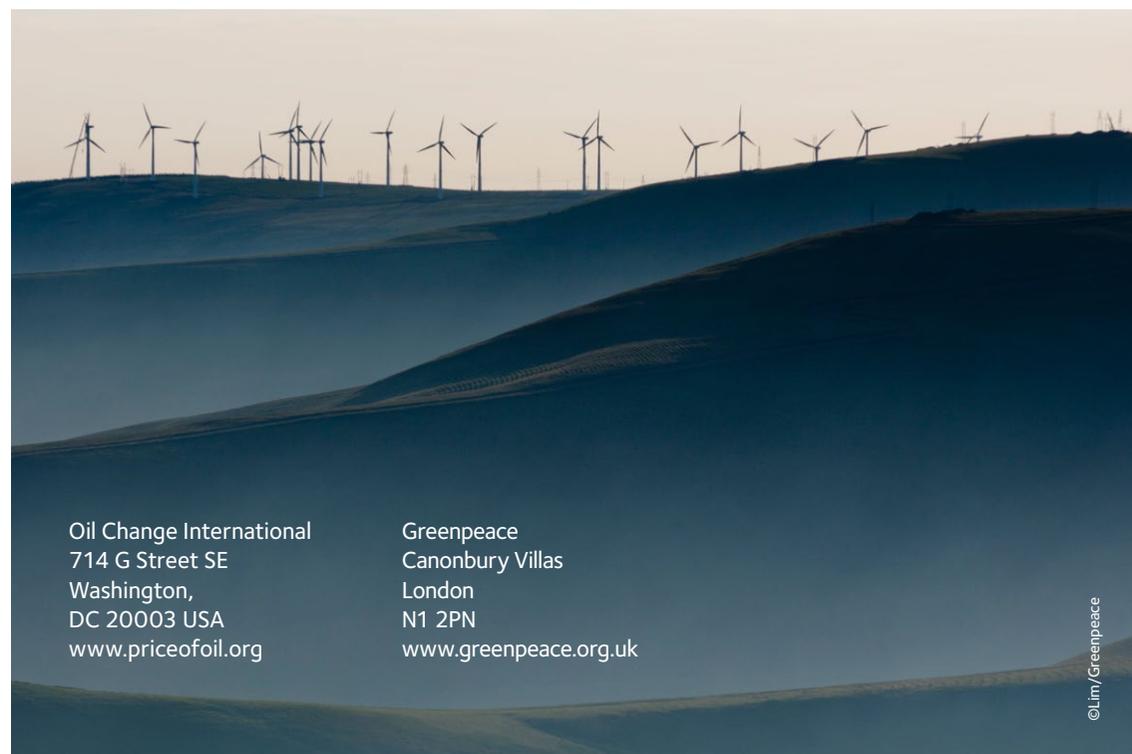
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