Carbon Tracker Initiative

Lost in Transition:

How the energy sector is missing potential demand destruction

October 2015

Acknowledgements

About Carbon Tracker

The Carbon Tracker Initiative is a team of financial specialists making climate risk real in today's financial markets. Our research to date on unburnable carbon and stranded assets has started a new debate on how to align the financial system with the energy transition to a low carbon future.

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Disclaimer

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Introduction

Demand destruction = climate security

The majority of the world's fossil fuel suppliers appear to be betting on demand for their product growing as per business as usual (BAU). The direction of travel we observe from policy and technological signals is for destruction of demand. This paper is designed to explore the downside for fossil fuel producers and understand why our energy future may differ from their expectations. This in turn provides optimism that the world can deliver a low emissions trajectory. It is clear that the world will need to deviate from BAU if we are to prevent dangerous levels of climate change.

Changing system dynamics

At the highest level there have traditionally been three fundamental factors that determine energy demand: population, economic activity and the efficiency of technologies employed to supply energy to the economy. The relationship between these factors is constantly changing. Forecasting energy demand also requires assumptions on the evolution of personal preferences and behaviour. This all needs to be built into strategic planning and scenario analysis.

Will the future repeat the past?

Many financial and industry energy projections are based on extrapolating historical trends or energy mixes. This leads to a built-in assumption that the Scenarios are used to help people understand different futures and identify blind spots in their current assumptions about what might transpire. Many financial and industry energy projections suffer from 'straight-line' syndrome, where historical trends or energy mixes are extrapolated into the future over long periods. This can lead to a built-in assumption that the future will repeat the past – something that does not match-up with either preventing climate change or adapting to it.

Scenarios struggle to consider non-linear change

The risk of 'straight-line syndrome' hints at the biggest remaining energy modelling challenge, which is to understand system transformations, i.e. dramatic changes in policy or technology which cause non-linear change in trends. This is much more challenging to model or predict. Furthermore, most businesses can cope with gradual incremental changes during a long transition, but the impact on incumbents of an energy technological revolution would be of a much greater magnitude.

Beyond growth

The market view can change very quickly - for example when China indicates it is downgrading its economic growth forecasts, or the 2015 crash in commodity prices. Market analysts are increasingly serving warnings about different aspects of the fossil fuel industry. Yet, a bit like an oil tanker, there is a significant lag time for large fossil fuel producers to change course accordingly. This is leading to a material divergence of views between corporate and financial analysts. The US coal mining sector is an example of the vast value destruction that can occur when bullish industry projections of demand continue to drive corporate strategy despite market signals and analyst sentiment to the contrary. It demonstrates the reluctance of incumbents to accept a scenario other than growth, creating a need for investors to challenge corporate fossil fuel demand assumptions and their subsequent capex plans.

Why are scenarios and models important?

Business planning tools

Businesses, governments and investors all need to plan for the future. The capital that is spent now will create fossil-fuel based assets in the future, which will contribute emissions for the next few decades. As has been demonstrated by Carbon Tracker's carbon supply cost curves, these business planning decisions may be risky. We found there is over $1trillion of potential capital investment going into fossil fuel projects that would be unviable if prices are lower than companies expect, e.g. Shell abandoning its $7bn endeavour exploring for oil in the Arctic. To put it simply, these investments in future fossil fuel supply are predicated on a potential misread of future demand that is presented in or informed by corporate energy scenarios. If demand ends up falling short of these expectations it will result in oversupply and weakening prices, affecting future revenues.

Shareholder engagement

Following engagement around carbon asset risk and future capital investment plans, as well as shareholder resolutions seeking more disclosure of climate risks in these areas, there is increasing focus on the scenarios being applied by companies. (See initiatives from our partners CERES, IIGCC, LAPFF, CIG, Share Action & Client Earth on Carbon Asset Risk & Aiming for A).[1] It is our contention that, given the important role these scenarios play in business planning, it is vital that they are constantly challenged, reviewed and updated to reflect the latest thinking on energy futures. We feel it is critical that those that are relying upon them as justification for future investments understand the full range of potential outcomes and what factors determine those - it is simply good risk management.

[1] http://www.ceres.org/issues/carbon-asset-risk; http://www.ccla.co.uk/ccla/press/Aiming%20for%20A%2021st%20January%20Press%20Release_FINAL.pdf

Risk assessment

This report only focuses on the downside demand potential for fossil fuels because it is our contention that the base case energy scenarios being used are currently skewed to the upside. In terms of understanding risks, it is therefore necessary to focus on the extent to which these scenarios are potentially underestimating the pace and scale of the transformation of the energy sector.

Who produces scenarios and models?

As would be expected with it being its core business, the oil and gas industry is one of the largest contributors of energy outlook scenarios. This provides a helpful readout of which demand futures the companies may be expecting in making their capital investments, although many stop short of describing their scenarios as a 'prediction' or 'business forecast'. The renewables industry is also starting to produce more data on its progress, although does not yet have the same resources in place.

Many companies cite the International Energy Agency (IEA), the international body focused on the world's energy system, to justify their outlook of energy demand out to 2040. This is particularly the case in the coal sector where few companies have their own scenarios to refer to and so tend to selectively quote the IEA's business as usual (BAU) CPS out of context. Even oil and gas companies who produce their own outlooks use the IEA forecasts to inform their own or use as a market benchmark. Consequently, it is important to understand the IEA's scenarios and the underlying assumptions in their models as another way to gauge the expectations of the fossil fuel industry. Other national institutions such as the Energy Information Agency (EIA) in the US also offer global scenarios and projections, which are referenced in SEC filings for example.

The analyst teams of investment banks and brokers also have thematic research teams, strategists and economists, who produce macro-pictures of the future. These often build in scenarios around future supply, demand, prices, and technological change. Climate modelling is also subject to various assumptions and fundamental inputs. Integrated Assessment Models developed by various academic institutions and applied by the IPCC have enhanced our understanding of the way the climate will respond to changing atmospheric concentrations of greenhouse gases. Historically they have not been designed to indicate the feedback effects on our economies. A full list of the fossil fuel company scenarios referenced in this report can be found in Appendix 1.

Why do corporate and energy scenarios need to be challenged?

It's not easy to get right

This analysis is not designed to be critical of those who are taking on the complex job of trying to model the world's energy and climate systems into the future - to some degree any projection of the future energy and climate system is doomed to failure in terms of being exactly right. The recent volatility in the oil price is a prime example of how difficult it is to accurately predict just one parameter. The purpose is to ensure the range of possibilities is being considered by fossil fuel companies, market analysts and investors. It is not our concern that energy scenarios end up being wrong, more that they don't represent a full range of getting it wrong and do not exhibit bias; i.e. why didn't some commentators wildly overestimate the potential for clean energy advances as well as underestimating them?

Projections have been some way off

With the benefit of hindsight we are able to review the accuracy of past projections and scenarios published by the energy industry. As expected, they did not get it right all of the time. However, in the case of renewable energy forecasts, the error has been vast. Figure i.1 and i.2 show the IEA have persistently underestimated the total capacity additions of solar PV and wind, which is likely to have fed through to energy industry thinking more broadly. Over time the IEA have updated their thinking, but there is still a tendency for many renewable energy projections to remain behind the curve. This is why we feel it is valuable for energy modellers to entertain a range of options that deviate from their current view of the world.

Figure i.1: IEA solar PV capacity forecasts against actual

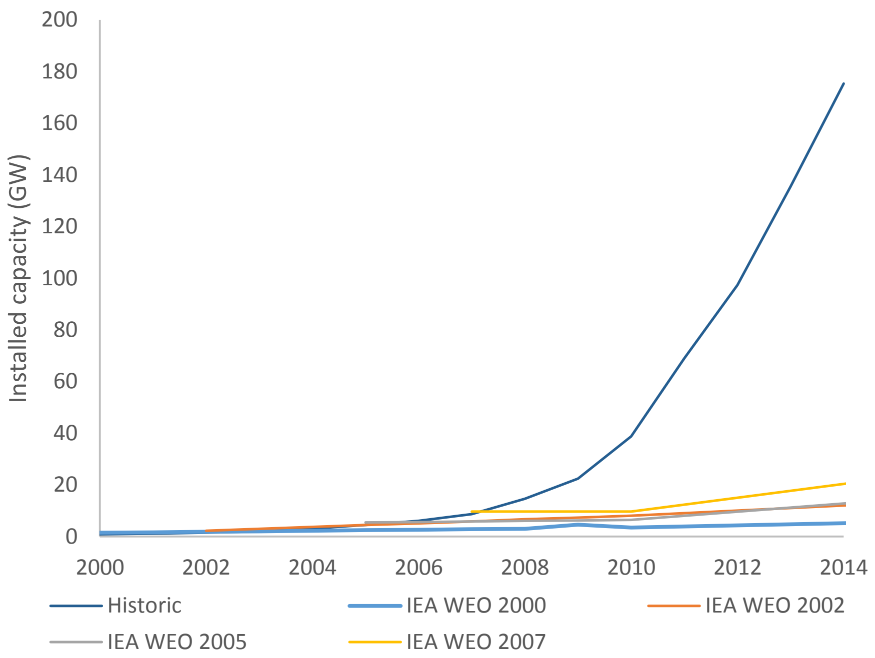
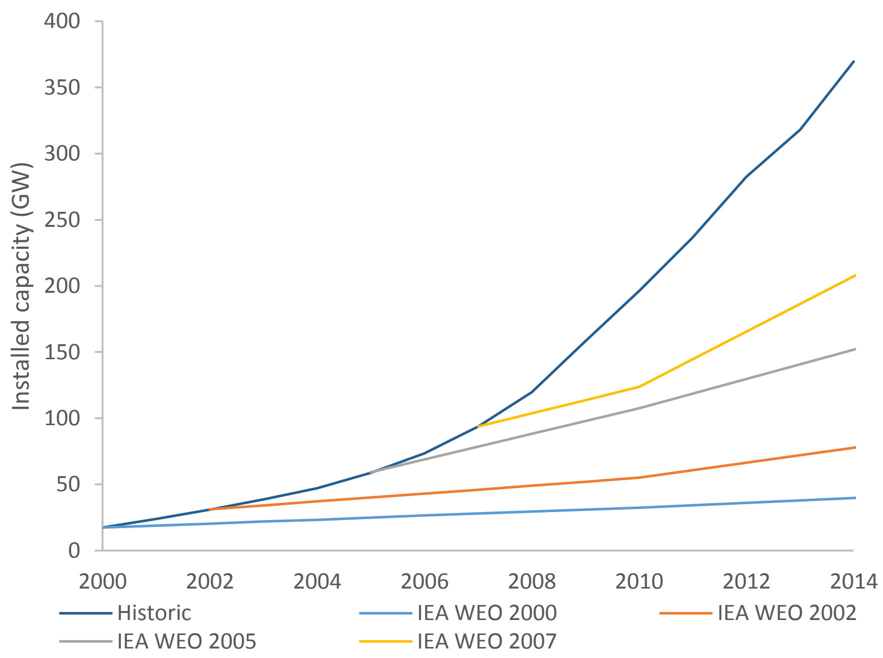


Figure i.2: IEA wind capacity forecasts against actual[2]



[2] Historic data is from IRENA. Old IEA WEO data sourced from Greenpeace Energy [R]evolution 2013.

SCENARIO	IEA WEO 2000	IEA WEO 2002	IEA WEO 2005	IEA WEO 2007
% DIFFERENCE TO ACTUAL IN 2012	-87.2%	-76.5%	-54.1%	-41.5%

SCENARIO	IEA WEO 2000	IEA WEO 2002	IEA WEO 2005	IEA WEO 2007
% DIFFERENCE TO ACTUAL IN 2012	-95.6%	-89.7%	-90.1%	-84.6%

What energy demand assumptions can be challenged?

There are a number of different models available – some financial, others on energy systems and finally those projecting emissions and the resulting climate change. Understanding how they relate to each other (or not) and what the feedback effects will be are critical to plotting a low carbon future. For example:

- The World Bank has a number of economic models covering macro and micro indicators of growth, development and population[3];
- The IEA has an energy system model covering assumptions, supply and demand factors and outputs[4]; and
- Emissions are often displayed using Sankey diagrams representing emissions sources.[5]

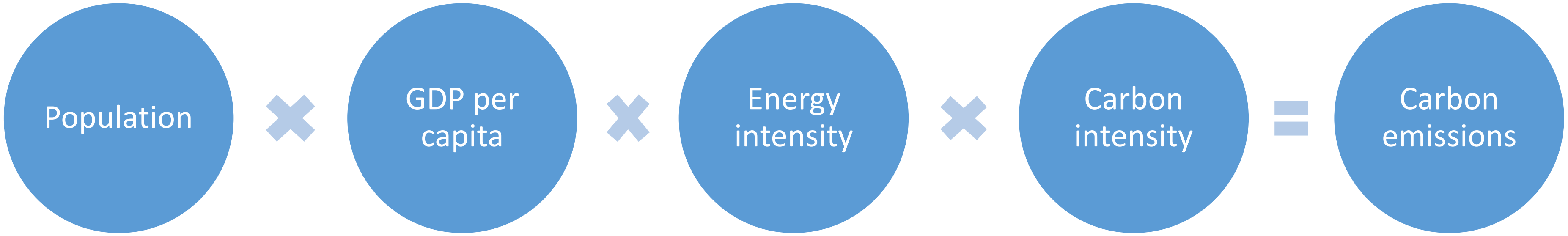
Because of the complexity of the economic, energy and climate systems, it is common for simplified economic models to be developed to explain the major relationships. These may not be able to capture the full complexity or inter-connectedness, but they provide a means of understanding how the systems are working. The Kaya Identity is one economic model that brings together those factors that determine energy demand and CO_2 emissions in a simple way. tries to bring the factors together in a simplistic way. It consists of four high level variables around which the 9 BAU industry demand assumptions challenged in this report are structured – refer Figure i.3.

3 http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTDECPROSPECTS/0,,contentMDK:20279477~menuPK:538204~pagePK:64165401~piPK:64165026~theSitePK:476883,00.html

4 https://aleklett.wordpress.com/2012/11/29/an-analysis-of-world-energy-outlook-2012-as-preparation-for-an-interview-with-science/wem-overview/

5 http://www.wri.org/sites/default/files/world_ghg_flow_chart_2005.png

Figure i.3: This report is structured around the Kaya Identity



Assumption 1:
Global population will increase to 9 billion by 2040

Assumption 2:
Global GDP maintains recent growth rates to 2040

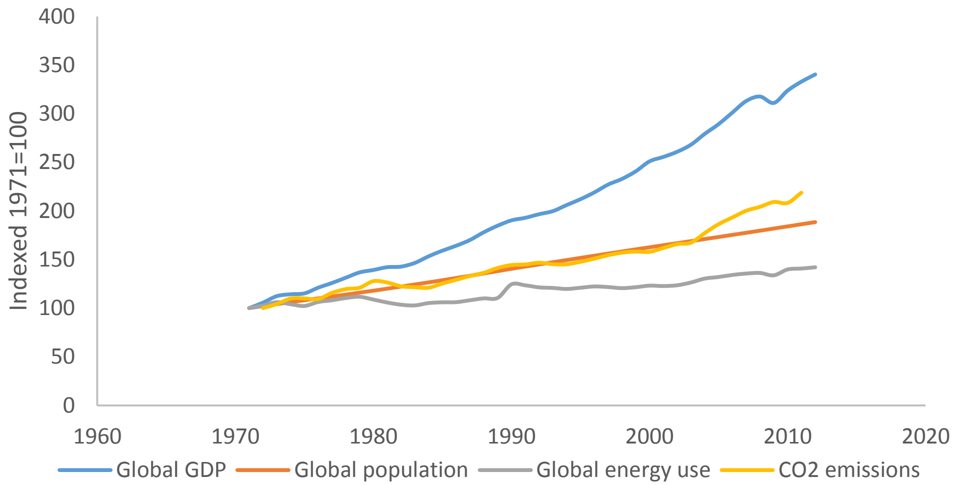
Assumption 3:
Reductions in the energy intensity of GDP slow markedly

Assumptions 4-9:
Carbon intensity of energy remains high as fossil fuels maintain share

Chapter 10:
Calculating downside CO_2 emissions with the Kaya Identity

The long term relationship between energy, population and GDP is changing, with GDP growing faster than population or energy – refer Figure i.4. If any of these variables start to plateau or decline in the future it will result in changes to subsequent CO_2 emissions.

Figure i.4: The relationship between energy, population and GDP is changing



Source: World Bank, 2015

This indicates why it is necessary to adjust the ratios over time and understand the impact of potential future shifts on fossil fuels. We stress-test the impact on fossil fuel demand if each ratio disappoints on the downside:

Population: We examine the potential for fossil fuel demand destruction in population growth is lower-than-expected.

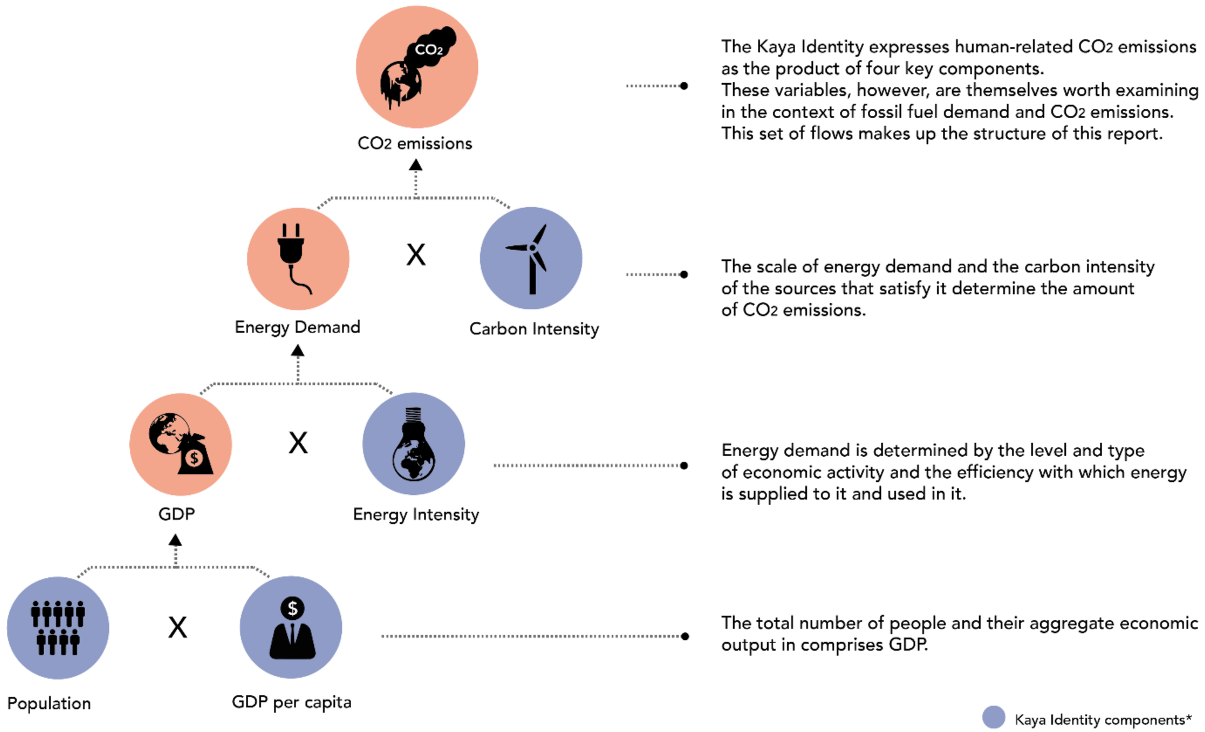
GDP per capita: The relationship between population and productivity. We test the impact if global GDP growth is lower than expected for a given population increase, i.e. the productivity of additional man hours disappoints.

Energy intensity: The amount of energy required to meet demand from economic growth. We test the impact on fossil fuel demand if energy intensity falls accelerate due to greater decoupling of energy demand from GDP growth.

Carbon intensity: The amount of carbon emitted per unit of energy required. We examine the impact if penetration rates of renewable energy technologies surprise on the upside.

To conduct this downside analysis, we have compared forecast assumptions offered by just mainstream institutions with those of the energy industry to understand the potential for variation in outcomes. If we were to add in more extreme views this would further stretch the potential for a downside to demand future. At the end of this report we bring together the downside assumptions of each component of the Kaya Identity and examine the impact it can have on CO_2 emissions. The flow chart below summarises this logic behind the report structure.

Figure i.5: What factors do we examine within the energy demand system



BAU Assumption 1. Global population will increase to 9 billion by 2040

"The global population is projected to rise to 9 billion in 2040." Exxon Outlook for Energy 2015.[6]

World population levels could fall short of the 9 billion mark fossil fuel companies expect by 2040. Population and migration need to be considered in the context of climate change taking place. As our flow chart in Figure i.5 illustrates, changing the number of people on the planet has a major influence on GDP growth and, therefore, energy demand projections. However, the energy industry universally apply the same assumptions.

Key Findings

- There is significant variation in the level of future global population between scenarios – some models come out over a billion people lower by 2050, for example.
- The level of population is driven by key factors including fertility, family planning, longevity, and mortality.
- Non-OECD populations are growing whilst OECD populations are declining. Lower global population growth (8.3bn by 2050) could reduce fossil fuel consumption by 17% against a central scenario of 9.6bn by 2050, keeping all other variables constant in the DECC Global Calculator.
- A key assumption relating to the impact of additional populations is urbanisation rates. Higher levels of urbanisation are expected to increase energy demand. However, if urbanisation rates disappoint, fossil fuel demand could fall 3%, keeping other variables constant in the DECC calculator.

In energy models, population and GDP per capita constitute total GDP growth, which in turn, can result in additional energy demand. In layman's terms, how many more people will there be and how productive will they be? In this chapter we isolate the role of population growth from GDP and look at its role in energy demand.

[6] http://cdn.exxonmobil.com/~/media/global/files/outlook-for-energy/2015-outlook-for-energy_print-resolution.pdf

How many people will there be according to the scenarios?

All fossil fuel companies that disclose their population growth assumptions adhere to the same school of thought based on UN forecasts – that population will grow steadily. BP, ExxonMobil and the IEA, all assume in their scenarios that global population will hit 8.7 billion by 2035 and 9 billion by 2040. Statoil source population modelling from IHS Connect that also foresees 9 billion people by 2040. All EIA scenarios project 8.8 billion in 2040.[7] These forecasts are aligned with the UN's 2015 medium-variant population projection that sees global population rising to 9.7 billion by 2050 and 11.2 billion by 2100 – refer Figure 1.1.[8] This scenario is an increase on the previously common view that population would peak around 9 billion people by 2050.[9]

Figure 1.1: The UN expect global population to grow significantly

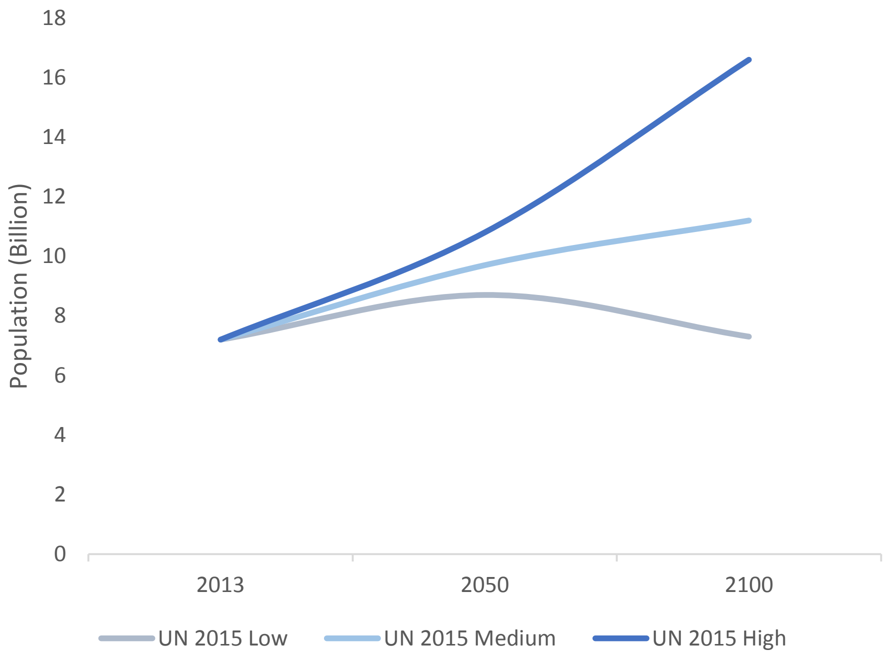
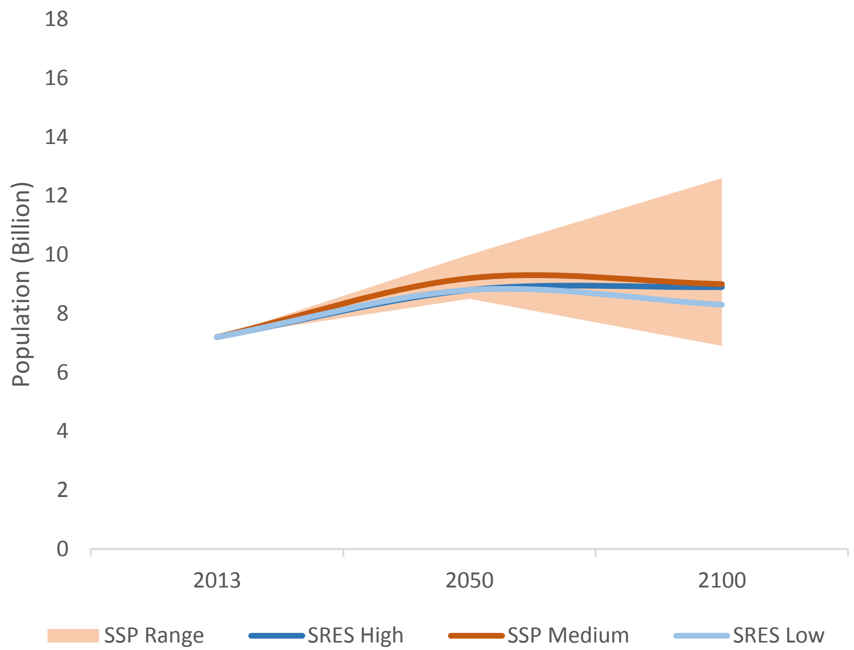


Figure 1.2: IIASA show that the extent of global population growth is far from certain



Source: UN, IIASA

[7] Shell don't give quantified details on their population assumptions, but state they also use the UN Population Division's figures.
[8] http://esa.un.org/unpd/wpp/Publications/Files/Key_Findings_WPP_2015.pdf
[9] See Lutz et al. 2001.

Potential for divergence increases post-2050

The UN have 95% confidence the global population will be between 8.4 and 8.6 billion in 2030. Beyond this point, uncertainty increases drastically typified by the head of the UN Population Division, John Wilmoth, who admits that UN modelling 'may still be off by two billion' by 2100.[10] This demonstrates the potential for significant variation in the actual global population from the numbers being used. The UN's latest Population Prospects document put the chances of global population stabilising and falling before 2100 at 23%.[11]

Linking population to climate models

Figure 1.2 displays two modelling projects by the International Institute for Applied Systems Analysis (IIASA), an international network of science academies from 45 countries specialising in analysing complex global issues. The first set of IIASA outputs is based on the Special Report on Emissions Scenarios (SRES) that underlie the IPCC's emission scenarios and gives these projections a clear link to climate science. This modelling suggests a far smaller range between high and low population growth futures than the UN. Both scenarios see a global population of 8.8 billion by 2050 – 0.9 billion people less than the UN medium-variant scenario universally quoted and modelled by the fossil fuel industry.[12] A divergence occurs between high and low scenarios between 2050 and 2100, but both remain between 8 and 9 billion people. This plateauing or even declining global population is very different to the steady growth of UN forecasts post-2050.

Multi-dimensional models also indicate lower population levels

The second approach from IIASA is based on five socioeconomic pathways (SSP) that the authors state use a multi-dimensional modelling of future fertility, mortality, migration and educational transitions that goes further than the simple population size modelling approach of the IPCC and UN. These scenarios show a smaller range than the UN model and the median trajectory holds a lower course than that of the UN's median-variant – a difference of 0.5 billion by 2050.[13]

Converting population assumptions into fossil fuel demand destruction

Population is the first factor in the Kaya Identity. In Table 1.1 we demonstrate what the potential impact of population change could be on fossil fuel demand with the help of DECC's Global Calculator. This tool can adjust population levels, whilst all other factors like GDP growth are based on IEA scenarios and held the same.

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[10] http://news.nationalgeographic.com/news/2014/09/140918-population-global-united-nations-2100-boom-africa/
[11] http://esa.un.org/unpd/wpp/Publications/Files/Key_Findings_WPP_2015.pdf
[12] http://www.sciencemag.org/content/319/5866/1047
[13] http://dx.doi.org/10.1016/j.gloenvcha.2014.06.004

Table 1.1: Fossil fuel demand in different population growth scenarios (2011-2050)

Year	**2011**	**2050**				
Scenario		**Base Case**	**IEA 4DS**		**IEA 2DS**	
Population	7.0	9.6	8.3	% change to base case	9.6	% change to base case
Cumulative coal consumption (Gt)	6.2	208.7	155.5	-25.5%	145.7	-43.2%
Cumulative oil consumption (Trn litre)	4.7	192.0	168.7	-12.1%	145.5	-32.0%
Cumulative gas consumption (Tm^3)	3.0	117.0	107.0	-8.6%	94.5	-23.8%

Source: DECC Global Calculator

Table 1.1 shows that aggressively reducing population growth to 2050 from the UN forecast level of 9.6bn (to which all fossil fuel companies subscribe) to 8.3bn reduces demand for fossil fuels by 17%. As one would expect, this saving predominantly constitutes cut-backs in demand for the most CO_2-intensive fossil fuel, coal. Coal demand is 26% lower in the low population growth scenario to 2050 compared to the central assumption, whereas oil and gas only are only 12% and 9% lower respectively.

To make these estimates, the DECC scenarios make assumptions about the energy intensity per capita of this additional population. Subsequent energy demand is dependent on where this population growth occurs and by what method access to energy is improved in these growth regions.

The geography and age distribution of population growth

As noted, there is regional variation underlying the global ratios in the Kaya Identity and that is certainly true of population trends, where regions are heading in opposite directions. This means it is the balance between the regions that determines the overall trends.

OCED population is ageing

The global population is likely to grow in the future, but both IIASA and the UN agree that this will not be in OECD nations. Europe sees a 26% decline by the end of the century in the UN's medium variant. This extends to a 40% decrease in IIASA's modelling. A declining population translates into an aging population – those of working age in OECD countries peaked in 2013 - which itself leads to lower energy demand through lower economic growth because of lower labour productivity.

Non-OECD population growth focused in a few key regions

Almost all future population growth is projected in non-OECD nations. This is no longer centred on China who are in a group of 'emerging countries' whose fertility rate is converging on those akin to developed countries - the UN see China's population peaking in 2028 and declining by 26% by the end of the century. Instead, growth is expected to occur in 'least developed' countries and is highly concentrated in a few countries and regions in particular.[14]

To 2050 half of all population growth is expected in Africa alone due to its highly youthful population which will reach adulthood in coming decades. In fact, approximately 50% of global population growth to 2050 can be concentrated in 9 countries – India, Nigeria, Tanzania, Congo, Indonesia, Uganda, Pakistan, Ethiopia and the US - largely due to an influx of over 1m immigrants annually.

Non-OECD population growth does not necessarily equal fossil fuel demand

The non-OECD nations in this list of 9 key growth nations, i.e. excluding the US, accounts for 46% of global population growth to 2050. Fossil fuel companies are betting on these populations being a source of additional demand. Coal companies in particular are optimistic demand will grow as these nations develop their economies. In reality, even strong population growth in these countries may not result in greater coal demand.

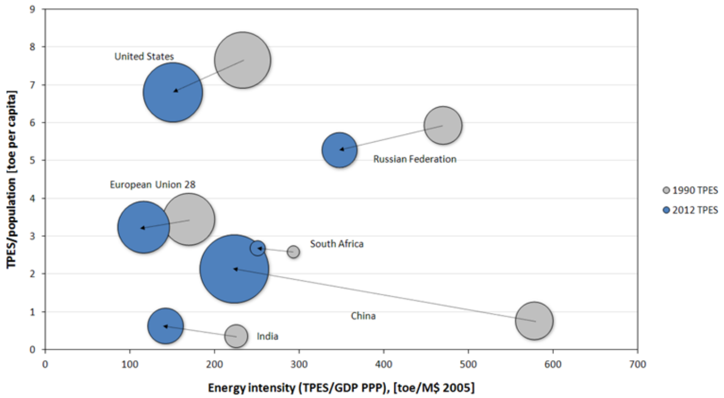
Table 1.2: Population growth regions do not match up with coal reserves geographically

	COAL RESERVES (BT)	POPULATION CHANGE 2015-2050 (MILLION)
INDIA	60.6	394.2
NIGERIA	0	216.3
TANZANIA	0	83.7
CONGO	0	118.0
INDONESIA	28	64.6
UGANDA	0	62.9
PAKISTAN	2.1	120.7
ETHIOPIA	0	38.9
GLOBAL	891.5	2376

Table 1.2 shows that those non-OECD countries that are forecast by the UN to see strong population growth to 2050 have little to no coal reserves with which to provide energy to additional populations. Put simply, these 8 countries will account for 46% of population growth to 2050 but only have 10% of global coal reserves. If you take India out of this equation, coal reserves in the remaining countries are negligible. This lack of domestic coal supply increases the chances that this fuel is leapfrogged by alternatives such as low-cost off-grid or mini-grid renewable energy.

[14] According to the UN, a least developed country exhibits the lowest Human Development Index ratings, such as health care, literacy and per capita income.

Figure 1.3: Energy intensity per capita and energy intensity per GDP (1990-2012)[15]



Although coal may not be the answer, it is likely non-OECD growth regions will require more energy as demand per capita is currently lowest in the world's least developed countries where population growth is likely to occur. Therefore, these nations have the greatest scope to increase. Figure 1.3 shows that in non-OECD nations like China and India energy intensity per capita has been increasing, whilst in the OECD it has been decreasing. It is clear that the geography of future population growth will affect energy intensity per capita.

Source: IEA

Urban-rural population ratio

"By 2050, around three quarters of the population is expected to be living in cities." Royal Dutch Shell, 2013[16]

In a bid to take advantage of the broader access to electricity and higher incomes available in urban areas, it is expected that the rate of urbanisation will increase significantly in the world's least developed countries. The latest UN World Urbanisation Prospects report predicts global rural populations to peak in the next few years and decline thereafter, highlighting that almost all additional populations globally will reside in newly urbanised regions.[17] Currently, 40% of African and 48% of Asian populations live in rural areas – this is expected to rise to 56% and 64% respectively by 2050 in the UN scenario.[18]

[15] https://www.iea.org/newsroomandevents/graphics/2014-08-19-energy-consumption-per-capita-and-energy-intensity.html
[16] http://www.shell.com/global/future-energy/scenarios/new-lens-scenarios.html
[17] http://esa.un.org/unpd/wup/Highlights/WUP2014-Highlights.pdf
[18] http://esa.un.org/unpd/wup/Highlights/WUP2014-Highlights.pdf

Urbanisation is often cited as a driver of future energy demand growth because urban dwellers tend to have a higher energy intensity per capita than rural dwellers. In turn, this means cities are a key determinant of future CO_2 emissions – currently cities are the source of 70% of global CO_2 emissions.[19] Urbanisation can come in different forms however. Rapid unplanned rates of urbanisation can outstrip the ability of cities to plan and grow, resulting in informal settlements at the fringes of existing cities. These additions are often not properly connected to official services such as electricity grids or transport networks, which may restrict the level of energy consumption per capita. In contrast, new well planned high density cities can be highly efficient and low carbon by design. There are also major international efforts at the city level to improve their contributions to reducing emissions.[20] These nuances mean higher rates of urbanisation do not inherently translate into greater energy and fossil fuel demand.

Potential fossil fuel demand destruction from urbanisation assumptions

Table 1.3 illustrates the potential reduction in fossil fuel demand that could occur if global urbanisation rates ceteris paribus are lower than expected, as calculated by the DECC global calculator.

Table 1.3: Lower than expected urbanisation rates results in carbon mitigation

Year	**2011**	**2050**				
Scenario		**Base Case**	**IEA 4DS**		**IEA 2DS**	
Urbanisation %	52%	66%	58%	% difference to base case	66%	% difference to base case
Cumulative coal consumption (Gt)	6.18	208.7	200.9	-3.7%	145.7	-30.2%
Cumulative oil consumption (Trn litre)	4.7	192.0	187.9	-2.1%	145.5	-24.2%
Cumulative gas consumption (Tm3)	3.02	117.0	111.8	-4.4%	94.5	-19.2%

Source: DECC Global Calculator

These scenarios show that a lower rate of global urbanisation would cause fossil fuel demand to fall by 3% to 2050 within 4°C parameters. This helps you get some of the way from a 4°C to a 2°C world. Interestingly, Table 1.3 suggests that lower levels of urbanisation would affect all fossil fuel groups more or less equally.

[19] https://www.foreignaffairs.com/articles/2015-08-18/city-century
[20] http://www.c40.org/

Conclusion

- There is significant variation in the level of future global population between scenarios – some models come out over a billion people lower by 2050, for example.
- The level of population is driven by key factors including fertility, family planning, longevity, and mortality.
- Non-OECD populations are growing whilst OECD populations are declining. Lower global population growth (8.3bn by 2050) could reduce fossil fuel consumption by 17% against a central scenario of 9.6bn by 2050, keeping all other variables constant in the DECC Global Calculator.
- A key assumption relating to the impact of additional populations is urbanisation rates. Higher levels of urbanisation are expected to increase energy demand. However, if urbanisation rates disappoint, fossil fuel demand could fall 3%, keeping other variables constant in the DECC calculator.

BAU Assumption 2: Global GDP maintains recent growth rates to 2040

"GDP is expected to more than double…and increases in income per person is a key driver behind growing demand for energy." BP, 2015[21]

It's all about growth, which will mean more energy demand, right? Economic growth itself does not always materialise – perhaps due to lower population growth, disappointing productivity of labour or macro-level factors such as financial downturns or conflict. Further, climate change impacts possess great potential to disrupt and constrain economic growth, but these feedbacks are not often integrated into energy modelling.

Conclusion

- GDP compound annual growth rate (CAGR) forecasts to 2040 range from 2.8% (Statoil) to 3.4% (IEA NPS) resulting in a difference in global energy demand of 14679Mtoe between 2012 and 2040. This would have significant implications for fossil fuel demand.
- The vast majority of GDP growth is expected in non-OECD countries, but major economies like China are already slowing down.
- The future impacts of climate change are rarely factored into GDP forecasts when modelling energy systems. Yet studies show it is likely to be significant, e.g. reducing GDP growth in the non-OECD by 0.6% per annum.

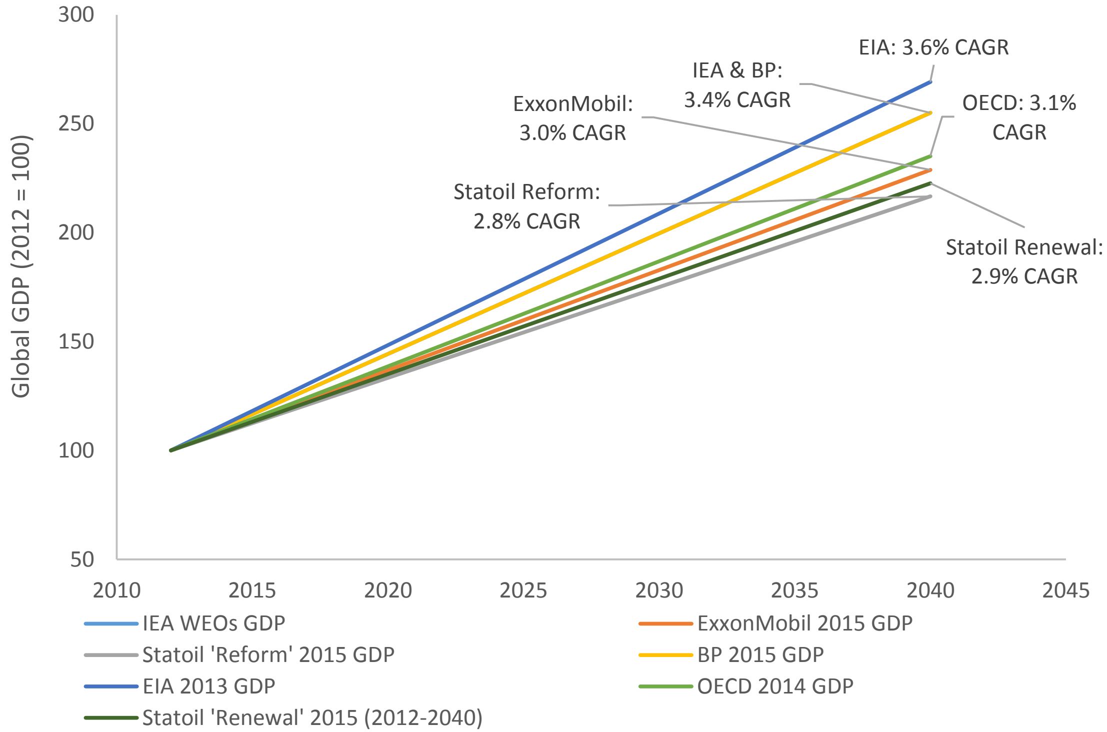
Population and urbanisation are key inputs to GDP. Most energy forecasters use GDP as a starting point, however, and hereby have made assumptions about population factors as per the baselines highlighted in Assumption 1. This assumed rate of future GDP growth has significant implications for energy demand expectations. As the IEA note, economic activity is "the principal driver of demand for each type of energy service".[22]

This chapter examines differences in assumed GDP growth rates, their impact on energy demand and the potential for feedback effects of climate change adaptation and mitigation to affect this level of growth.

[21] http://www.bp.com/en/global/corporate/energy-economics/energy-outlook-2035.html
[22] http://www.worldenergyoutlook.org/publications/weo-2014/

What will the rate of global GDP growth be?

Figure 2.1: Forecasts of GDP growth[23]



At a global level, geopolitical uncertainty, financial volatility - especially in developing markets - and the rate of deflation in advanced economies all serve to threaten future GDP growth. Furthermore, forecasting institutions have different assumptions about the expected productivity of the global workforce in the future, i.e. GDP per capita, which affects forecast growth levels.

Aggregated together, these factors make forecasting economic growth treacherous. Figure 2.1 summarises industry forecasts for global GDP growth. For many the IEA act as a benchmark - they assume across all three of their scenarios that global GDP will remain at 3.4% growth per year on average to 2040.[24] Evidently this is at the high end of the range of energy industry forecasts. Median forecasts are approximately 3.2% to 2040, while Statoil's Reform scenario is at the low-end of the presented range at 2.8%.

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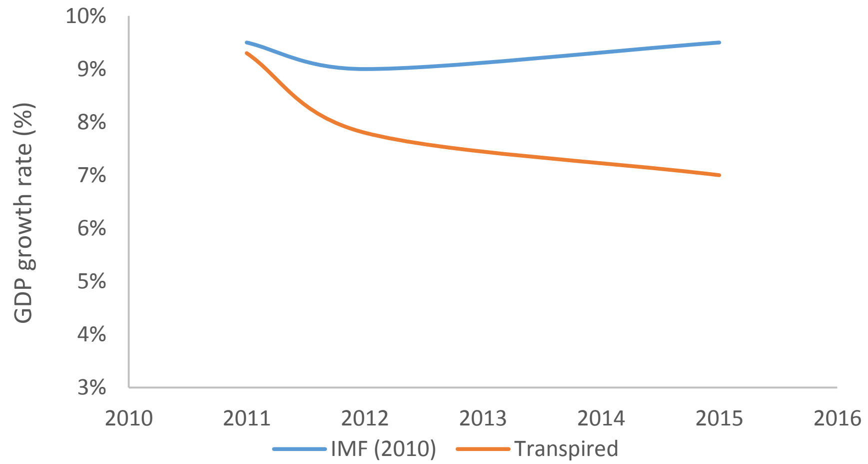
[23] When comparing long term GDP forecasts there are a number of consistency factors that need to be watched for: 1) country inclusion differences; 2) basis for calculation, e.g. the IEA uses GDP in US$ in 2013 Purchasing Power Parity (PPP) while the OECD use either US$2005 PPP or US$2010. The OECD GDP forecasts in Figure 2.1 and our Kaya Identity calculations are in US$2010 PPP so differences to the IEA could be due to slightly different methodologies.

[24] http://www.worldenergyoutlook.org/publications/weo-2014/

Figure 2.2: IMF 2010 forecasts of Chinese GDP growth against what transpired



Source: IMF, World Bank

Focus on China – a recent tendency for overestimation

China's is one country whose economy is expected to grow significantly over the next couple of decades.[25] Recent history reveals a tendency for China's GDP growth to be overestimated. In 2010, the IMF estimated in its economic outlook that China's economy will grow by 9.5%, 9.0% and 9.5% in 2011, 2012 and 2015 respectively – refer Figure 2.2.[26] In 2011, the actual GDP growth rate in China was 9.3%. In 2012 a greater divergence occurred as GDP grew 7.8% in China, i.e. the IMF were out by 1.2%. This is likely to have resulted in energy demand that was lower-than-expected by anyone following the IMF's GDP forecasts. To illustrate, energy demand increased by 0.28% per 1% of GDP growth in 2012 – just below the 1.2% of GDP growth the IMF were out by that year.

That was equivalent to 808Mtoe of energy demand that did not materialise in China in 2012, equal to roughly half of total energy demand in the whole of Europe. This is a significant discrepancy in demand. Evidently, forecasting GDP in rapidly changing, key growth markets like China is difficult and has frequently been overestimated. China has cut its target for 2015 to 7%[27], already below the World Bank forecast of 7.3% from 2011-2020 and fully 2.5% below the IMF forecast made just 5 years ago.[28] It is also clear that GDP has significant consequences for energy demand and so adequately considering a range of scenarios is imperative.

Lower GDP rates in China and India equal lower CO_2 emissions

A range of long-term GDP growth rates are forecast for China by the fossil fuel industry and IEA – refer Figure 2.3. Given the forecast for 2015 GDP growth is 7%, all long-term projections see a slowdown in China's economic growth. The IEA INDC scenario is noteworthy because it calculates that for China to meet

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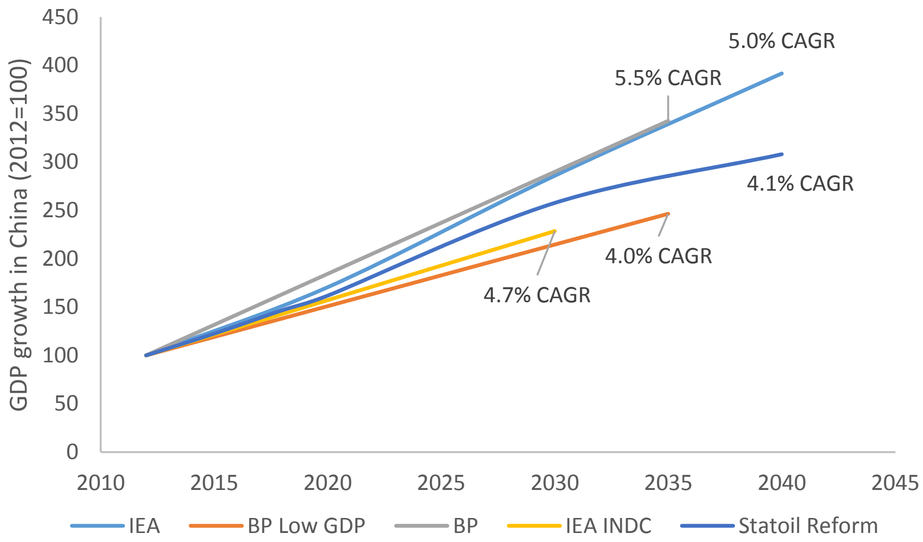
[25] http://www.bloomberg.com/news/articles/2015-04-10/the-world-s-20-largest-economies-in-2030
[26] https://www.imf.org/external/pubs/ft/weo/2011/02/pdf/text.pdf
[27] http://www.theguardian.com/business/2015/jul/15/china-surprises-economists-with-gdp-rise-of-7
[28] http://www.imf.org/external/pubs/ft/weo/2015/01/pdf/text.pdf

its Intended Nationally Determined Contribution (INDC) commitment, GDP growth will have to be contained to an average of 4.7% to 2030. Neither BP nor Statoil's central 'Reform' scenario foresee this transpiring.

Figure 2.3: Forecasts for GDP growth in China[29]



BP's latest Energy Outlook provides run-throughs of both the highest and lowest assumed GDP growth rates – refer Figure 2.3.[30] BP's "low-GDP scenario" classifies future GDP rates in China and India as one of four 'key uncertainties' in the future energy system. In this scenario, they apply a 4% per annum GDP growth rate to China and India as opposed to the base case assumption of 5.5% in both. This results in global energy demand being 8.5% lower than the base case by 2035, lowering global CO_2 emissions by 9% by 2035, equal to 48GtCO_2 between 2012 and 2035. This is a good example of the importance of stress-testing downside GDP scenarios.

Converting lower global GDP rates into potential fossil fuel demand destruction

The IEA is the industry reference point for energy scenarios. They assume 3.4% global GDP growth per annum from 2012 to 2040. This corresponds to total primary energy demand increasing 1.1% on average to 2040 in their central NPS. As demonstrated in Figure 2.1 earlier, the IEA's GDP forecast is at the upper-end of industry estimates (assuming methodological differences to be minor). The OECD forecasts GDP growth to 2040 to average 3.1% per annum.[31] This is more of a median perspective on future GDP growth. Statoil's Reform scenario is a further 0.3% lower at 2.8% GDP growth per annum and sits at the low-end of the industry forecast range.

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[29] CAGR calculations reflect average over the forecast period and, therefore, do not take into account the changeable growth rates in some forecasts.
[30] http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html
[31] https://data.oecd.org/gdp/gdp-long-term-forecast.htm#indicator-chart

In Table 2.1 we adjust energy demand in the IEA NPS (1.1%pa) to reflect the magnitude of differences with the OECD and Statoil GDP growth rates to illustrate what could happen to energy demand if downside GDP forecasts come to fruition. Our calculations consider energy demand in three time periods to integrate the trend of reducing energy intensity of GDP, which we assume to be the same as IEA NPS.[32]

Table 2.1: Energy demand impact of lower GDP growth

	IEA NPS (GDP 3.4% pa)	NPS adjusted to reflect difference to OECD (GDP 3.1% pa)		NPS adjusted to reflect difference to Statoil Reform (GDP 2.8% pa)	
	Energy demand (%CAGR)	Energy demand (%CAGR)	Difference in energy demand to NPS (Mtoe)	Energy demand (%CAGR)	Difference in energy demand (Mtoe)
2012-2020	1.4%	1.3%	-664	1.2%	-1324
2020-2030	1.1%	1.0%	-3147	0.9%	-6253
2030-2040	0.9%	0.8%	**-7410**	0.7%	**-14679**

We find energy demand reduces by approximately 7.4btoe per 0.3% fall in global GDP growth rates from an IEA baseline – this is equivalent to over half a year's global energy demand in 2012. Lower energy demand on this scale will have knock-on implications for fossil fuel demand. Forecasts of GDP combine assumptions about the scale of future population growth and the productivity of this population, i.e. GDP per capita. So while the illustrative calculation above examines GDP in isolation, it is in fact determined by assumptions of these two factors. In Chapter 1 we showed lower population growth could directly reduce fossil fuel demand, this in effect will lower GDP growth in any log run output model. Equally, lower assumed GDP per capita will have the tantamount effect to lower GDP growth.

[32] Energy intensity ratios and so energy demand might vary depending on what causes GDP to be less – we have kept all assumptions the same for this illustration.

Climate change feedback effects

Failure to tackle climate change will impact GDP

For all the sophistication of many climate models, most are not designed with feedback effects on GDP built in. GDP is treated as an exogenous factor, that is an isolated input to the model, rather than one which iterates in relation to the scenario that develops. This means that in a 4°C or 6°C warming scenario, there is no in-built mechanism to reflect the impacts of the associated increased extreme weather events, disruption to economic activity, migration, conflict, etc. on economic growth. Even where some impacts are integrated, they may not be a complete set due to modelling limitations.

Damages calculations

This omission is even more significant given the majority of economic growth is predicted to occur in non-OECD countries, which is also where the most significant climate impacts are expected. Moore & Diaz's research into damages indicates that the average annual growth rate in poor regions is cut from 3.2% to 2.6%. Dietz and Stern have also explored this fundamental flaw in traditional integrated assessment models, noting that it was not plausible that the world could experience 5-6°C of warming without catastrophic impacts on mankind's ability to function on the planet. This is an important dimension that needs to be factored in to assessing the fossil fuel industry's expectations of growth in a business as usual world. There may be self-limiting factors at work once climate change impacts increase, dampening growth and demand for fossil fuels.

Lower cost long term

Statoil's Energy Perspectives 2015 gives an indication that a scenario which prevents dangerous levels of global warming and sees strong growth of renewables (the Renewal scenario), sees higher economic growth than a gradual transition or a world with increasing rivalry and dysfunction. In particular this comes through in the 2030s, and the analysis states that the gap would only grow further if it was extended beyond 2040. Tackling climate change is often portrayed as a cost to society, albeit one that is likely to reduce costs later on. Economic analyses such as those by Lord Stern have illuminated how it will be cheaper to address climate change sooner than later. Citi's Energy Darwinism research also concludes that there is very little difference in total energy expenditure to 2060 required in 'Action' and 'Inaction' scenarios – in fact costs are 1% lower with 'Action' to tackle climate change compared to BAU.

Climate change feedback effects

GDP does not reflect value erosion

The investment in climate adaptation measures and solutions actually contributes to GDP – for example through investment in infrastructure and lower fuel cost expenditures. Bloomberg New Energy Finance (BNEF) analysis in early 2015 showed that clean energy power capacity additions are now greater than fossil fuels, and set to dwarf them going forward. The IEA found that net savings in a 2DS compared to 6DS are between $31trn (discount rate of 3%) and $8trn (10% discount) to 2050. Transforming the energy sector can therefore be positive for growth and decoupling from emissions growth secures the climate. GDP as an indicator does not capture changes in stocks or assets as it is concerned with annual flows. This means that as an indicator it will not pick up the erosion of value in natural resources that can result from falling demand and prices.

Conclusions

- GDP CAGR forecasts to 2040 range from 2.8% (Statoil) to 3.4% (IEA NPS) resulting in a difference in global energy demand of 14679Mtoe between 2012 and 2040. This would have significant implications for fossil fuel demand.
- The vast majority of GDP growth is expected in non-OECD countries, but major economies like China are already slowing down.
- The future impacts of climate change are rarely factored into GDP forecasts when modelling energy systems. Yet studies show it is likely to be significant, e.g. reducing GDP growth in the non-OECD by 0.6% per annum.

BAU Assumption 3: Reductions in the energy intensity of GDP slow markedly

Over the past few decades, improving efficiency of the energy system has meant demand has not kept pace with GDP growth. The energy industry expects this to continue, but not necessarily accelerate. However, a number of economies have already cut the cord that tied energy demand to GDP growth, raising questions about whether this decoupling could spread globally to allow for growing economies without expanding energy demand.

Conclusion

- The assumed energy intensity of GDP growth significantly impacts subsequent energy demand and CO_2 emissions. Industry and energy analyst scenarios of energy intensity falls range between -1.9% and -2.8% per annum to 2040.
- The energy intensity of key growth economies is expected to halve by 2040, but could fall more depending on the rate of transition to service-based economies and the utilisation of more efficient technologies within the energy system.
- Applying energy intensity gains of -2.8% reflects lower energy demand equal to 36848Mtoe to 2040 against an energy intensity assumption of -2.2%, assuming all else is constant. Demand for each of the fossil fuels falls by between 22% and 42% as a result.

Energy intensity is a measure of the amount of energy used per unit of GDP. Global energy intensity has been falling, but this varies across geographies. Energy intensity will continue to fall in the future, the rate of this decline, however, is up for debate.

The significance of GDP growth as a driver of energy demand is diminishing

The world is increasingly decoupling energy demand from GDP growth – refer Figure 3.1. This is as a result of the world's largest energy consuming nations transitioning towards service-based economies and energy efficiency gains worldwide.

Figure 3.1: Global GDP growth is decoupling from energy demand

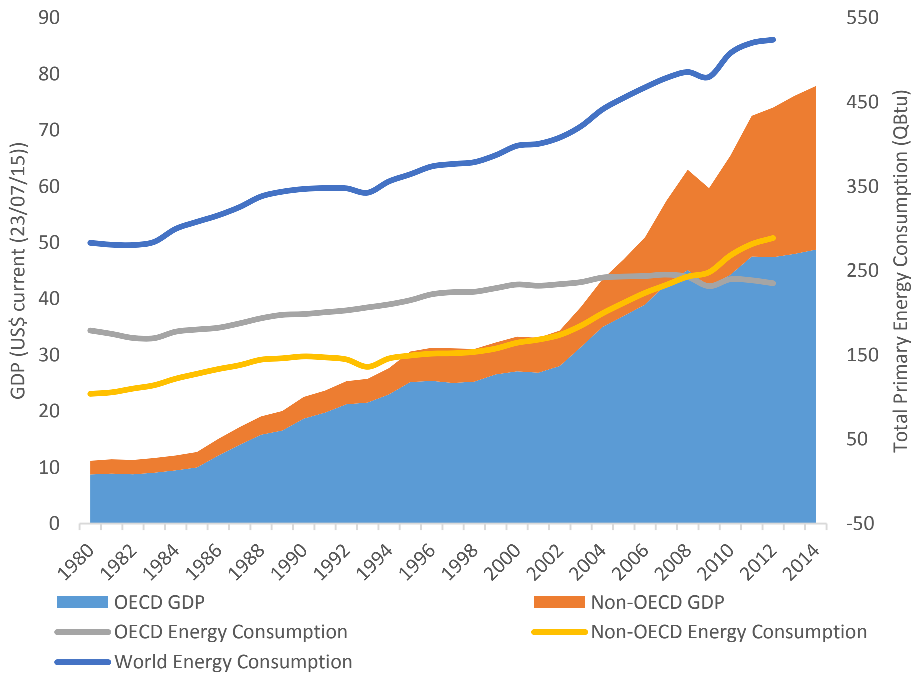
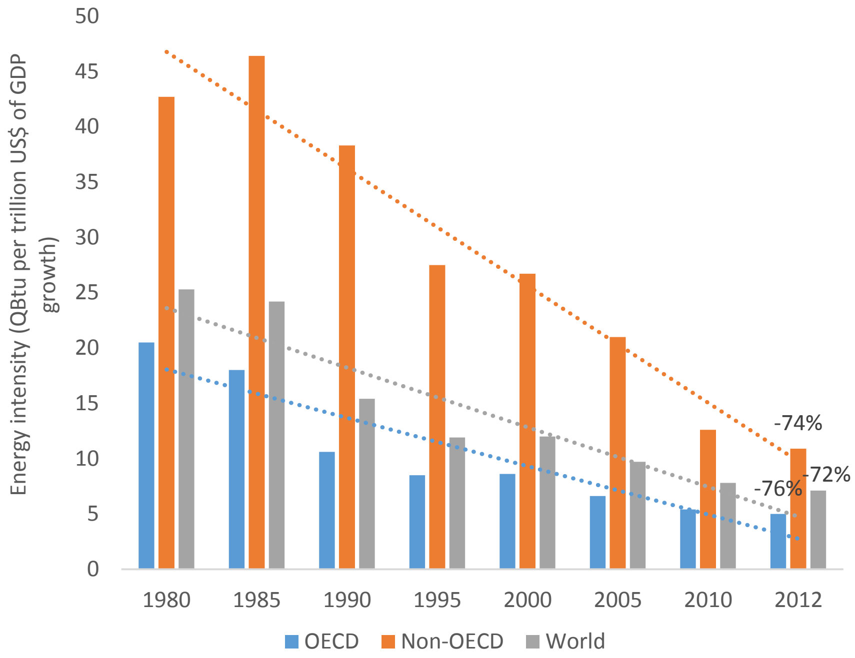


Figure 3.2: Energy intensity ratios, 1980 to 2012



Source: US EIA, World Bank

NB: 2012 % change is against 1980 start year

Source: World Bank, 2015

OECD – GDP and energy consumption are already diverging in some countries

Figure 3.1 shows that between 1980 and 2012, the GDP of OECD nations grew 5.4% annually, whereas total primary energy consumption only grew 0.9% each year. Over this period, energy intensity of GDP in OECD nations has fallen 76% - refer Figure 3.2. Energy demand has been slowing considerably. Since 2000, OECD energy demand has been virtually flat – 0.05% average growth rate. This is the result of a number of OECD countries fully decoupling energy demand from GDP. For example, between 2005 and 2012 Japan grew its economy 3.8% annually on average, while energy demand fell 1.5%. Europe has a similar historical trend of increasing GDP and decreasing energy demand. Across the OECD, lower energy intensity has been chiefly a result of improving energy efficiency, i.e. maintain the same level of energy service using less per unit of energy. The more countries that manage to decouple, the weaker the relationship between global GDP and energy demand will be.

The traditional stages of economic development

The relationship between economic development and energy demand has a typical evolution, which consists of:

1) Rapid energy demand increases as agrarian-led economies shift to industrialisation;
2) Energy growth continues but more slowly as industrialised economies shift towards less energy intensive service based sectors and replace imports for domestic production; and
3) Per capita income reaches a ceiling beyond which any further increase has minimal to no impact on energy consumption.

At the macro-level, technological, efficiency and regulatory improvements mean economies' energy demand plateau and can even decline. Since the turn of the century, non-OECD GDP growth has been almost triple that of OECD nations. This trend is expected to continue because non-OECD nations are still very much in the process of developing their economies. Consequently, future GDP growth in non-OECD regions is central to much of the energy demand growth forecast by the fossil fuel industry.

Energy efficiency has been a successful energy management strategy in the OECD

The IEA's latest Energy Efficiency Report 2014, found that energy reduction due to efficiency improvements equalled 1337Mtoe for 11 IEA member countries in the OECD in 2011 (Figure 3.3) – this is equivalent to the total final energy consumption (TFC) of the EU in that year.[33] It also led to capital savings equivalent to US$743 billion. Major drivers of this efficiency contribution were improvements in heating, lighting and appliances in residential buildings and vehicle fuel economy standards. Efficiency improvements are a way to reduce the energy intensity of economic activity.

The widespread application of energy efficiency measures is a consequence of their low cost. Energy efficiency is often referred to as the 'first fuel' because its low cost should make its implementation a priority – Refer Figure 3.4.

[33] http://www.iea.org/Textbase/npsum/EEMR2014SUM.pdf. The 11 countries were Australia, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Sweden, the UK and the US.

Figure 3.3: Energy efficiency in 11 countries saved a continent's worth of energy

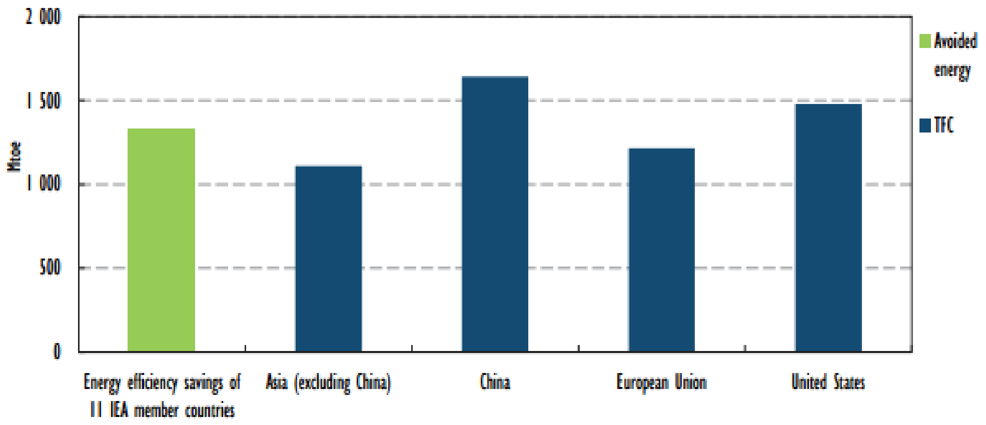
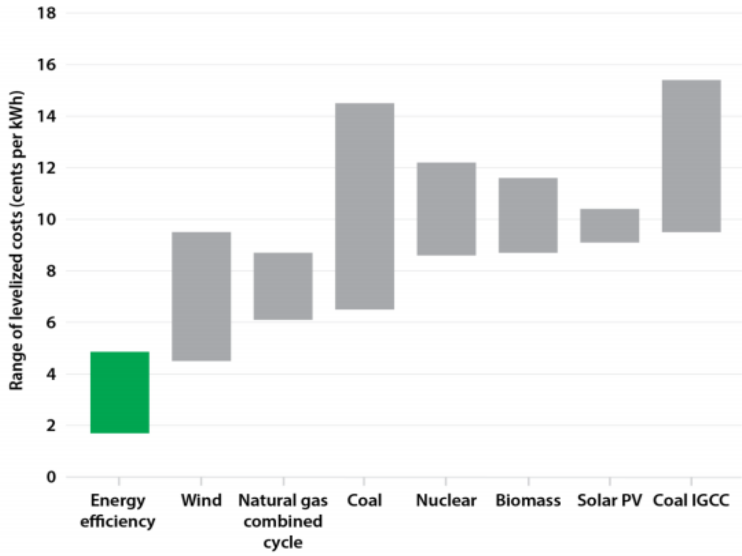


Figure 3.4: Energy efficiency is the 'first fuel'



Source: IEA Energy Efficiency Market Report, 2014

Some options even provide payback on the initial investment within the first year, meaning there is an immediate saving on annual costs. HSBC estimate investment opportunities totalling $365billion in 2012 for energy efficiency.[34] There are opportunities to set up financial structures which can facilitate implementing efficiency measures with longer paybacks. Forecasts see energy efficiency continuing to play a huge role in offsetting energy demand growth, particularly as a low-cost option in non-OECD developing countries.

Non-OECD countries tread a different energy path

The IEA's NPS foresees 97% of total primary energy demand growth between 2012 and 2040 coming from non-OECD regions.[35] In other words, potential growth markets for energy producers rely almost exclusively on non-OECD countries. Coupling of energy demand and economic growth in non-OECD countries, however, will not follow the same evolution as in OECD countries because the modern energy context is very different to that since industrialisation. Technological advances and more efficient ways of consuming energy mean the link between economic growth and energy consumption

[34] https://www.research.hsbc.com/R/20/K2kb6gL5ynU7
[35] http://www.worldenergyoutlook.org/publications/weo-2014/

in non-OECD states is already weaker than the equivalent stages in OECD nations in the past. This is evident because between 1980 and 2012, GDP grew 7.8% in non-OECD countries while energy consumption only grew at 3.2%.

Industry scenarios show energy intensity is already expected to halve by 2040

This context of efficiency gains in OECD and non-OECD nations means all forecasts see a degree of energy demand decoupling from GDP growth. But there is variation between companies and energy scenarios in the expected energy intensity of GDP.

Energy intensity is the ratio of GDP growth to energy demand. Figure 3.5 shows that fossil fuel companies (where data is available) and energy analysts broadly agree the energy intensity of global GDP will reduce by approximately 50% over the next two decades. This equates to energy intensity falls between -1.9% and -2.3% annually, with the IEA's 450 scenario requiring -2.8% annual improvements.

Figure 3.6 indicates that the industry sees global energy demand increasing by around a third with a doubling of GDP. Given the rate of GDP growth these organisations assume, (3% - 3.6% CAGR), this would occur within 20-24 years. There are differences in reaching this outcome:

- ExxonMobil have the most conservative forecast of energy intensity falls at -1.9% pa. This is the result of relatively strong energy demand growth, particularly in the short-term, and modest global GDP growth of 3% per year to 2040.
- BP and EIA GDP growth forecasts are similar to those of the other scenarios, but global energy demand remains more strongly coupled to economic growth. As a result, energy demand grows each year by 1.5% on average over the forecast period.
- The IEA 450 scenario shows the energy intensity trajectory required to meet a 2°C climate outcome while global GDP grows at 3.4% annually to 2040. This sees energy intensity improve by 2.8% each year as opposed to 2.3% in the NPS.

Figure 3.5: The industry expects energy intensity to halve by 2040[36]

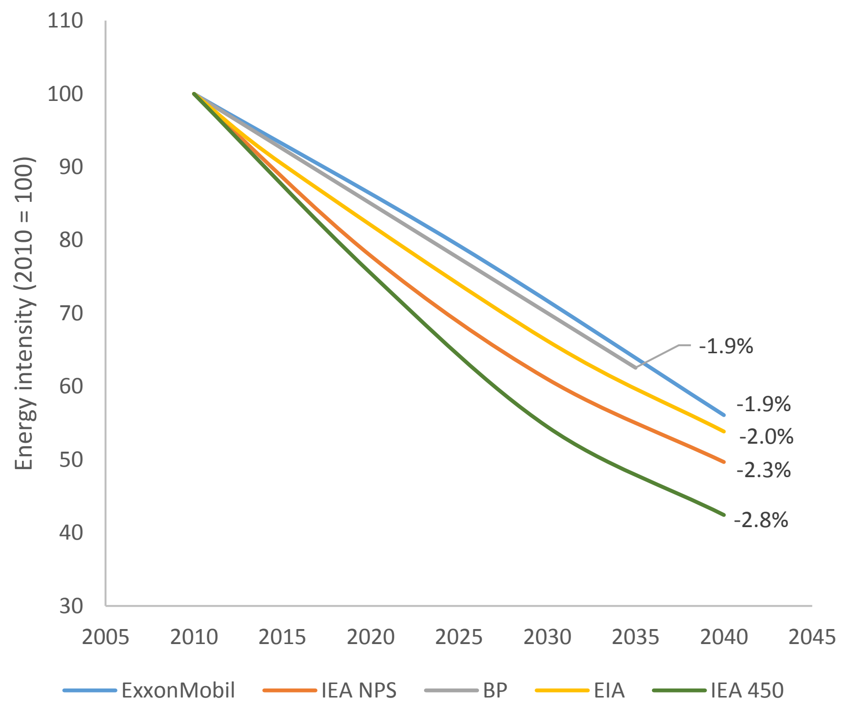
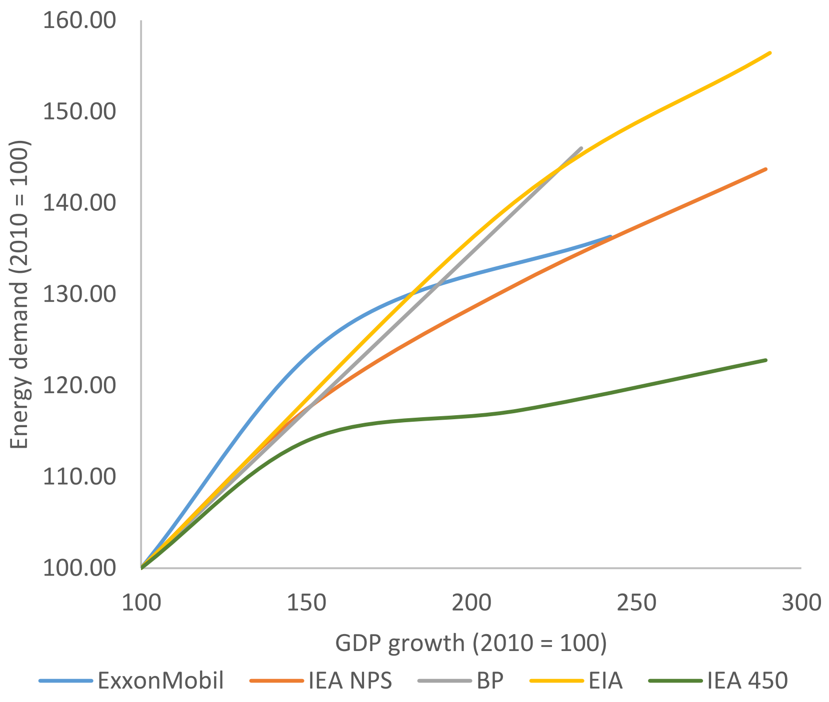


Figure 3.6: Industry ratios between energy demand and GDP growth[37]



Potential for further falls in energy intensity

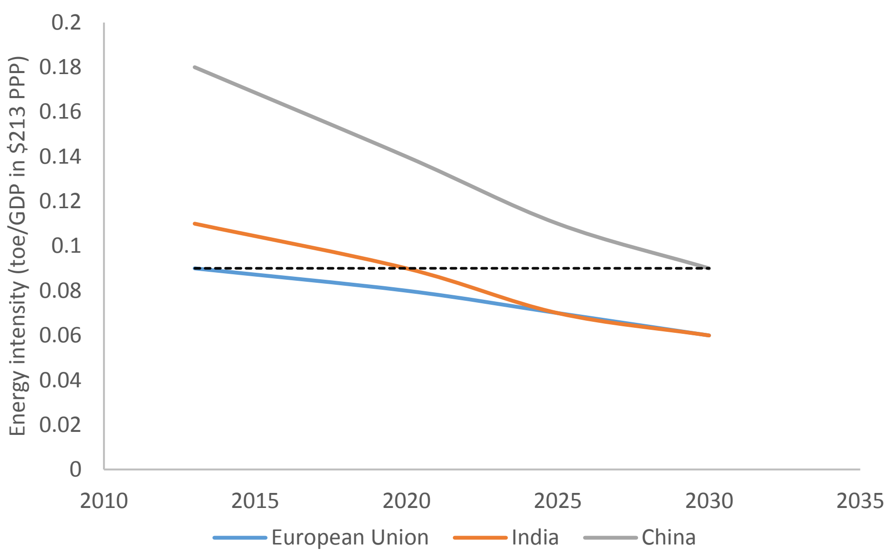
It is significant that of those who believe the energy intensity of the global economy will half by 2040, one is the US Energy Information Agency (EIA) - who disclose that their reference case is a 'business-as-usual trend estimate' which does not assume any new policies or regulations,[38] and another is the IEA NPS which should be viewed as a conservative central scenario shaped by only policy announcements that have been made and proposed, not those that

[36] BP calculations based on readings from graphs provided
[37] Curves are over each respective forecast period – all go out to 2040 other than BP which stops at 2035.
[38] http://www.eia.gov/pressroom/presentations/howard_04162012.pdf

are likely or could be applied in the future. It is highly likely that policy and technological factors will emerge that are not integrated into these forecasts. These drivers would serve to accelerate the rate at which energy demand decouples from GDP growth, resulting in deeper reductions in energy intensity than currently forecast.

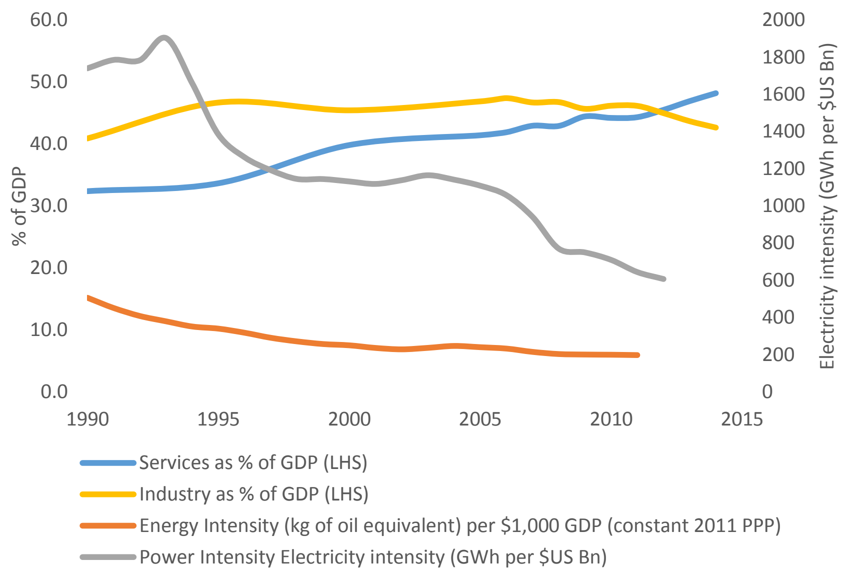
For example, China will be a key economic and energy growth centre in the future. Many forecasts appear somewhat conservative of the potential for energy intensity improvement in China. For example, the IEA INDC scenario, which sits between the NPS and 450 in terms of energy intensity (much like where the industry consensus is positioned – Figure 3.5), only sees China achieving an energy intensity in 2030 that is equal to where the EU is now - see Figure 3.7.

Figure 3.7: National energy intensity forecasts in IEA INDC scenario



Source: IEA Energy and Climate Change, 2015

Figure 3.8: A structural economic shift is occurring in China



Source: World Bank, 2015

This forecast seems conservative in light of the faster than expected economic transition in China. Between 2000 and 2012 annual energy demand in China increased on average by 0.84% for each per cent of GDP growth.[39] For the latter 5 years, from 2007 to 2012, lower energy demand growth has lowered this rate to an average of 0.68% energy demand growth per percent of GDP growth. Unofficial statistics suggest energy demand growth has slowed even

[39] Calculated from World Bank GDP and energy data

further, with growth amounting to 4.3% in 2012, 3.7% in 2013 and 2.6% in 2014.[40] This is compared to an average of 8.5% since 2000. For many this is a sign that China is undergoing an economic transition that is structurally changing the relationship of energy and GDP, in particular towards a service-based economy – refer Figure 3.8 – which is 6 times less power intensive than industry-led economies.[41]

Converting accelerated reductions in energy intensity into fossil fuel demand destruction

The IEA scenarios give a good insight into what could happen if deeper and faster energy intensity falls come to fruition in the global economy. Both the NPS and 450 scenarios assume 3.4% GDP growth to 2040, but the NPS sees energy intensity falls of -2.2% on average per annum while the 450 scenario is more advanced at -2.8% on average. Table 3.1 shows what this means for cumulative energy demand.

Table 3.1: Exploring how deeper energy intensity gains impact energy demand

	IEA NPS		**IEA 450**		
	Energy intensity %	Cumulative energy demand (Mtoe)	Energy intensity %	Cumulative energy demand (Mtoe)	**Difference in energy demand (Mtoe)**
2012-2020	-2.2%	127526	-2.6%	125469	**-2057**
2020-2030	-2.4%	286997	-3.2%	272951	**-14046**
2030-2040	-2.0%	462961	-2.5%	426113	**-36848**

The subsequent difference in energy demand is significant at 36848Mtoe cumulatively between 2012 and 2040, approximately three times global demand in 2012. A fall in energy demand of this scale has significant implications for fossil fuel demand – coal demand is approximately 42% down, oil demand down 32% and gas demand down 22%.

Conclusion

- The assumed energy intensity of GDP growth significantly impacts subsequent energy demand and CO_2 emissions. Industry and energy analyst scenarios of energy intensity falls range between -1.9% and -2.8% per annum to 2040.
- The energy intensity of key growth economies is expected to halve by 2040, but could fall more depending on the rate of transition to service-based economies and the utilisation of more efficient technologies within the energy system.

[40] http://uk.businessinsider.com/we-are-reaching-peak-energy-demand-2015-6?r=US&IR=T
[41] http://www.carbontracker.org/report/the-great-coal-cap-chinas-energy-policies-and-the-financial-implications-for-thermal-coal/

- Applying energy intensity gains of -2.8% reflects lower energy demand equal to 36848Mtoe to 2040 against an energy intensity assumption of -2.2%, assuming all else is constant. Demand for each of the fossil fuels falls by between 22% and 42% as a result.

BAU Assumption 4: Carbon intensity of energy remains high as fossil fuels maintain share

"The Paris agreement should certainly be geared around an end-goal of net-zero emissions but the realistic, albeit still aggressive, time span for this is 80+ years, not 35 years." David Hone, Shell Climate Change Advisor[42]

It is common that energy is conflated to mean fossil fuels, meaning the future of energy is expected to be very carbon-intensive. In reality, energy can be provided using a number of technologies, especially for power supply. Therefore, even where energy demand is increasing, this does not necessarily mean that demand for fossil fuels is increasing. The direction of travel from the G7 and many companies, cities and regions is already to phase out fossil fuels.

Conclusions

- Currently, fossil fuels make up 81% of global energy demand. Fossil fuel companies do not see this changing greatly over the next two decades. Most see fossil fuels making up three-quarters of energy by 2040; this share is 59% in the IEA 450, 2C scenario.
- This equates to conservative carbon intensity falls of approximately 0.4% per annum in energy industry forecasts. These scenarios exceed the initial commitments made by countries in their INDCs by up to 100GtCO_2, taking the world to 6°C of warming.
- Discussions of 'net-zero' emissions have featured in recent UN climate talks; such a deep decarbonisation of the global energy system would have serious implications for the demand of fossil fuels.
- For example, a 2°C scenario assumes carbon intensity falls per annum of 1.8% compared to falls of 0.4% in a central scenario. This results in fossil fuel demand being 4867Mtoe lower, with coal in particular being hit hard.

Fossil fuel companies don't foresee a change to the status quo

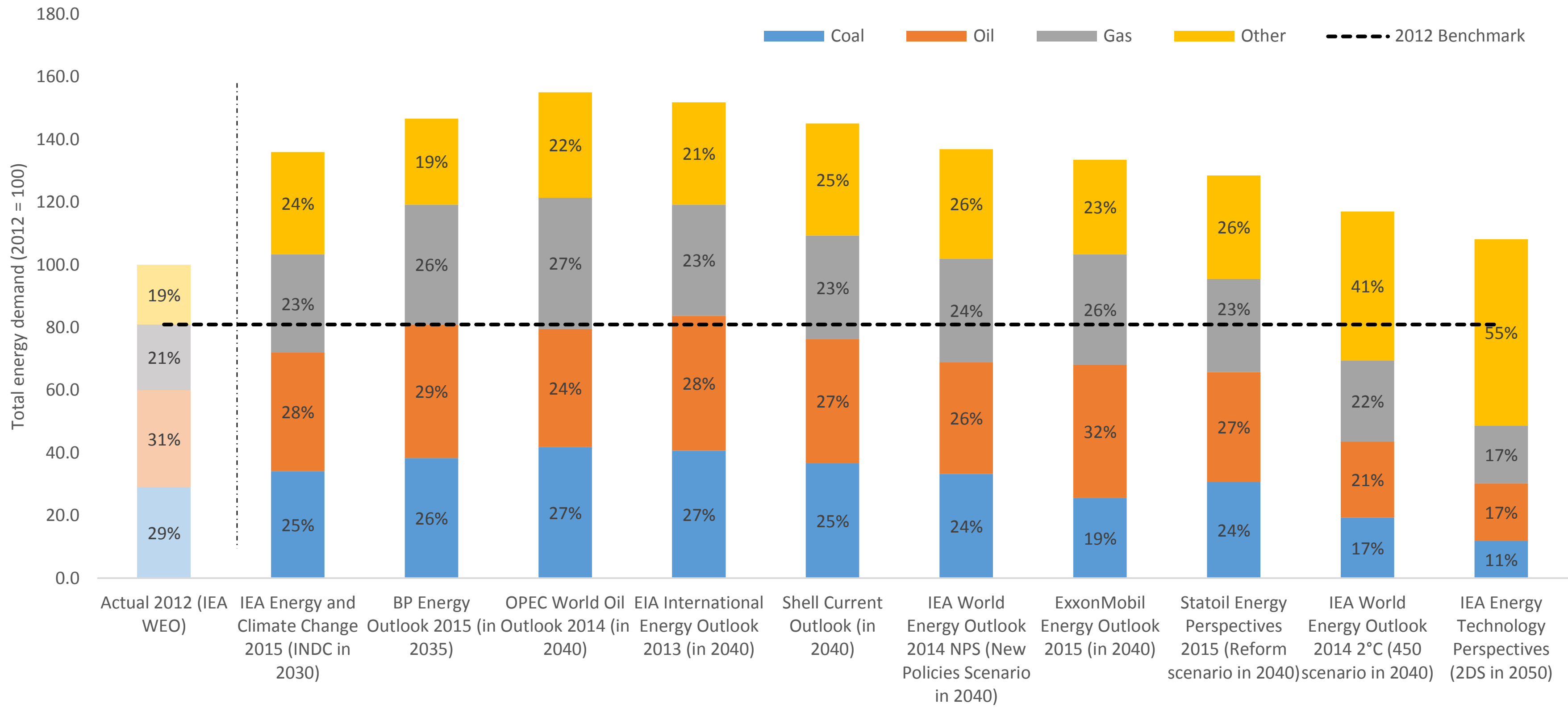
Our analysis so far has posited the downside potential of future energy demand in the first three components of the Kaya Identity. The final ratio is the carbon intensity of energy supplied to meet this demand, i.e. CO_2 emissions per unit of energy. In some narratives, energy is conflated to mean fossil fuels, reflecting an assumption that fossil fuels will continue to dominate energy supply. This standpoint ignores the likelihood that other technologies will

[42] http://blogs.shell.com/climatechange/2015/01/

contribute significantly to supply energy in the future, particularly power. It ignores the fact that carbon intensity is reducing in many regional markets. What is more, recent statements from the G7 and the latest draft of the potential international climate agreement suggest there is a clear imperative that many regions will aim for net zero greenhouse gas emissions by 2050, as captured by the Track0 grouping of governments and businesses.[43]

These signals are contrary to the notion that the majority of energy will still be supplied by fossil fuels. Figure 4.1 shows that, in spite of the arguments against, fossil fuel companies and energy analysts still see approximately three quarters of future energy demand being met by fossil fuels.

Figure 4.1: Breakdown of future energy supply[44]



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43 Track0.org

44 2012 baseline is taken from the IEA World Energy Outlook. For forecasts beginning in 2010, the CAGR over the entire forecast period was applied to the 2012 start year.

Demand for fossil fuels will increase

- All energy industry scenarios see fossil fuels meeting approximately three quarters of future energy demand, this reflects a small reduction from the 81% of energy supplied by fossil fuels in 2012;
- However, combined with growth in total energy demand, fossil fuel demand is set to increase in all scenarios (apart from in 2°C outcomes);
- BP and Shell's 'Current Outlook' both see high energy demand growth and high energy shares of fossil fuels in the future.
- ExxonMobil and Statoil's central Reform scenario both demonstrate lower levels of energy demand growth. ExxonMobil, however, do not foresee this adversely affecting demand for oil and gas, however. In fact it is quite the opposite, as oil grows to 32% of energy demand and gas to 26% - both shares are higher than any other company expects. This growth in energy share comes at the expense of coal (19%).
- Figure 4.1 shows absolute fossil fuel demand decreases in the IEA's 2°C 450 scenario as coal, oil and gas's share of energy demand falls to 59% by 2040. To 2050, fossil fuel's share of the energy mix falls to 44% in a 2DS.
- At 76% of energy supply from fossil fuels by 2030, the IEA's INDC scenario estimates these climate commitments do not achieve a 2°C outcome.

Differentiating between fossil fuels

- One might expect that coal would suffer more amongst the fossil fuels as it is more carbon intensive but there is in fact limited variation in how each fuel is affected. Aside from the ExxonMobil outlook and the 450 scenario (as mentioned above), coal typically loses only 2-5% of its 29% market share. However when you consider that in the US, coal has lost 12% of market share to gas (+8%) and renewables (+4%) in less than 10 years this seems to underestimate the potential for change.
- Oil struggles to maintain its market share in any of the scenarios down to falling by 10% in the IEA 450 scenario (again with ExxonMobil as the exception). This will be surprising to some given it is viewed as having less potential for substitution. However, it could experience more rapid fleet turnover and consumer choice than the power sector.
- Gas at most gains 6% of market share, with the lowest gain of 1% in the IEA 450 scenario. This reflects that whilst there is growth for gas in a low carbon scenario, it is limited if there is still a CO_2 emissions restriction to consider. The limited switch to gas may also disappoint some in the sector, as it only makes limited inroads into coal's market share, only overtaking it in the ExxonMobil and IEA 450 scenario.
- Any claims that three-quarters of energy will come from fossil fuels in 2040 can disguise significant variation across the fuels. So for the coal sector, there is a big difference between a statement that fossil fuels will still have three-quarters of the market in 2040 according to the IEA; and a statement coal that may only have 17% of the market in 2040 according to the IEA 450. Both could be considered accurate, but give very different impressions.

Existing INDC commitments not a factor

The energy industry forecasts the future energy mix to have a high carbon intensity, meaning subsequent CO_2 emissions will be high. The IEA's INDC scenario estimates the energy and CO_2 pathways likely to come out of UNFCCC negotiations at COP21. This IEA scenario is likely to be conservative because it is only includes submitted INDCs from countries that make up 34% of global energy-related CO_2 emissions and estimates likely contributions from other key emitters like India and China which could be underestimations.[45] This scenario reflects the minimum pathway of CO_2 mitigation that the world's governments will agree to and so is a huge signal of future political intention on climate change. However, these commitments appear to be being ignored by fossil fuel companies so far.

Table 4.1 shows over just the next 17 years, fossil fuel companies believe CO_2 emissions could amass to anything between 11.2GtCO_2 and 100.8GtCO_2 above the conservative IEA INDC scenario. For companies to forecast and plan for anything higher than this absolute minimum is verging on denial of the materiality of any climate action, as it only captures climate policy commitments, let alone air quality measures, technology advances and market shifts. Table 4.1 confirms that no company even sees the IEA NPS CO_2 emissions trajectory being achieved by 2030.

Table 4.1: Cumulative CO_2 difference to INDC (2013-2030)[46]

	TOTAL CO_2 EMISSIONS, 2013-2030 (GTCO_2)	CUMULATIVE DIFFERENCE TO THE IEA INDC SCENARIO (GTCO_2)
IEA INDC	575.9	**0**
IEA NPS	587.1	11.2
EXXONMOBIL	596.0	20.1
STATOIL	596.7	20.8
BP	613.7	37.8
EIA	614.8	38.9
SHELL MOUNTAINS	631.1	55.2
SHELL OCEANS	676.7	100.8

45 https://www.iea.org/publications/freepublications/publication/WEO2015SpecialReportonEnergyandClimateChange.pdf

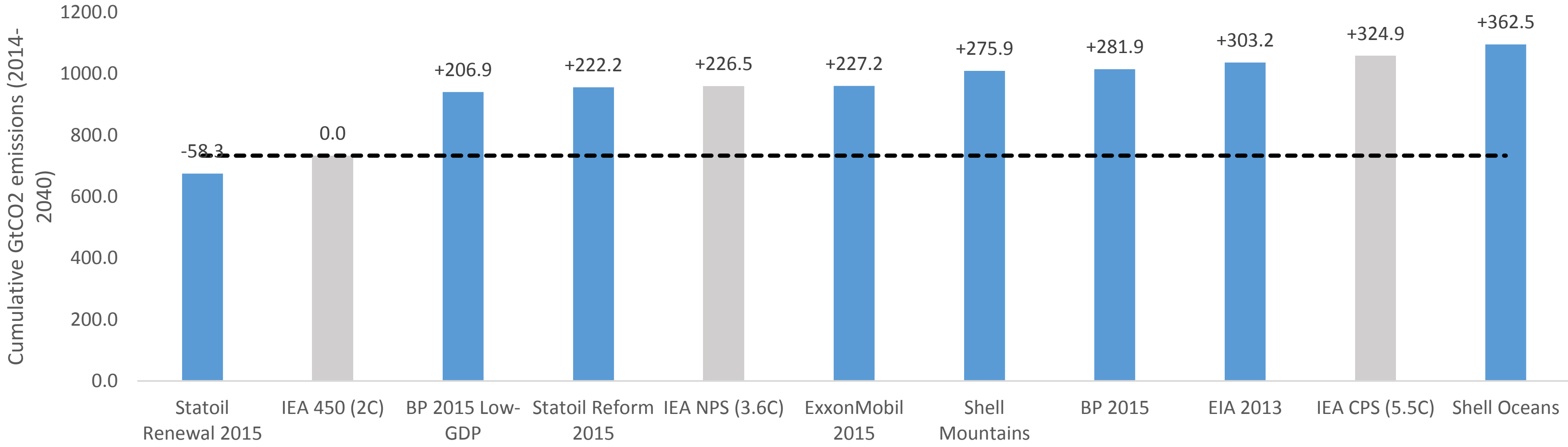
46 For companies that do not give a 2013 CO_2 emissions value, linear growth is assumed between two given emissions values and that value is used in the calculation. Again, we use emissions values that have been adjusted to the IEA NPS for consistency.

"We believe that governments will carefully balance the risk of climate change against other pressing social needs over the Outlook period…and that an artificial capping of carbon-based fuels to levels in the "low carbon scenario" is highly unlikely" – ExxonMobil, 2014[47]

The industry expects up to 6°C of warming

The IEA state that their CPS is consistent with the 6DS scenario in their Energy Technology Perspectives series which reflects 'potentially devastating global average long-term temperature increase of around 5.5°C'.[48] The IEA CPS models CO_2 emissions 44% higher than their 2°C/450 scenario by 2040 (refer Figure 4.2).

Figure 4.2: What do industry forecasts mean in °C? (2014-2040)[49]



NB: Those scenarios which explicitly state temperature rise implications have been filled in a different colour to aid comprehension.

[47] http://cdn.exxonmobil.com/~/media/global/files/other/2014/report---energy-and-carbon---managing-the-risks.pdf
[48] http://www.iea.org/etp/etp2015/
[49] Industry forecasts of CO_2 emissions have been adjusted to historic CO_2 emissions levels as published in the IEA's World Energy Outlook 2014. These adjustment values can be found in Appendix 2.

Shell's Oceans scenario greatly exceeds this difference to 2°C, hereby implying a long-term temperature increase greater than 5.5°C. Emissions in Shell's Mountains and BP's 2015 Outlook roughly split the IEA's NPS and CPS suggesting a climatic future approximately 4.5°C higher over the long-term. These are the worst offenders, but all the scenarios featured in Figure 4.2 greatly exceeding the 2°C target of the UNFCCC. This suggest downside alternatives are not being adequately integrated into these models.

Global carbon intensity forecasts – Shell are out on their own

Carbon intensity is a measure of the amount of CO_2 emitted per unit of energy supplied. As such, it can give a useful indication of the fuel mix expected to supply future energy demand. Figure 4.3 shows that all industry forecasts see the carbon intensity of energy falling in the future. Gains range from -0.1% to -2.3%. The US EIA is the most conservative on carbon intensity improvements. Statoil, ExxonMobil and potentially BP all seem aligned to the IEA NPS by 2040, while Shell's Mountains and Oceans scenarios forecast carbon intensity improvements even beyond the IEA INDC. On the surface, these assumptions from fossil fuel companies seems laudable, however, the carbon intensity calculation only tells half of the story.

Figure 4.3: Carbon intensity of energy forecasts

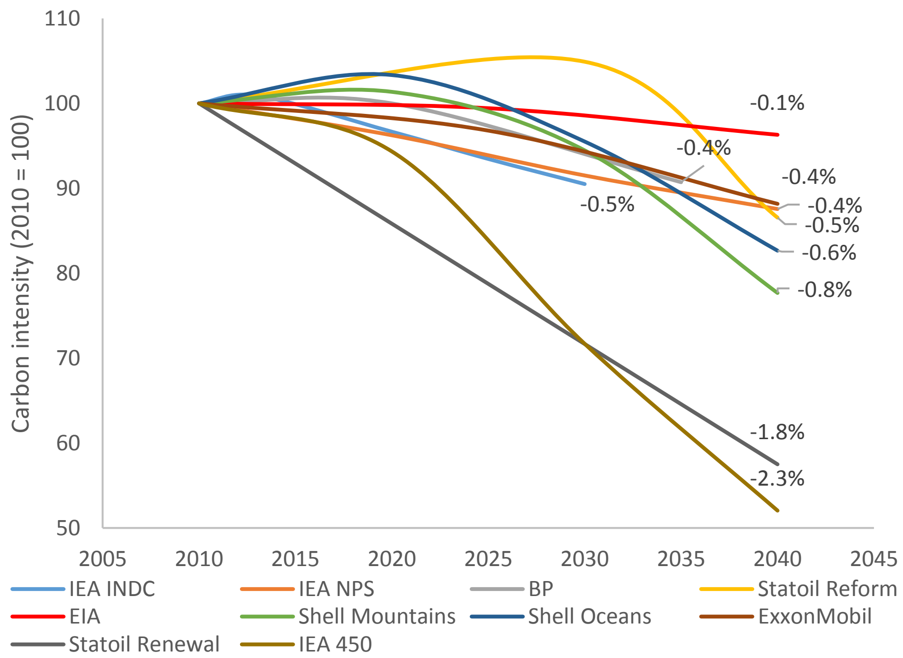
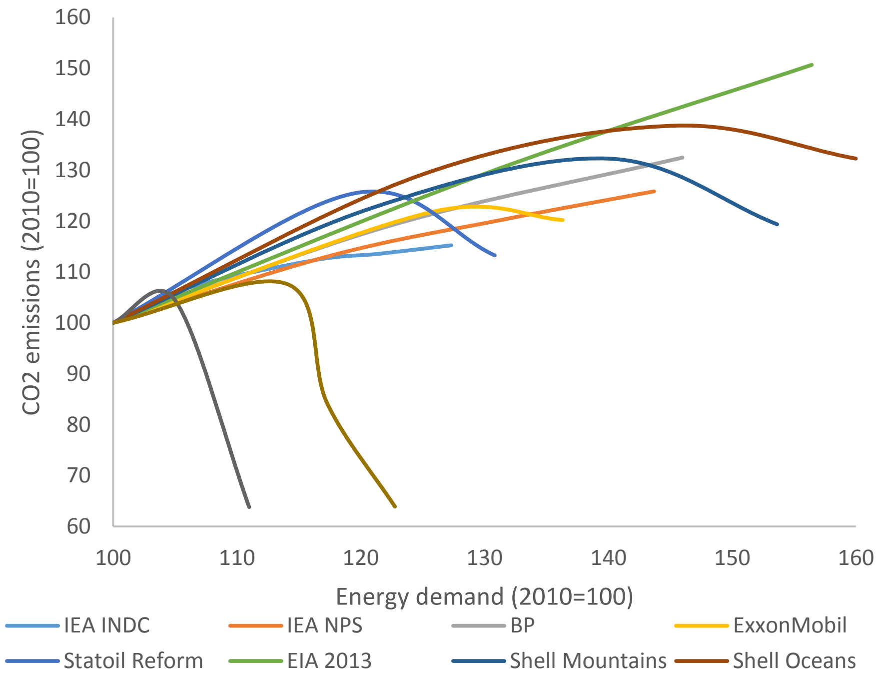


Figure 4.4: Energy demand and CO_2 emissions to 2040, unless stated



Carbon intensity is a calculation of two component parts – total primary energy demand and CO_2 emissions. Figure 4.4 splits carbon intensity forecasts into these components. It shows that Shell achieve a low carbon intensity in their Mountains and Oceans scenarios by forecasting partlicularly strong growth in primary energy demand consistent only with the US EIA. Aside from Statoil's Reform scenario, no other company aligns with the IEA NPS trajectory for CO_2 emissions. Statoil's Reform scenario, ExxonMobil's Outlook and the IEA NPS only result in carbon intensity improving 12-13% over 30 years. For example, BP is consistent with the IEA NPS in terms of carbon intensity (Figure 4.3), not so much down to a low CO_2 emission assumption, but rather a high expectation of future energy demand. Figure 4.4 confirms that Statoil is the only company that forecasts CO_2 emissions in line with the IEA INDC, albeit 10 years later in 2040. Their Reform scenario sees a steep decline from a high 2030 peak that means cumulative emissions over time still exceed that of the INDC scenario. The timing of the peak in emissions is critical to when fossil fuel demand drops off and delivering a low carbon scenario.

The decarbonised energy system in a 2°C world presents a different future for fossil fuels

Significant reductions in the carbon intensity of the global energy system are required to achieve the IEA 450 scenario (-2.3% carbon intensity) and keep climate change to 2°C. The current draft UN climate text published in Geneva in 2015 frames these cuts as achieving 'net-zero' and/or 'near-zero' emissions. When exactly the global energy system must achieve net-zero emissions is dependent on how quickly we move away from carbon intensive energy fuels in the next five to ten years. Broadly speaking, studies show that to have a high chance of greater than 85% of limiting global warming to 2°C, CO_2 emissions from fossil fuels and industry need to be zero by the 2040s and certainly no later than 2070.[50]

There have been a number of studies at different geographical scales looking at what energy supply could feasibly look like in a heavily decarbonised world by 2050.[51] Figure 4.5 compares the global fossil fuel share of primary energy demand in two deep decarbonisation scenarios to fossil fuel industry forecasts. The most aggressive scenario is Deng et al.'s (2012) study which presents a pathway to a 'fully sustainable energy system', meaning a zero carbon power system and 5% of total energy coming from fossil fuels in industry, building and transport sectors. Clearly all industry forecasts exceed that of Deng et al., but of those that go out to 2050, this disparity is greatest to Shell's Current Outlook which sees fossil fuels supplying 70% of energy demand in 2050, as opposed to 5%. Deng et al. (2012) state their scenario 'is considered achievable because it is based on currently available technology and realistic deployment rates'.[52] For example, it assumes wind and solar capacity grows between 25-30% each year. This is ambitious growth to 2050, but in the context of an average growth in wind of 25% and 45% for solar over the past decade, it is not impossible. Deng et al.'s (2012) study emphasises that deep decarbonisation pathways are worth consideration and that it is not certain fossil fuels will maintain their share of primary energy demand.

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[50] http://climateactiontracker.org/assets/publications/briefing_papers/CAT_Bonn_policy_update__final.pdf

[51] For example see those referenced in Professor John Wiseman's Pathways to Low Carbon Economy, March 2014: http://www.visionsandpathways.com/wp-content/uploads/2014/05/Wiseman_Zero-Carbon-Economy-Transitions_290514.pdf;

[52] Deng, Y., Blok, K. and van der Leun, K. (2012) Transition to a fully sustainable global energy system. *Energy Strategy Reviews, 1, 109-121.*

Figure 4.5: Deep decarbonisation pathways see phase-out of fossil fuels

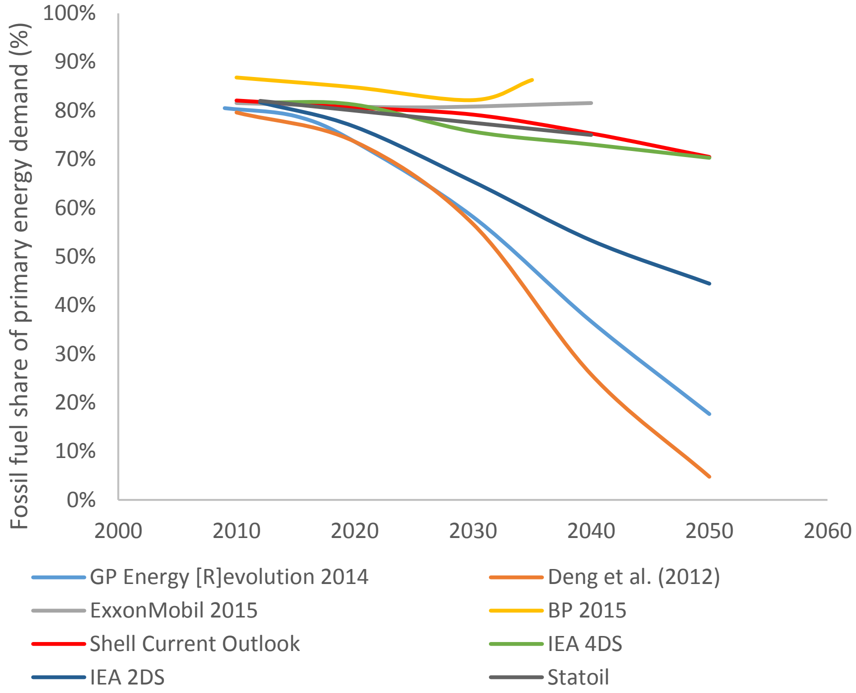
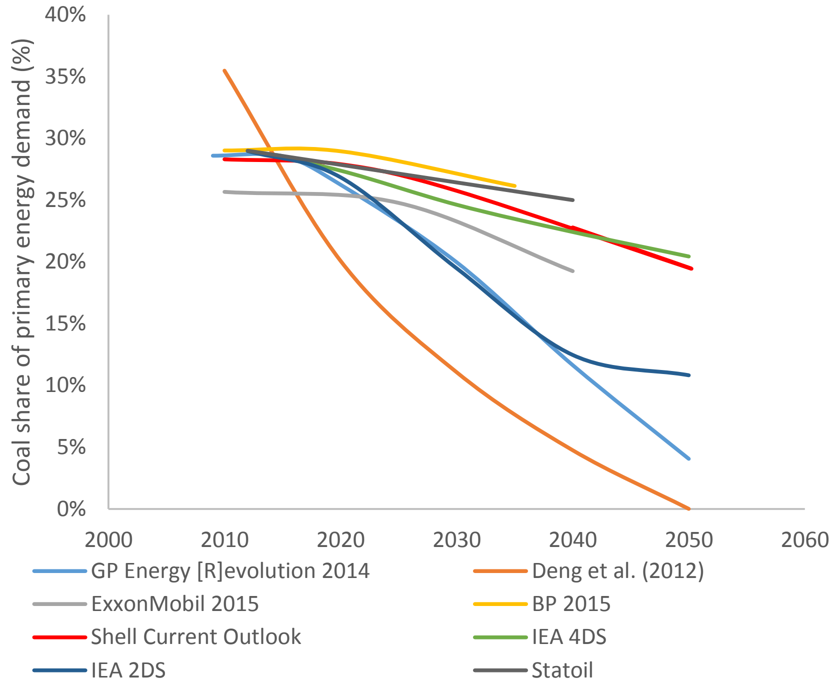


Figure 4.6: Coal's share of energy demand suffers under climate constraints[53]



Converting carbon intensity falls to 2°C into fossil fuel destruction

Achieving carbon intensity reductions in line with a 2°C trajectory as opposed to an average industry expectation reflects huge differences in the prospects of fossil fuel demand. To illustrate this fact, we compare the IEA NPS (carbon intensity falls of -0.4%) and Statoil's 2°C Renewal scenario (carbon intensity falls of -1.8%).

[53] Figure 3.5 shows that fossil fuels make up 5% of primary energy demand in 2050. Deng et al.'s does not break down what comprises this 5%. Hence in Figure 3.6 we have to assume that coal's share of energy is zero. One should assume that coal makes up some part of the 5% of total energy supply from fossil fuels displayed in Figure 3.5, we do not know how much, however.

Table 4.2: Impact in 2040 of assuming accelerated carbon intensity reductions

	STATOIL 2°C RENEWAL		IEA NPS		DIFFERENCE IN FOSSIL FUEL DEMAND (MTOE)
	Share of total energy demand	Demand (Mtoe)	Share of total energy demand	Demand (Mtoe)	
COAL	14%	1978	29%	4448	-2470
OIL	24%	3391	31%	4761	-1370
GAS	24%	3391	21%	4418	-1027
RENEWABLES	11%	1554	5%	918	636

Table 4.2 shows the different outcomes from scenarios that assume very different carbon intensity gains to 2040. In total, fossil fuel demand is 4867Mtoe lower in Statoil's Renewal scenario than the IEA NPS. Demand for fossil fuels is markedly less while penetration of renewable energy technologies is more than double.

Conclusions

- Currently, fossil fuels make up 81% of global energy demand. Fossil fuel companies do not see this changing greatly over the next two decades. Most see fossil fuels making up three-quarters of energy by 2040; this share is 59% in the IEA 450, 2C scenario.
- This equates to conservative carbon intensity falls of approximately 0.4% per annum in energy industry forecasts. These scenarios exceed the initial commitments made by countries in their INDCs by up to 100GtCO_2, taking the world to 6°C of warming.
- Discussions of 'net-zero' emissions have featured in recent UN climate talks; such a deep decarbonisation of the global energy system would have serious implications for the demand of fossil fuels.
- For example, a 2°C scenario assumes carbon intensity falls per annum of 1.8% compared to falls of 0.4% in a central scenario. This results in fossil fuel demand being 4867Mtoe lower, with coal in particular being hit hard.

Whether one foresees carbon intensity falling in line with fossil fuel industry expectations or in line with a 2°C target is determined by assumptions of future coal, oil, gas and renewable energy prospects. It is also dependent on the perceived likelihood of transformational factors having a paradigm shifting impact on the energy system.

Chapters 5 to 9 takes each of these determinants of carbon intensity and examines the drivers of potential downside fossil fuel demand in each. Having presented the case for deeper falls in carbon intensity, we then apply this ratio in the Kaya Identity, along with those of population, GDP per capita and energy intensity, to understand the CO_2 implications of potential downside fossil fuel demand in Chapter 10.

BAU Assumption 5: Renewable energy technologies do not penetrate at speed or scale

The economics of renewables are constantly changing. In calculating comparable marginal costs, it is necessary to make assumptions about capital costs, load factors, and lifetimes. Due to the limited track record of the sector, and the constantly evolving technology, initial assumptions could prove conservative.

"I grant we have made mistakes. We were late entering the renewables market – possibly too late." Chief Executive Peter Terium commenting on RWE's £4bn write-down to the value of its European power plants, March 2014.[54]

Key Findings

- The growth of power generation from wind and solar has been consistently underestimated by the IEA. More fundamentally, a lack of consistent and transparent measurement of renewables' contribution to the energy system makes it incredibly difficult to formulate a coherent picture of future demand.
- Component costs for onshore wind and solar photovoltaics (PV) have made rapid progress and – on a levelised-cost basis (LCOE) – are in certain geographies already, or close to being, cost-competitive with coal and gas power generation.
- If current solar generation is being underestimated by 50%, as small-scale generation is not included by many institutions, then the LCOE will have reduced by 25% more than expected.
- If the solar load factor used in a model is increased by 5% it can result in the LCOE reducing by a quarter.
- Synergies between renewables, storage facilities and improved girds are changing the economics of power generation and market re-structuring is required to accommodate this.

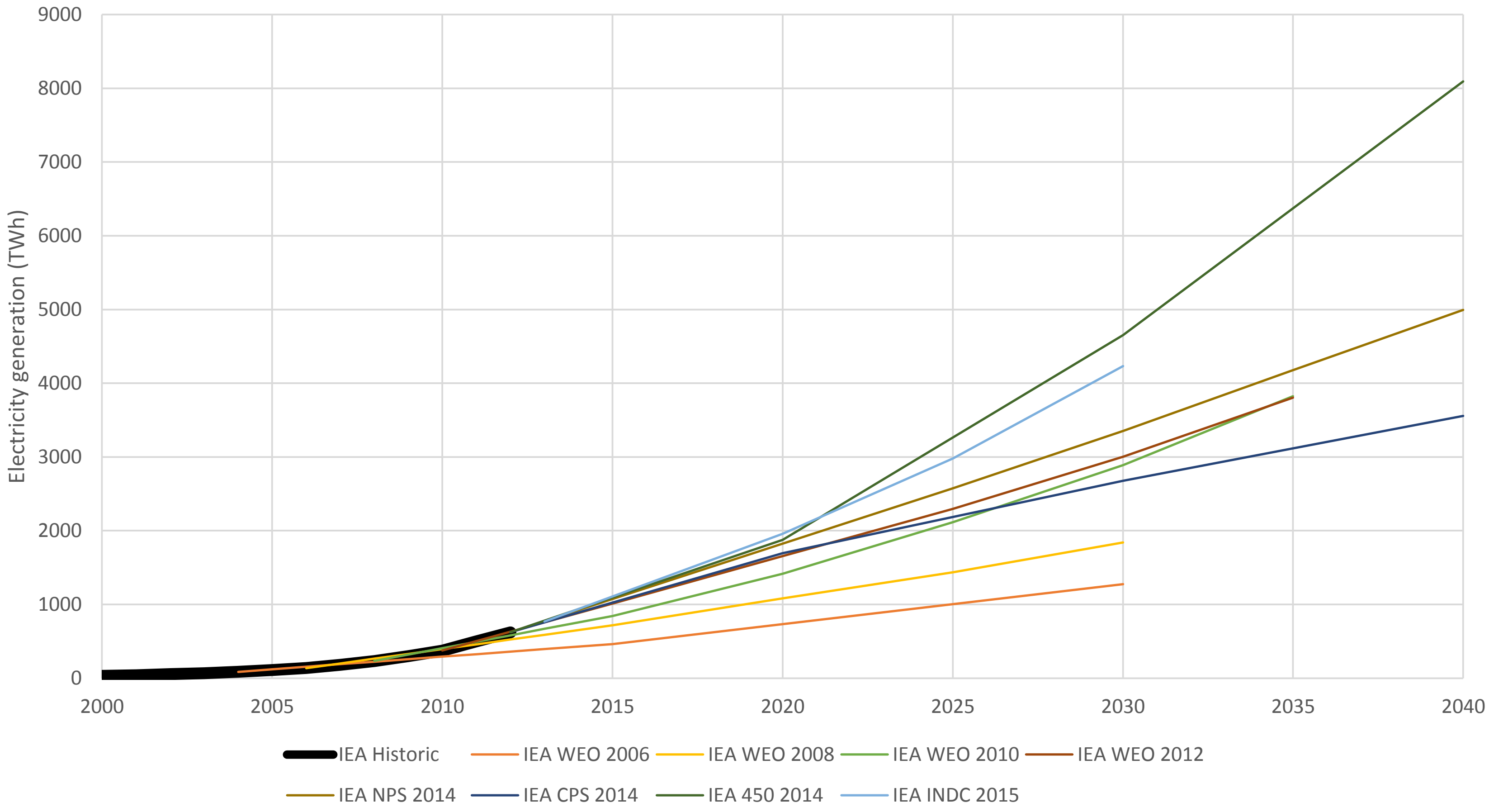
How accurate have previous predictions of renewables growth been?

The IEA's forecasts of future renewable demand serve as a benchmark and help inform a discussion around industry comparisons. Figure 5.1 below, shows how IEA forecasts for electricity generated from wind and solar sources have evolved over time. Ignoring minor inconsistencies - such as differing historic starting points, due to retrospective recalculations - it is clear with hindsight that growth has been significantly underestimated. As a result the IEA has

[54] http://www.telegraph.co.uk/finance/newsbysector/energy/10675543/UK-among-RWE-woes-as-it-posts-first-loss-since-1949.html

continued to increase its estimates as time has progressed. This partly reflects the challenges inherent in forecasting, particularly with technologies for which growth is so unpredictable and potentially so rapid.

Figure 5.1 How IEA WEO projections of solar plus wind generation have evolved since 2006[55]



[55] For old WEOs, the Reference Case has been plotted. References to solar include PV and Concentrated Solar Power (CSP)

What rate of renewables generation growth do models currently indicate?

Comparing apples with apples?

Figure 5.2 overleaf shows some of the projections for wind and solar generation from a range of industry scenarios. We have endeavoured to show them on a comparable basis, within the constraints of the data available. The projections do not all start from the same date or level and some are based on long-term compound annual growth rates (CAGRs) rather than more detailed information. Additionally, the classification of renewables can differ between companies. It was not possible to identify clear levels or trends just for solar and wind from BP and ExxonMobil's outlook, as they are grouped together with other renewables. Moreover, the figure used to display the contribution of renewables to the final energy mix also differs between companies. For example, the IEA's most accurate figure is 'electricity generation'; BNEF's is 'power generation'; and fossil fuel companies typically reference renewables as a proportion of total primary energy demand or total final consumption. Shell is an exception as they measure final consumption of electricity. The lack of transparency and consistency around the precise definitions of these measures is a crucial obstacle to comparing the evolution of renewables. It makes it difficult to produce a comparative analysis and means their outlooks for individual technologies are not indicated.

Annual growth rates

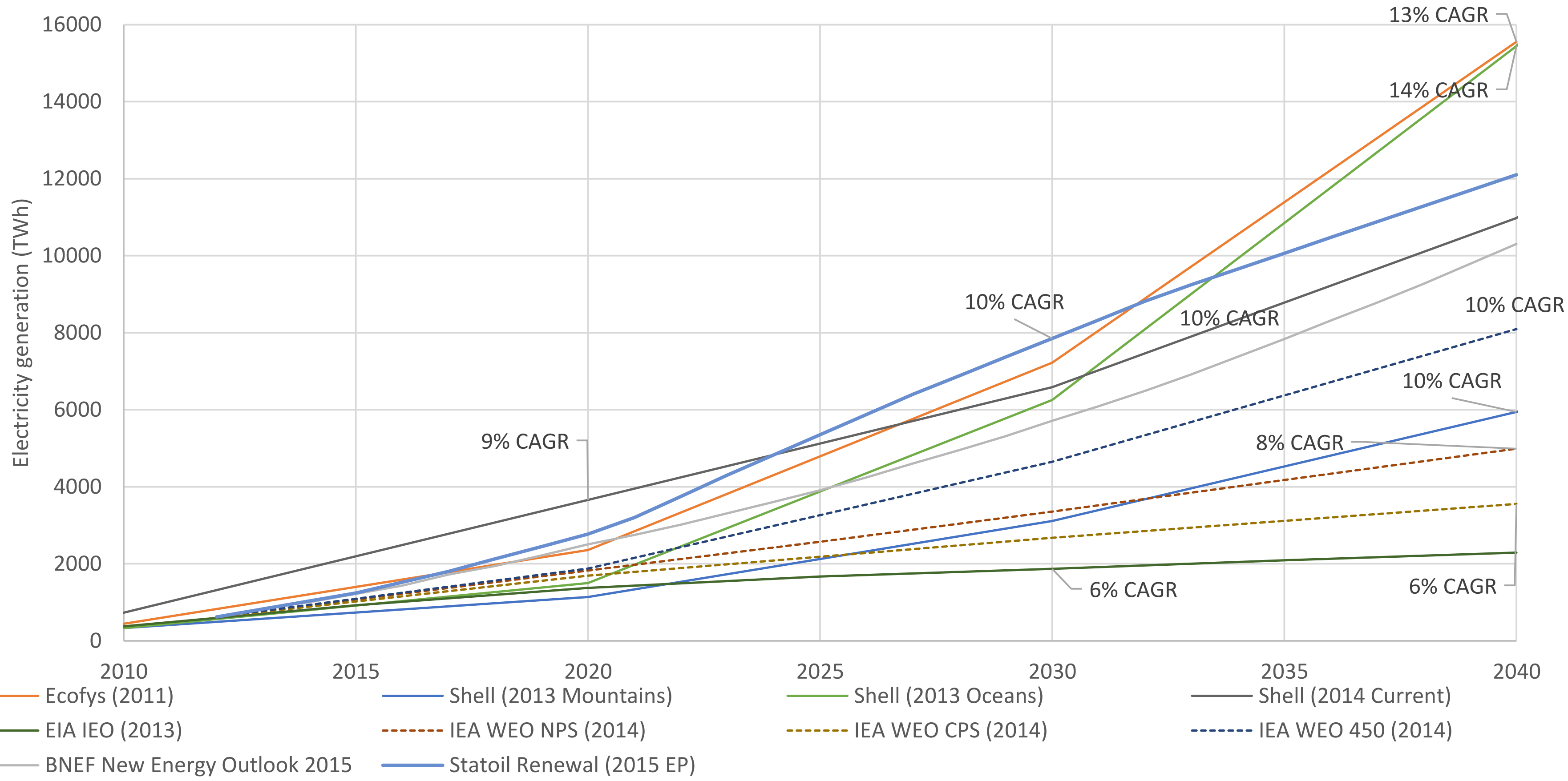
By using the data available, it is possible to compare the CAGRs each scenario expects for renewables growth. These start in different years and at different levels. Figure 5.2 compares the average annual growth rate between 2010 and 2040, giving a picture of which scenarios are more optimistic for renewables. A comparison of these CAGRs indicates three groups of scenarios: First the IEA CPS and NPS and EIA scenarios with 6-8% CAGR; second the IEA 450, Shell Outlook, BNEF and Statoil Renewal scenarios with roughly 10% annual growth, and finally more aggressive scenarios such as Shell Oceans and Ecofys, with 13-14% growth. It is also worth noting that these higher growth scenarios are non-linear and see the rate of growth increasing over time. This suggests the IEA and EIA may still have some catching up to do in terms of renewables possibilities.

Strong renewables growth does not necessarily equal lower fossil fuel demand

Shell Oceans is the most aggressive industry scenario for future levels of renewables generation, with almost double the IEA 450 level in 2040. But as we have noted in the previous section on carbon intensity, many of the company outlooks have much higher total energy demand, so this renewables growth is not necessarily displacing fossil fuels but meeting higher overall demand. The BNEF, Ecofys, Statoil Renewal and IEA 450 scenarios are consistent with lower levels of energy demand growth and therefore their higher renewables growth would have an impact on fossil fuel demand. This is an important detail to understand why the incumbents see little impact on their businesses in their outlooks where energy demand continues to grow at higher rates. They are not combining higher rates of renewables growth with lower projections of energy demand growth.

There has been renewed pressure from investors and stakeholders engaging with the energy sector to understand scenarios which limit global warming to 2^{o}C. Statoil have already produced a scenario more aligned to a high renewables rollout and more companies are expected to follow. Statoil's projection for solar and wind in its Renewal scenario for 2040 is estimated to be 11000 TWh, which is around 4000 TWh higher than the 6935 TWh foreseen in the IEA 450 scenario. Bloomberg New Energy Finance's latest outlook is slightly less aggressive with its forecast for renewable electricity generation, but still markedly more bullish than the IEA, anticipating roughly 5800 TWh and 1300 TWh more than the IEA NPS and 450 scenarios respectively.

Figure 5.2 Comparing annual growth rates for wind and solar electricity generation



What factors determine the level of renewables in models?

Policy & Technology virtuous cycle

Policy developments, such as the INDCs, are easier than technological developments for energy modellers to translate into changes in the energy mix than technological advances. For example the IEA INDC scenario is driven by national policy announcements in the run up to the Paris 2015 Conference of the Parties (COP) in which countries clearly stipulate carbon intensity or renewable energy generation targets. Such policy signals lend themselves to a more linear approach to modelling energy futures. The advancement of new technologies tends to be less predictable and more tumultuous and is therefore often under-weighted in forecasts. Furthermore, technology and policy drivers are closely inter-related. For example, policy-driven increases in demand and supply serve to reduce costs and further increase renewable energy uptake. So far, these factors have tended to mean that the rate of growth can outperform predictions within a few years.

What potential is there for higher rates of renewables generation?

Figure 5.3 The S-curve of technological and market maturity for energy technologies[56]

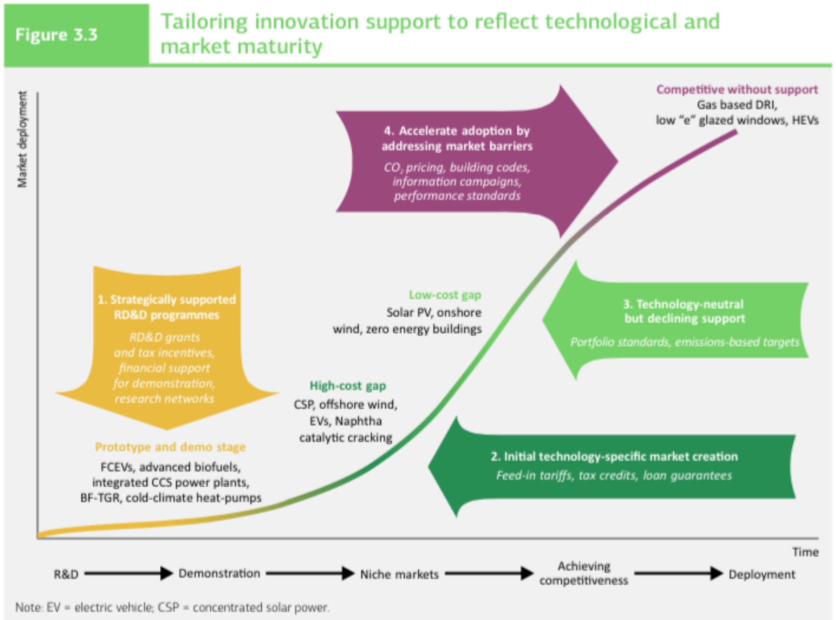
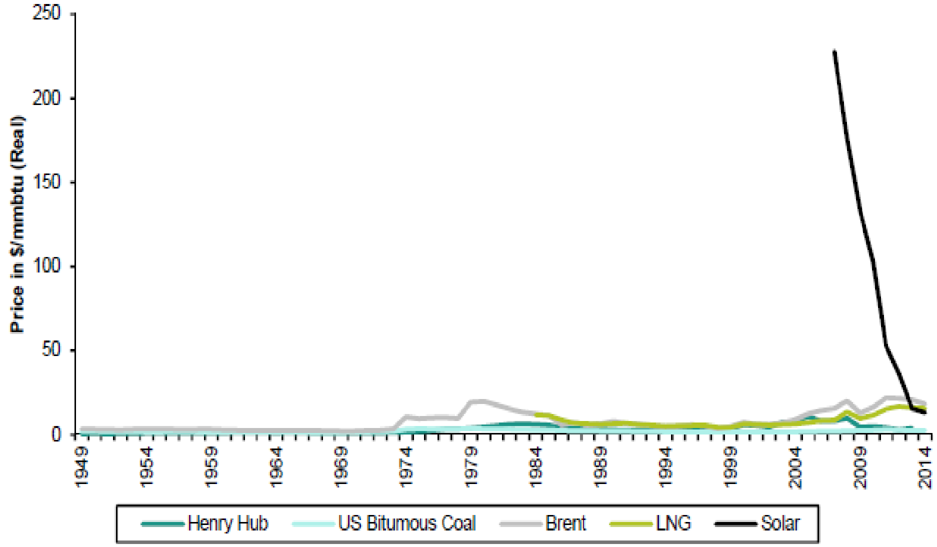


Figure 5.3 indicates where different technologies are on the S-curve of development. It shows that offshore wind and concentrated solar power (CSP) have not reached the same level of deployment as their cousins onshore wind and solar PV. This shows that there is still significant cost-down potential to come with growing market deployment. Alternatively, of course, inadequate support for these technologies may mean that they fail to progress beyond their present stage of being a niche market. This applies to all potential low carbon technologies. It is disappointing that to date CCS has not progressed beyond the first stage of R&D.

56 http://www.iea.org/etp/etp2015/

Figure 5.4 Welcome to the Terrordome – Solar's cost reduction in context[57]



Source: EIA, Bloomberg L.P., 2014 BP Energy Survey, and Bernstein estimates and analysis.

Component costs falling at rapid rates

Many studies have analysed the rate of cost reduction experienced by wind and solar photovoltaics in recent years. BP acknowledges that solar PV and wind have followed 'well-established learning curves' and through 'technological advances, learning-by-doing, and economies of scale', costs will continue to fall significantly throughout their Outlook period to 2035.[58] Alliance Bernstein's 'Terrordome', featured in Figure 5.4, displays the product of this growth. Here, Bernstein's analysis discusses the evolution of energy production, whereby solar, a technology rejected throughout the 20th century for being cost-ineffective, has now joined fossil fuels in the group of cost-effective, scalable energy generation.

Crucial to the potential of wind and solar PV being serious transformational technologies is the recent speed at which their associated prices have fallen. Bloomberg New Energy Finance analysis shows the steep experience curve of crystalline silicon (c-Si) PV modules over the last four decades, revealing that, during the period 1976 to 2014, for every doubling of cumulative production of modules, the price reduced by almost 25%.[59] Such is the impact of economies of scale upon solar PV that the price of electricity generated from c-Si PV cells has fallen from US$76.67/watt in 1977 to $0.74/watt in 2013.[60] This rapid decrease in solar module costs has been aided by continued progress in the efficiencies of module cells. Similarly, analysis from IRENA notes the significant cost reductions in wind power component costs.[61] Despite substantial increases in wind turbine size, prices steeply dropped from roughly $2.50/MW in the mid-1980s to $0.50/MW in the early-2000s. While learning rates for wind have been and will continue to slow – since they are further along the technological development curve than PV – component cost reductions can still be expected to occur.

[57] Bernstein (2015) Asia Strategy: Shouldn't we all be dead by now?
[58] http://www.bp.com/en/global/corporate/energy-economics/energy-outlook-2035.html
[59] http://about.bnef.com/content/uploads/sites/4/2015/04/Final-keynote_ML.pdf, see slide 13
[60] http://costofsolar.com/cost-of-solar-panels-10-charts-tell-you-everything/
[61] IRENA, 'Renewable Energy Technologies: Cost Analysis Series', Volume 1: Power Sector Issue 5, 2012

Levelised costs show that new renewables are catching up to incumbents

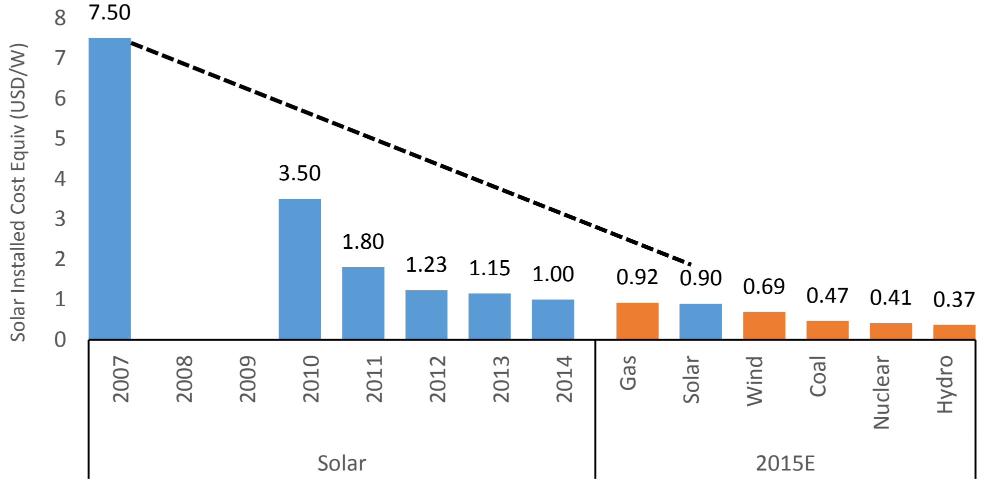
The discussion above refers only to certain components of wind and solar costs. For a more complete way to compare the cost competitiveness of technologies, the industry typically measures the levelised cost of electricity (LCOE). The LCOE is a calculation of the costs of the initial capital, ongoing operation and maintenance (O&M) and fuel over the asset's lifetime, divided by the power output over that lifetime. Therefore, the falling costs of capital outlay and c-Si modules, discussed above, contribute to a lower LCOE for wind and solar, but are only part of the story. Whilst LCOE provides a more holistic metric, it is important to note that, since wind and solar have no fuel costs and much lower O&M costs than fossil fuels, it is the capital costs that largely determine their cost-competitiveness. This means that developing alternative financial structures to overcome this initial hurdle, and getting investors comfortable with them is as important as developing the technology.

Renewables already splitting gas and coal in China

Analyses of current and future LCOE for wind and solar are consistent with the narrative of renewables becoming increasingly competitive with fossil fuel power generation. Alliance Bernstein contend that solar-generated electricity in China has experienced an almost 90% reduction in price over the last eight years. It is now cheaper than gas-generated electricity and quickly on its way to catching up with wind and coal – refer Figure 5.5. Bernstein summarise the root cause of this succinctly: '*Solar is a technology. Costs fall over time and will continue falling. Fossil fuels are, by definition, extractive. Costs tend to rise over time.*'[62]

China is obviously a key region where demand for energy is expected to grow and concern over air quality has reached crisis point. India is another key region for future energy demand growth and both countries have recently announced goals of building 200 GW and 100 GW of solar capacity by 2020 and 2022, an increase from their existing 7 GW and 1 GW of solar capacity, respectively.

Figure 5.5 Alliance Bernstein: Solar installed cost vs. other types of energy generation on an LCOE basis in China



Source: Alliance Bernstein, CTI analysis (2015)

[62] Bernstein (2015) Asia Strategy: Shouldn't we all be dead by now?

CCS makes coal and gas uncompetitive

In a number of markets, onshore wind is widely considered to already be at a cost-competitive level, even with the additional costs of variability added. Certainly with the added costs of capturing CO_2, renewables are cheaper than new nuclear and gas and coal with CCS.[63] Importantly, this is based on conservative assumptions of integration costs. To echo Alliance Bernstein, as the price of storage decreases and grid integration improves, onshore wind is only going to get cheaper, unlike its fossil fuel competitors.

Overall, renewables costs making good progress

There have been significant declines in the LCOEs of wind and solar PV in the last year. Indeed, BNEF's latest 2015 cost-competitiveness report illustrates that if conditions permit (in the form of Europe's high carbon prices or East Asia's small gas supply), onshore wind is already cheaper than coal and gas on a LCOE basis and PV is quickly catching up. Incumbent fossil fuel suppliers are in danger of failing to anticipate this disruptive potential. As BNEF state, 'onshore wind and solar PV are both now much more competitive against the established generation technologies than would have seemed possible only five or 10 years ago'.[64]

LCOE only tells half the story: it's all about the synergies

ExxonMobil attest that growth of installed capacity, often cited as evidence of the inevitable transition to renewable energy, is misleading: 'Wind and solar… have much lower effective capacity utilization levels [than nuclear] because they are intermittent sources.'[65] In their 2015 *Energy Perspectives* report, Statoil state that, 'the LCOE concept provides only part of the information needed to assess the viability of high shares of variable renewable power in total power supply.'[66] The fossil fuel industry anticipates that not only will the costs of integrating these technologies into power grids be expensive, but that also, with the lack of sufficient storage technologies, other fuels will be integral to filling the supply deficits.

One can argued that: (1) the wholesale improvement in renewable capacity factors - the percentage of the actual electricity output compared to its potential to continuously operate at full capacity - anticipated by the IEA; and (2) that improved power storage will reduce the severity of renewable energy having significantly lower capacity factors than coal, gas or nuclear power stations (see Assumption 6 for more details).

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[63] IRENA, 'Renewable Power Generation Costs in 2014', 2015
[64] http://about.bnef.com/press-releases/wind-solar-boost-cost-competitiveness-versus-fossil-fuels/
[65] http://cdn.exxonmobil.com/~/media/global/files/outlook-for-energy/2015-outlook-for-energy_print-resolution.pdf
[66] http://www.statoil.com/en/NewsAndMedia/News/2015/Pages/04Jun_Energy_perspectives.aspx

Routes to achieving greater flexibility for renewables

Renewable energy is making a substantial contribution to power supply in some regions of the world. For example, the '*Energiewende*' in Germany saw renewables provide nearly 26% of Germany's power in 2014.[67] This level of penetration requires energy systems to adapt and there is a downside for coal and gas assets, unless their payment model changes.

Even as one of the early movers, Germany has overcome these teething problems without impacting energy supply. The flexibility and design of energy infrastructure and markets can only improve as energy companies and regulators get more experience and storage technologies advance. Agora Energiewende declare that in Germany, grids are currently a cheaper source of flexibility than energy storage. For example, on some occasions, the *Energiewende* produces an excess of power that can be exported.[68] Expanding this grid further with grid connections to European neighbours is a potential cost effective method of managing power surpluses/deficits. This measure effectively utilises other countries as 'indirect storage' facilities. In the near-term, such measures provide a cost-effective solution to facilitate the integration of renewable power into grids while other flexible capacity solutions, such as storage, become more competitive (for more information see Assumption 6).

[67] http://www.ft.com/cms/s/0/cc90455a-9654-11e4-a40b-00144feabdc0.html#axzz3luTVjCNz
[68] Agora Energiewende (2013) *'12 Insights on German's Energiewende'*

Box 1. The *Energiewende* – the German experience of integrating variable renewables

'*Energiewende*' – Germany's programme to reduce greenhouse gas emissions by 80 to 95 percent by 2050 on 1990 levels – is an example of the possibility of integrating variable renewable sources (for Germany this is wind and solar PV) into an energy system. Germany aims to reverse existing power generation structures, so that wind and solar become the 'base-load' power sources and fossil-fueled power plants will be optimised to supply residual demand. If wind and PV share 40% of Germany's power generation – their target for 2022 – only 10 to 25 GW conventional fossil fuel capacity (roughly 20-25% of total operating capacity) operating 6000 to 8000 hours per year will be needed. As wind and PV power generation continues to increase, the need for fossil-fueled capacity will only decrease.

Germany claims that, with the correct incentives, the following are examples of realistic approaches to help to achieve these decarbonisation targets:

- Upgrading combined-heat and-power and biomass plants so that they can supplement wind and PV power generation – this could be carried out now with no technical challenge and at relatively low-cost;
- Improving flexibility in existing fossil-fuel power plants: reducing minimum outputs, increasing load-gradients and shortening start-up times are all achievable improvements;
- Upgrading grids so that electricity is only distributed to meet specific demands; using surplus electricity for other uses, such as heating, or utilising integrated European grid systems so that surplus power can be bought and sold to meet demand – in effect creating 'indirect storage facilities' which are much more cost-effective than building currently expensive storage facilities; and
- Adapting industry power consumption to align with wind and PV power generation: it is currently technically possible to shift demand to coincide with the windier and sunnier times of the day to avoid the need for fossil-fueled generation to meet demand. Efficiency gains help to reduce the reliance on conventional power plants: a 10% reduction in consumption by 2020 on 2008 levels corresponds to 60 TWh reduction in demand and 8 GW reduction in capacity.

Changing the relative economics of renewables and fossil fuels

Level of capacity utilisation

There can be significant variation in the capacity load factor applied to different technologies, i.e. what percentage of the time will they be operating at full capacity (or the equivalent). For example it is not uncommon for the range of solar capacity factors within a country to spread from 10% to 20%, with the average around 15%. Given it is dark on average for 50% of the time, then this places an obvious maximum potential load factor for solar PV of 50%. Concentrated solar power plants with storage have load factors of up to 60% (e.g. molten salt storage CSP in South Africa), further raising the potential in appropriate locations as the costs come down. There is also variation with latitude, which impacts the angle of the sun's rays, cloud cover and daylight hours. As solar installations consist of a large number of small arrays, including domestic installations, it is difficult for energy agencies to collect detailed information on the actual level of generation. The IEA use country-specific load factors where possible to reflect the site-specific nature of load factors.[69]

Should the capacity utilisation rate increase beyond an average of 15%, this would have material gains in the quantity of power generated from the solar panels and result in a decrease in cost per energy unit. Therein lies the potential for a significant swing in market dynamics. For example, SolarCity's announcement of a new residential solar panel only made marginal efficiency gains on the previous market leader SunPower (an increase from 21.5% to 22%). Yet, due to SunPower's panels being more expensive than the average, the overall generating cost for SolarCity's product was markedly lower than previous market leading panels (initial estimates show decrease from $3.60/watt to $0.50/watt).[70]

Reduced load factor for coal and gas plants

Obviously if a lower capacity factor is assumed across a country then it may underestimate the actual contribution being made by renewables. This means that the generation contribution for renewables is often an estimate, rather than an actual measurement of capacity used. If a higher capacity factor is used in financial modelling, this also improves the rate of return on investment. This can make renewables more attractive and also mean they can cover a greater proportion of energy demand. Alternatively, large coal and gas plants may not see the levels of utilisation expected when they were commissioned, meaning subsequent returns disappoint too. In the past, where the power markets have been structured around significant base load, coal or gas plants could be running 80% to 90% of the time. However if renewables are given priority and increase capacity this could drop to 30% or 40% over time.[71]

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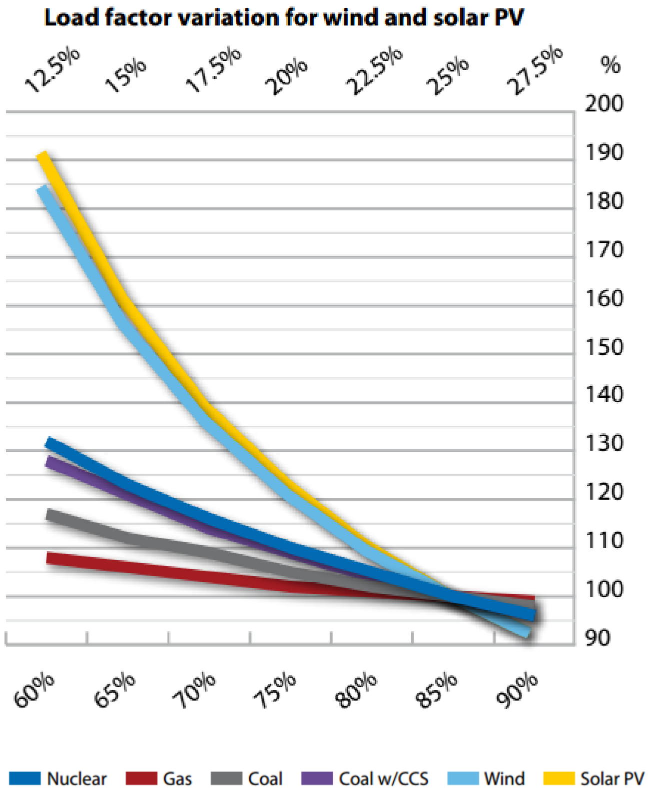
[69] Projected Costs of Generating Electricity (2015) IEA

[70] See http://www.solarcity.com/newsroom/press/solarcity-unveils-world%E2%80%99s-most-efficient-rooftop-solar-panel-be-made-america for SolarCity press release of new PV panel; see http://www.extremetech.com/extreme/215555-0-55-per-watt-from-solarcitys-record-breaking-new-solar-panel?utm_source=Energydesk+Daily+Email&utm_campaign=11aa4744ff-Energydesk_Dispatch5_9_2013&utm_medium=email&utm_term=0_ad1a620334-11aa4744ff-141762977 for cost comparison; see http://www.fool.com/investing/general/2015/01/31/why-solar-panel-efficiency-matters-more-than-you-t.aspx for SunPower cost.

[71] For example Carbon Tracker varied its load factor for future years in developing different scenarios for the Moorburg coal plant in Germany. http://www.carbontracker.org/wp-content/uploads/2015/06/CTI-EU-Utilities-Report-v6-080615.pdf

Figure 5.6: LCOE as a function of a variation in the load factor[72]



To substantiate the point made about efficiency and cost reductions working in tandem, Figure 5.6 shows analysis from the IEA that if the load factor is doubled from 12.5% to 25% for solar PV or wind, it can halve the LCOE. Nuclear, coal and gas are less sensitive to load factors, as other factors such as construction cost, fuel cost or carbon cost are significant, which are not for renewable energies.

For example, taking the US as an example, we can identify a range of solar capacity factors being indicated in 2013:

- BP Statistical Review: 9%
- NREL: 20%
- EIA[73]: 20%

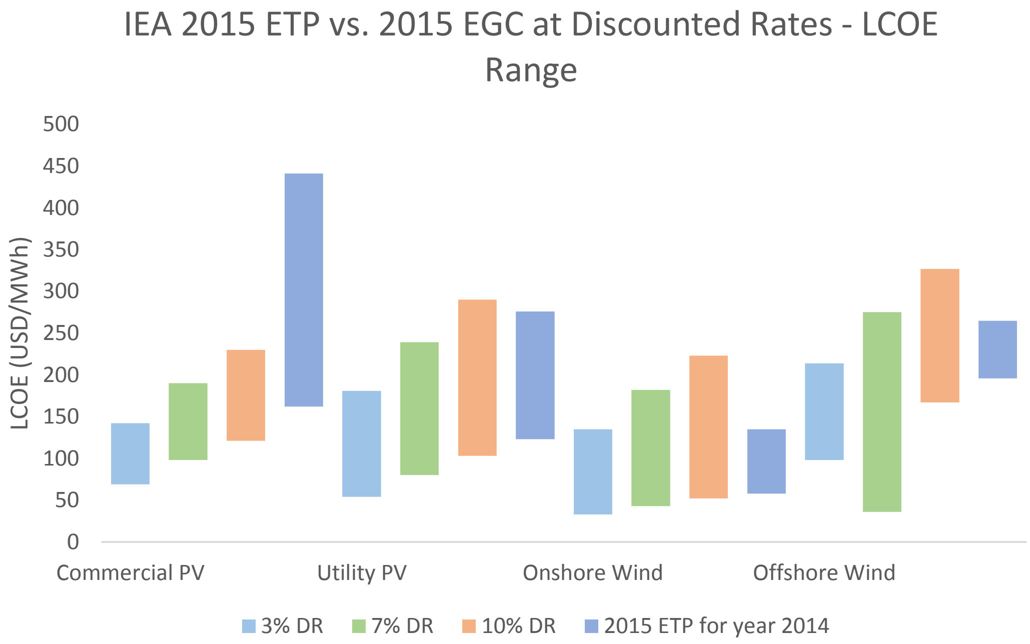
Obviously if it is assumed that solar installed capacity has twice the level of generation activity, then this significantly changes the picture in terms of its potential contribution to energy supply.

[72] http://www.iea.org/publications/freepublications/publication/projected_costs.pdf
[73] http://www.eia.gov/todayinenergy/detail.cfm?id=14611

Discount rates

While LCOE demonstrates the progress that new renewables are currently making, it is to be noted that using the LCOE measure reveals capital intensive technologies, such as solar and wind, to be sensitive to increasing discount rates. This is due to their sensitivity to electricity price volatility and because a significant percentage of their total cost is investment cost longer periods are required to earn revenue to cover capital costs. Figure 5.7 shows that if the discount rate can be lowered then it makes renewables much more competitive. This is another reason why getting the right financial structures and having energy policy certainty are vital to reducing the capital costs of renewables. However, wind and solar are not exposed to the volatility of commodity prices affecting fuel and maintenance costs while coal and gas power plants are. The assumptions used for fuel prices and emissions measures are therefore more important for coal and gas power generation.

Figure 5.7: The impact of lower discount rates on renewables LCOEs



Source: IEA, CTI analysis (2015)

Market-based measures can change thinking around renewables

Analysis from MIT calls for a market-focused approach to comparing the economics of electricity generation technologies.[74] Since the LCOE function treats all electricity generation homogenously, it ignores the location and time of the electricity generated which determines the price (peak prices being higher than off-peak) and therefore the profitability of the electricity generated. As long as renewable technologies are 'intermittent' sources of electricity, rather than 'dispatchable', and therefore determined by factors such as cloud cover or gentle wind speeds, a competitive LCOE will not guarantee them as attractive investments. For example, an onshore wind turbine – cost competitive with a gas plant on an LCOE basis – could struggle to make a profit if its

[74]Paul L. Joskow, 'Comparing the Costs of Intermittent and Dispatchable Electricity Generating Technologies', MIT, *Center for Energy and Environmental Policy Research*, 2011

electricity happens to be produced during off-peak, lower-priced times of the day. Whereas the gas plant could comfortably earn revenue by providing a constant source of electricity to peak demand, high-price markets.

Of course, as initiatives such as Germany's *Energiewende* continue to emerge and renewables - plus storage and grid improvement - transition to a dispatchable technology, these technologies will attract more investment. Furthermore, in markets such as Germany's where renewables' generation is given priority, wholesale prices can fall dramatically and even into negative figures as excess fossil fuel generation pays the grid to take their electricity.[75] Of course, the levelised-cost function continues to document well the evolution of technologies. However, this analysis shows the need for a more transparent market-based approach to electricity generation to ensure that renewable technologies are developed and supported holistically, rather than concentrating too heavily on one aspect.

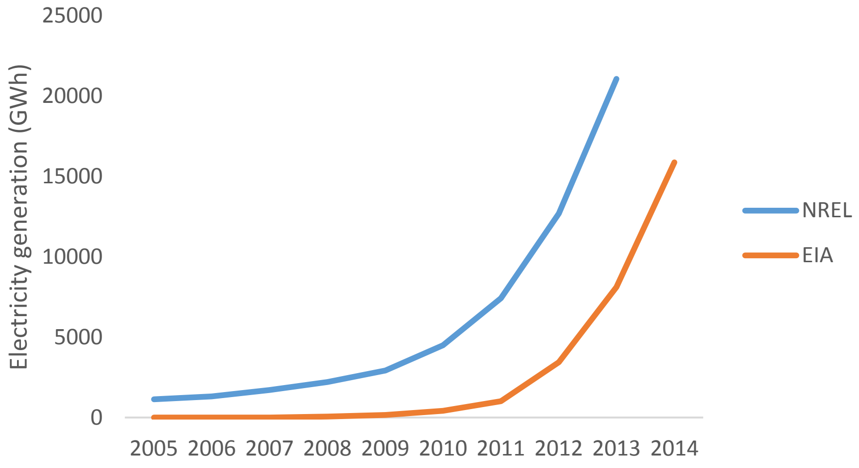
Are we already further ahead than some models think?

Small scale solar gone missing

As a new industry with many small installations, systems for monitoring the level of actual generation from installed capacity are not as established or widespread as for the incumbent large scale fossil fuel power plants. Taking two US government energy agencies (the EIA and NREL) for example give very different pictures of the level of solar generation, with the NREL consistently ahead of the EIA.[76] NREL give their own explanation of this - that the EIA survey of power generating facilities does not capture those below 1MW.[77] Given the significant gap between the two datasets, this would appear to be the majority of generation occurring in the US according to NREL estimates – refer Figure 5.8. NREL had solar generation above 1000 GWh in 2005, but this did not materialise in EIA figures until 2011. In 2013, NREL had 21074 GWh compared to less than half of that at 8121 GWh in EIA data. Looking elsewhere would also give a different picture - to compare the EIA numbers to other sources, the BP Statistical Review of Energy indicates a similar level of US solar consumption of 9.1 TWh in 2013, which matches the IEA figure for 2012.

[75] http://www.carbontracker.org/report/eu_utilities/
[76] http://www.nrel.gov/docs/fy15osti/62580.pdf ; http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_1_01_a
[77] https://financere.nrel.gov/finance/content/calculating-total-us-solar-energy-production-behind-the-meter-utility-scale

Figure 5.8 Small scale solar goes missing when comparing US government bodies



Source: IEA & NREL, CTI analysis (2015)

Comparing BNEF data with IEA data indicates a similar picture. The IEA indicate global PV solar generation as 97 TWh in 2012. BNEF have the same figure of 97 TWh for utility scale solar generation in 2013, but also have a separate number for small-scale generation of 64 TWh. Comparing the projections gives a similar impression of missing small-scale generation. The IEA project 459 TWh of solar PV in 2020 plus 42 TWh of CSP. By comparison BNEF project 384 TWh of utility PV generation and 396 TWh of small-scale. The BNEF data suggests that over half of solar PV generation could be omitted if only utility scale projects (not small scale facilities) are included in datasets.[78]

This apparent lag or underestimation in some of the best known sources of statistics could impact the views of utilities and analysts of fossil fuel producers assessing the state of the solar generation industry. It could also suggest to the climate community that less progress is being made than is actually the case, meaning emissions targets are closer than we think. If the volume is underestimated, then the rate of cost decline will also be expected to be lower, as explained later in this chapter.

Conclusions

- The growth of power generation from wind and solar has been consistently underestimated by the IEA. More fundamentally, a lack of consistent and transparent measurement of renewables' contribution to the energy system makes it incredibly difficult to formulate a coherent picture of future demand.
- Component costs for onshore wind and solar photovoltaics (PV) have made rapid progress and – on a levelised-cost basis (LCOE) – are in certain geographies already, or close to being, cost-competitive with coal and gas power generation.

[78] See difference between Utility scale PV and Small scale PV on 'Global power generation by technology, 2012-2040', https://www.bnef.com/dataview/new-energy-outlook/index.html

- If current solar generation is being underestimated by 50%, as small-scale generation is not included by many institutions, then the LCOE will have reduced by 25% more than expected.
- If the solar load factor used in a model is increased by 5% it can result in the LCOE reducing by a quarter.
- Synergies between renewables, storage facilities and improved girds are changing the economics of power generation and market re-structuring is required to accommodate this.

BAU Assumption 6: The energy system will see only incremental change, not transformational shifts

"Almost no one [would have predicted] that photovoltaic prices would have dropped as fast as they have, and storage is right at the cliff, heading down that price curve" – JB Straubel, CTO, Tesla Motors, 2015.[79]

Key findings

- Transformative factors have the potential to create significant paradigm shifts in the energy sector. These technologies typically penetrate markets in an S-curve, i.e. with a period of exponential uptake. Current energy models do not factor in any non-linear change, hereby neglecting the potential of new energy technologies.
- Energy storage is one possible transformation technology that is rapidly becoming more competitive as costs fall. Tesla's Powerwall demonstrated that storage cost reductions are 7 years ahead of the 2014 industry average forecasts and 25 years ahead of the US EIA estimate.
- Energy storage has the potential to be a 'gamechanger' in energy systems by facilitating the large-scale integration of renewable energy sources.
- IEA reference points demonstrate that 200GW of energy storage helps facilitate the addition of approximately 2500TWh of solar PV power.

The threat posed to future fossil fuel demand by what we classify as 'disruption' or 'transformational' factors is perhaps the scenario most overlooked by fossil fuel companies and energy system models. A transformative factor is differentiated from a more incremental change by the speed and scale of its potential impact. In layman's terms, it is a gamechanger that could initiate a paradigm shift in the demand dynamics within the system in question - a downside driver serves as a more gradually constraining force on demand. Whilst transformational factors may be hard to predict, and deemed less probable, the magnitude of their potential impact warrants consideration because ignoring them will make it very difficult for incumbents to adapt.

For example European utilities have admitted that they left investment into renewables too late. This is now challenging their business model based on centralised power plants and creating stranded assets out of both new and old power stations, which are being written down on a regular basis. In this section we focus specifically on the risk posed by stationary energy storage to the business models of fossil fuel companies, but a number of other factors

[79] http://cleantechnica.com/2015/07/22/energy-storage-tipping-point-within-10-years-tesla-motors-cto-jb-straubel-contends/

addressed in this report could be considered as potentially disruptive, such as cost reductions in solar energy (Assumption 5) electric vehicles in China (see Assumption 8).

Technological uptake occurs in S-curves not linear change

Figure 6.1 shows the S-shape curve of technological uptake that is typical for most technologies. It features a period of exponential demand growth, i.e. huge uptake over a short period of time that results in near market saturation of the technology. This period of rapid growth helps drive significant cost reductions. This results in asymptotic cost curves in which initially costs fall sharply before slowly converging towards a base level. This is the pathway that energy transition technologies such as solar and energy storage are undergoing. This trend of actual uptake and technology cost reduction contrasts with the linear changes and constant rates of change being used in energy models.

Figure 6.1: Technological uptake S-curves[80]

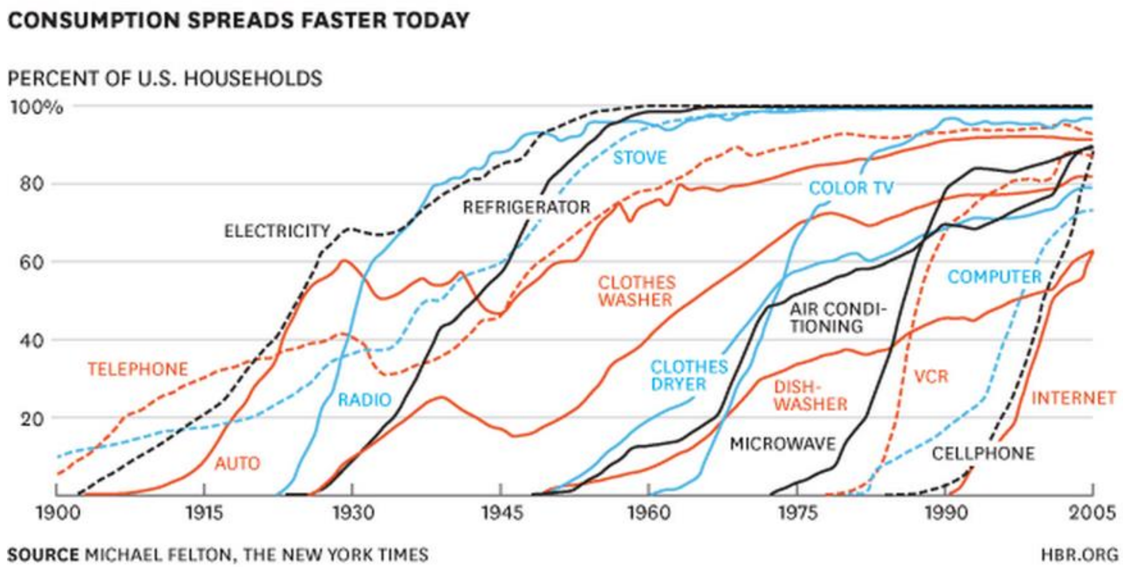
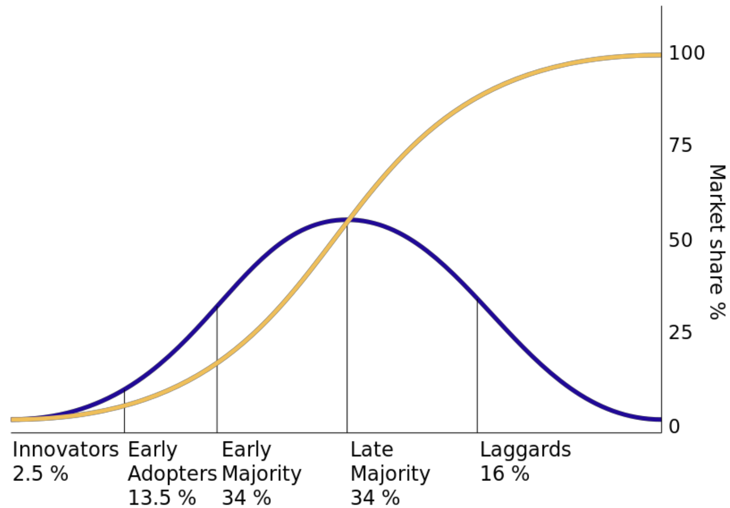


Figure 6.2: The different stages of technological uptake[81]



[80] https://hbr.org/2013/11/the-pace-of-technology-adoption-is-speeding-up/
[81] https://en.wikipedia.org/wiki/Diffusion_of_innovations#/media/File:Diffusion_of_ideas.svg

Domination versus diversification

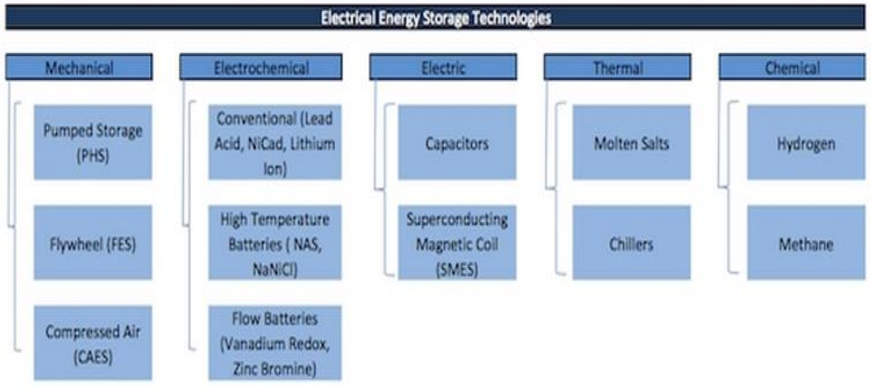
Figure 6.2 shows that initially demand is low, made up only of 'innovators'. This has some feed-through cost reduction effects, but research and development investment is still a significant factor. 'Early-adopters' then begin to increase uptake up to around 15% of the market. This threshold is widely considered as the tipping point at the bottom of the sharp exponential rise, beyond which a 'virtuous spiral' can occur. This is where demand is large enough that production alone can create the economies of scale and efficiency savings that drive continued cost reductions. While 15% is largely considered the benchmark for runaway uptake, this is fundamentally a subjective, sector-specific judgment, meaning variation does exist. For example, Bernstein believe for electric vehicles that this threshold is just 3% of the global fleet (expected in 2020), after which the next stop is 97%, 15 to 20 years later.[82] Again this domination by better, cheaper technology can be seen throughout history. Yet when we look at the energy mix scenarios of many climate models they appear hindered, perhaps by political sensitivities, inertia or extrapolations of the past. Many energy models seem to retain a well balanced diversified energy portfolio, with each type of generation retaining a decent share. Whilst this avoids upsetting any particular camp too much, it may not represent how the dynamics of an energy system will actually play out.

At what life-cycle stage is stationary battery storage?

Having understood the typical evolution of technologies and the vast potential for battery storage to become cheaper, the challenge becomes understanding where storage is in its life-cycle. This is difficult, predominantly because of the vast number of storage technologies available for application. Energy storage itself is not a new concept, but investor interest has focused on a few new and emerging energy storage options that is helping them grow from their currently marginal capacity (Figure 6.4).

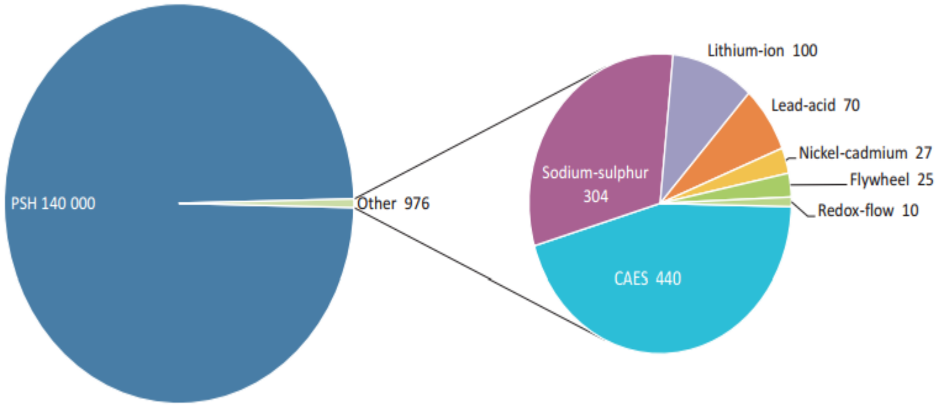
[82] Bernstein (2015) Asia Strategy: Shouldn't we all be dead by now?

Figure 6.3: Summary of energy storage technologies



Source: Deutsche Bank

Figure 6.4: Electricity storage installed capacity in 2013 (MW)[83]



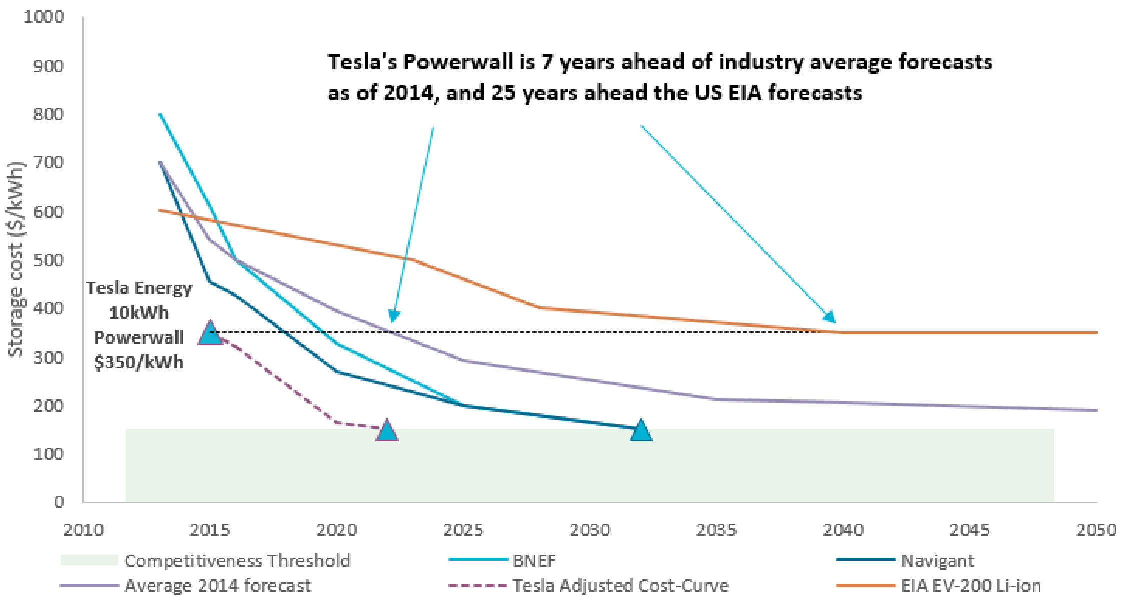
Here we are focusing on stationary installed storage, rather than batteries for electric vehicles for example. Scope for largescale expansion of pumped storage hydro (the dominant form of storage) is arguably limited, leaving the door open for these emerging storage technologies to thrive. Interest in the stationary application of electricity storage is growing. There is an increasingly widespread understanding of the huge impact storage can have on the wholesale power markets. Currently, sodium-sulphur batteries account for approximately 60% of all stationary batteries, almost singularly driven by Japan.[84] Nevertheless, the most data is available on stationary applications of Li-ion batteries (partly due to their application in EVs) and so will largely be the focus of our discussion (even though bulkier options may be more appropriate and cheaper in the long-term – discussion of these less mature, and therefore more transformative options follows).

[83] https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapEnergystorage.pdf
[84] https://www.sbc.slb.com/SBCInstitute/Publications/ElectricityStorage.aspx

Could we be at that inflection point preceding exponential uptake? Battery cost reductions are outpacing expectations

Figure 6.5 brings together a number of forecasts from 2014 of stationary Li-ion battery storage prices.[85] Excluding the US EIA, these learning curves seem to agree battery storage will see steep cost reductions until 2020 and continue declining steadily thereafter. It is widely considered that for storage to be financially attractive for widespread deployment, costs need to be around $150/kWh.[86] Figure 6.5 shows the average industry forecast does not see this price level being met by 2045. More bullish forecasts like those of BNEF and Navigant see this cost being achieved between 2030 and 2035. The introduction of Tesla's Powerwall on April 30th 2015 changed everything and now these forecasts all seem conservative.

Figure 6.5: Battery storage cost projections



It is thought battery costs for the Powerwall are around $350/kWh.[87] Figure 6.5 shows this cost level preceded the industry average forecast by 7 years and was fully 25 years ahead of the very conservative US EIA.

It is likely this means costs will hit the crucial $150/kWh threshold earlier than previously expected. We have drawn a 'Tesla adjusted curve' on Figure 6.5 that shifts the typical cost-down curve gradient forward 7 years to reflect the Powerwall announcement. This adjusted curve hits $150/kWh just after 2020. As a result of the Tesla announcement, Deutsche Bank also updated their forecast to suggest $150/kWh will be hit by 2020.[88]

The blueprint to reach this cost level has already been laid. Tesla's planned 'Gigafactory' with an annual production

[85] The data for this graph is interpretations of forecasts published by the Rocky Mountain Institute. Report available: http://www.rmi.org/electricity_grid_defection#economics_of_grid_defection. The original graph has been adapted from historic and projected consumer electric vehicle production costs.

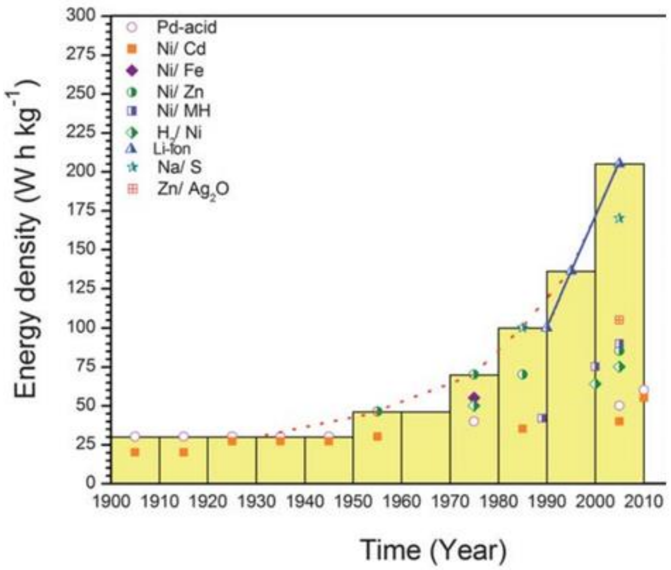
[86] http://www.nature.com/news/will-tesla-s-battery-change-the-energy-market-1.17469

[87] http://www.greenbiz.com/article/quantifying-teslas-impact-falling-battery-prices. One MIT study suggests the cost of the Powerwall could be as low as $200/kWh. Available at: http://mitei.mit.edu/news/whats-cost-got-do-it

[88] http://cleantechnica.com/2015/03/04/energy-storage-could-reach-cost-holy-grail-within-5-years/

capacity greater than the total supply of Li-ion batteries in 2013 is set for operation from 2016 or 2017. Subsequent economies of scale are claimed to reduce battery costs by a further 30%.[89] As costs come down, the rate of demand for energy storage will increase year on year and current trends suggest this will happen faster than most expect.

Figure 6.6: Energy density improvements of battery technologies



Potential for further battery improvements

Energy storage systems can not store and discharge energy without losses. The IEA currently estimate 75%-95% efficiency for Li-ion batteries.[90] Improving the efficiency of storage operation could be a significant contributor to cost reductions. As could increasing the energy density of units, i.e. more energy storage per dollar, or more cycles per charge. Tesla's CTO estimates that battery efficiency is improving about 8% per year, that energy density has doubled over the last 10 years and that this curve is not starting to plateau.[91] Figure 6.6 from one academic study appears to substantiate this claim regarding energy density improvements.[92]

Some disagree this will continue in the future, however, and believe Li-ion is reaching its energy density limit. This standpoint is neglectful of the sheer scale of research and development going into battery technologies. Battery storage is a field of technological innovation rather than an engineering problem. This has vastly increased the number of market entrants looking at this problem, and therefore, the number of potential solutions being proposed to increase the energy density of Li-ion.

Most recent examples feature eliminating dendrites – thin conductive filaments that form inside Li-ion batteries reducing efficiency and pose a risk of them catching fire – which according to one university can improve energy density by 4 times[93], or according to another makes Li-ion batteries 'more than 99% efficient and enables them to carry more than 10 times electric current' than previous versions.[94]

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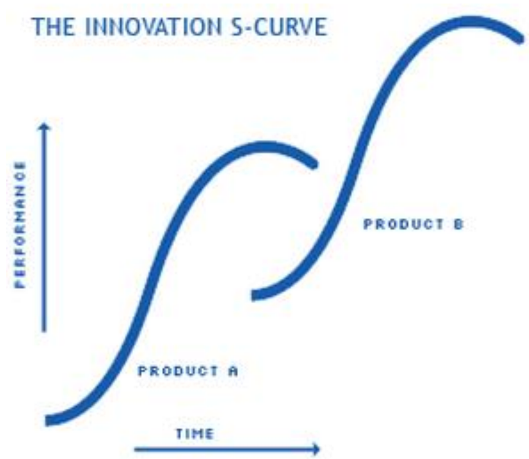
89 http://mitei.mit.edu/news/whats-cost-got-do-it
90 https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapEnergystorage.pdf
91 http://www.greentechmedia.com/articles/read/Tesla-CTO-on-Energy-Storage-We-Should-All-Be-Thinking-Bigger
92 http://pubs.rsc.org/en/Content/ArticleLanding/2011/EE/c0ee00777c#!divAbstract
93 http://batteryuniversity.com/learn/article/battery_breakthroughs_myth_or_fact
94 http://www.nanotech-now.com/news.cgi?story_id=50977

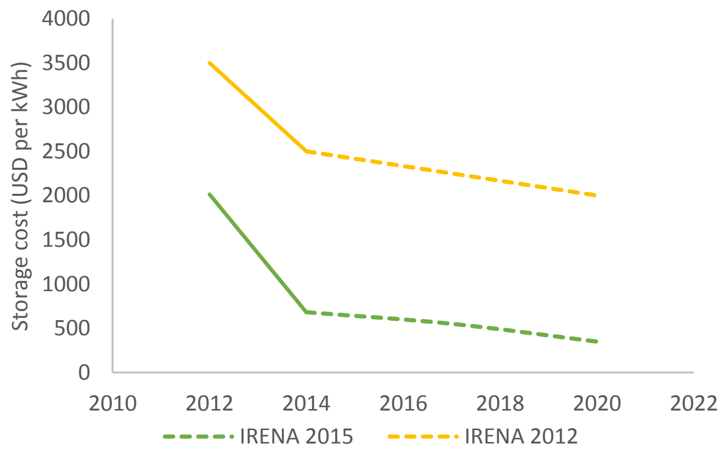
Figure 6.7: Emerging innovations build on those of the past



Limitations in Li-ion batteries do not constitute a step backwards, but greater potential from replacements

The very nature of technological innovation is fundamentally based on improving past ideas. In the 1990s lead-acid batteries were considered state of the art, then Li-ion came and changed the game. Tesla essentially took thousands of laptop batteries and 'made them sing' according to a Liverpool University academic, 'it's quite a technological achievement'.[95] Those focusing on eliminating dendrites are attempting to take the next step. If they and others attempting to improve the Li-ion battery fail, this simply opens the door for the hordes of other competing battery technologies, which will likely improve on the Li-ion iteration, as illustrated in Figure 6.7.

Figure 6.8: IRENA cost projections for flow batteries



Many researchers feel this next step lies with lithium derivatives, in the form of lithium-oxygen, lithium-sulphur or lithium-metal batteries. Others point to different battery technologies that could be more appropriate for stationary storage and cheaper in the long-term. For example, flow batteries can last for 5-10,000 cycles and costs have come down hugely since 2012 (Figure 6.8). Longer term, it is foreseen to be slightly more expensive than Li-ion batteries on current trajectories. Another option is compressed air storage that can deliver over 10,000 cycles.[96] Neither of these technologies are as yet commercially viable. However, the greater the uncertainty, the greater the associated disruption potential if this technology begins to penetrate energy markets.

[95] http://energydesk.greenpeace.org/2014/12/23/story-storage-go/
[96] http://rameznaam.com/2015/04/14/energy-storage-about-to-get-big-and-cheap/

What is the potential for energy storage to facilitate low-carbon power grids?

If you accept that the cost of renewable energy technologies will continue to decline in the future, the major pushback against their effective deployment is their intermittent nature, as highlighted in Assumption 5. This highlights the fact that technological innovation in isolation is not always sufficient to result in deployment. The coevolution of ancillary technologies is equally important. Energy storage is one essential ancillary technology for renewable energy. Energy storage makes renewable power sources more competitive by helping remove the barrier of intermittency. Storage can help distribute intermittent power in a way that helps balance supply and demand on grids more effectively. Although energy storage costs are coming down much faster than experts expected, they have still not yet achieved the cost threshold required to be widely competitive. Consequently, other solutions to help grid integration of renewable energy are required now.

Expanding and improving power grids can buy time for cost reductions in storage

Renewable energy is making a substantial contribution to power supply in some regions of the world. For example, the '*Energiewende*' in Germany saw renewables provide nearly 26% of Germany's power in 2014.[97] This level of penetration requires energy systems to adapt and there is a downside for coal and gas assets, unless their payment model changes.

Even as one of the early movers, Germany has overcome these teething problems without impacting energy supply. The flexibility and design of energy infrastructure and markets can only improve as energy companies and regulators get more experience, and storage technologies advance. Agora Energiewende declare that in Germany, grids are currently a cheaper source of flexibility than storage. For example, on some occasions, the *Energiewende* produces an excess of power that can be exported.[98] Expanding this grid further with grid connections to European neighbours is a potential cost effective method of managing power surpluses/deficits. This measure effectively utilises other countries as 'indirect storage' facilities. In the near-term, such measures provide a cost-effective solution to facilitate the integration of renewable power into grids while other flexible capacity solutions, such as storage, become more competitive.

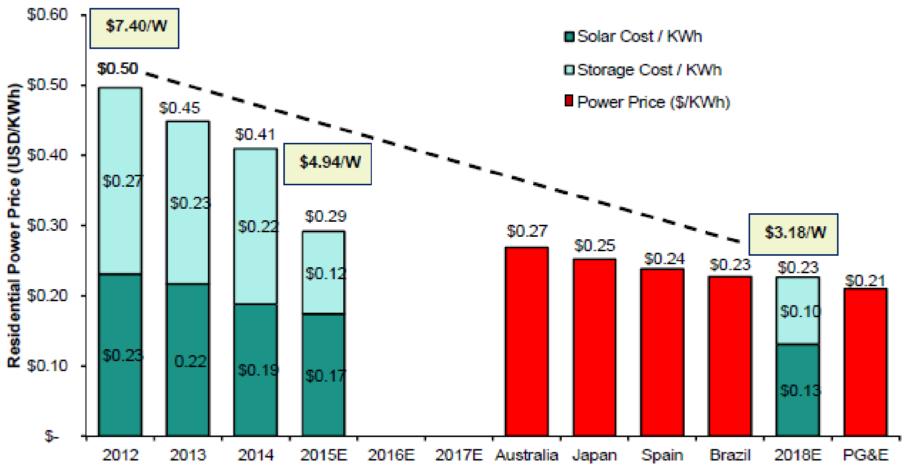
Battery parity just round the corner in some markets

As we have demonstrated, the wait for cost-competitive energy storage may not be long. Forecasts of 'battery parity' – the point where renewable energy, typically solar, and battery costs match grid supply costs – show renewables and energy storage could be cost competitive in the near-term. GTAI and Deutsche Bank conclude that based on price trends in solar, storage, electricity in Germany and FiTs that solar+battery is at grid parity in 2016.[99] Figure 6.9 shows that Bernstein foresee solar PV plus battery storage costs more than halving by 2018, by which point it will be cheaper on an unsubsidised basis than

[97] http://www.ft.com/cms/s/0/cc90455a-9654-11e4-a40b-00144feabdc0.html#axzz3luTVjCNz
[98] http://www.agora-energiewende.de/fileadmin/downloads/publikationen/Impulse/12_Thesen/Agora_12_Insights_on_Germanys_Energiewende_web.pdf
[99] http://rameznaam.com/2015/04/14/energy-storage-about-to-get-big-and-cheap/

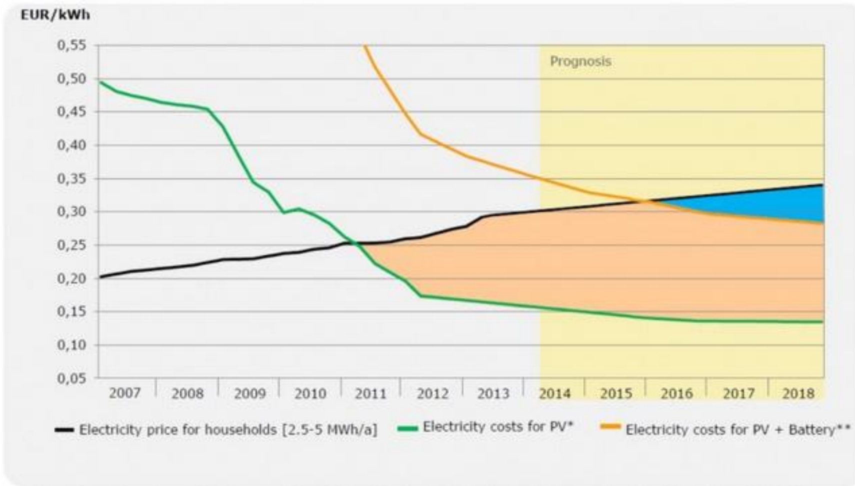
retail residential power prices in Australia, Japan, Spain and Brazil. Similarly, Figure 6.10 shows Deutsche Bank's belief that solar PV plus Li-ion batteries will be cheaper than retail power by 2016 in Germany.[100] These forecasts highlight five countries which are likely to be early-adopters of this new type of power system because: i) power prices are high and increasing; and ii) they have the high solar PV utilisation rates.

Figure 6.9: Bernstein forecasts of solar plus storage [101]



Source: Corporate reports, and Bernstein estimates and analysis.

Figure 6.10: Deutsche Bank forecasts of solar + battery costs in Germany[102]



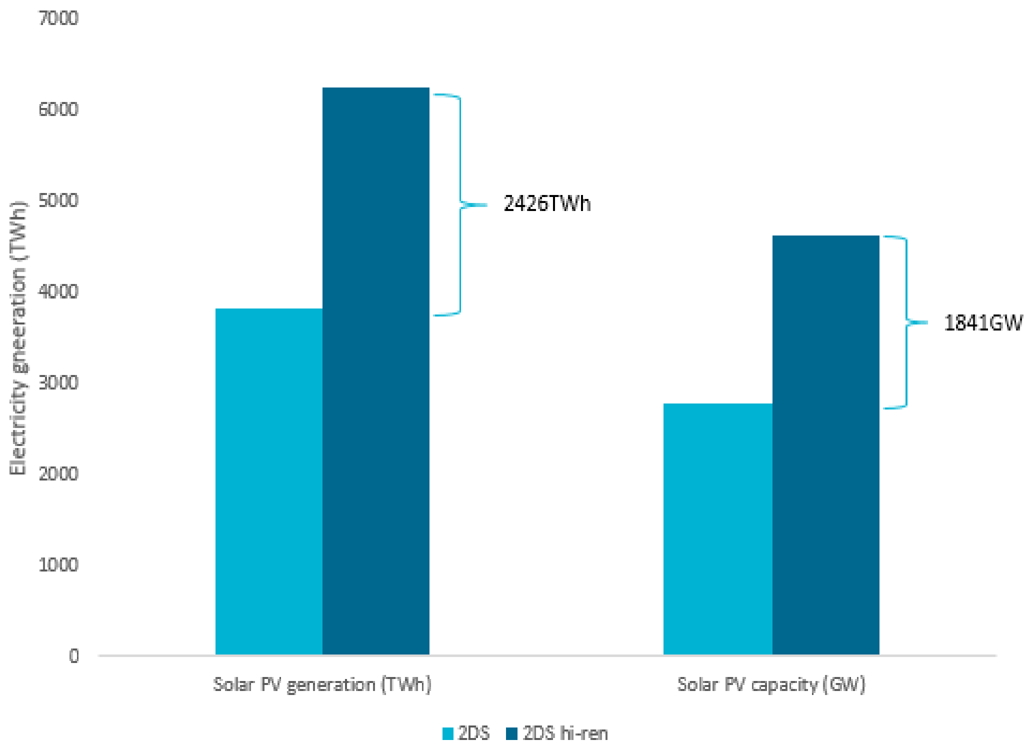
When storage is competitive, it could have a transformational impact on power markets

Few have attempted to model: 1) what impact the emergence of cost-competitive energy storage will have on the scale of renewable energy deployment; and 2) what the synergistic impact of renewables plus storage will be on conventional fossil fuel power sources. This uncertainty underpins the transformative potential of storage and the extent to which is threatens energy incumbents. The IEA offer a few useful reference points in this discussion. They assume growth in energy storage capacity from 127GW in 2012 to 400GW in their 2DS scenario and 600GW in their 2DS Hi-Ren by 2050.[103] One would expect increased storage capacity to be reflected in increased energy contribution from renewable sources. For example, Figure 6.11 shows solar PV

[100] http://rameznaam.com/2015/04/14/energy-storage-about-to-get-big-and-cheap/
[101] Bernstein (2015) Asia Strategy: Shouldn't we all be dead by now?
[102] http://rameznaam.com/2015/04/14/energy-storage-about-to-get-big-and-cheap/
[103] http://www.iea.org/etp/etp2014/

capacity and power generation by 2050 in these two scenarios. It shows power generation from solar PV to be 3824TWh in the 2DS and 6250TWh in the Hi-Ren scenario.

Figure 6.11: How might energy storage facilitate solar PV deployment?



It is not possible to isolate storage as a driver of this additional solar PV power generation – we acknowledge that other factors such as load management, interconnections and flexible generation all assist the integration of large scale solar PV. However, it is without doubt that energy storage capacity is a key pillar to the significant penetration of solar PV seen in both scenarios.

Figure 6.11 shows the 200GW additional storage capacity in the Hi-Ren scenario is one factor contributing to 2426TWh additional power generation from solar PV than in the 2DS in 2050. To put this figure in perspective, 2426TWh is almost the same as total solar PV electricity generation in the IEA's 4DS in 2050.[104] This implies storage could be a significant catalyst in the deployment of solar PV and renewable energy more broadly.

It goes without saying that if approximately 2500TWh of power generation comes from solar PV rather than conventional fossil fuel power sources, that this will have a transformative impact on utilities and fossil fuel producers alike.

[104] Exact number 2503TWh in 2050, ETP 2015.

Concurrent increases in EVs could increase the transformational impact

There are three main ways that electric vehicles (EVs) impact the discussion on energy storage:

Helping drive down costs of Li-ion batteries

Large scale investment into EVs has been one of the biggest drivers of the rapid cost reductions seen in stationary energy storage solutions to date. As the EV market continues to burgeon in the future, this cost-down trend will continue. We look in great detail at the potential penetration of EVs in Assumption 8. We highlight the Electric Vehicle Initiative – a multi-government policy forum of 16 countries including China and the US to promote the adoption of EVs worldwide – that has a target of 20m EVs on the road by 2020. EV penetration of this scale will significantly impact the cost and uptake of stationary energy storage units.

Providing additional storage capacity to deploy at peak demand

Scenarios that foresee rapid cost reductions and largescale uptake of Li-ion stationary storage batteries will inherently foresee rapid cost reduction (and presumably uptake) in electric vehicles (EVs). This brings another form of energy storage onto the market. As EV batteries degrade and lose capacity their functionality to drive a vehicle diminishes. However, their applicability as system-scale electricity storage remains.

We can estimate the likely contribution these battery units could make to power grids through the following assumptions:

- Cumulative 20m EV sales by 2020;
- The average EV battery capacity is 40kWh – the Nissan Leaf has a battery capacity of 24kWh while capacity can reach as high as 85kWh in the Tesla S. We apply 40kWh as an average;
- Battery capacity is at 80%, i.e. 32kWh – we assume the consumer choses to replace the battery after 20% capacity degradation, and that the battery is used rather than thrown away.

These assumptions mean by 2020 a total of 640GWh of energy storage capacity will be on the roads.[105] Now, this additional capacity will not be deployed to power markets all at once. This storage will be deployed at a rate depending on when EVs were purchased.

Globally, 640GWh is not a huge amount in terms of baseload power supply – to provide some perspective, the UK hit a record high electricity demand peak in 2014 of 53GW[106], therefore, additional EV-based storage could meet this demand for 12 hours. However, baseload supply would not be the intention.

[105] http://decarboni.se/insights/large-scale-energy-storage-and-electric-vehicle-effect-electricity-markets
[106] http://www.telegraph.co.uk/news/earth/energy/11358062/Electricity-demand-hits-highest-this-winter-as-wind-power-slumps-to-its-lowest.html

Most likely, this flexible power supply will be applied to the grid at the time of peak demand. This threatens the profitability of utilities because peak demand is the period of peak pricing. This intervention also threatens the need for conventional fossil fuel sources.

EV companies have identified this opportunity. In 2014, Nissan launched the first pilot project reusing EV batteries as a large scale system to store solar power. Located in Japan, Nissan noted the role of such projects in grid management and 'electricity liberalisation'.[107] Toyota and General Motors also foresee this as a business opportunity – "this system is ideal for commercial use because a business can derive full functionality from an existing battery while reducing upfront costs through its reuse" – GM.[108]

Vehicle to grid (V2G) enabled vehicles

Ultimately car makers seek to fully exploit the energy storage capacity of EVs to both take power from the grid and provide power to it. This requires bidirectional capability that currently is only available in Japan via Nissan and Mitsubishi who sell cars with two-way charging systems. Nissan's Leaf to Home system can supply an average Japanese home with two days of electricity in case of a power outage.[109] Currently, the V2G market is less than $900,000 annually. However, the US Department of Defense invested has invested $20m into the technology and one study believes that global revenue from V2G technology could be $191m by 2022.[110] This would see approximately 250,000 V2G-enabled plug-in EVs to be sold between 2013 and 2022.[111].

Looking holistically at the impact of energy storage on power markets, it is clear that as costs decline and uptake increases, not just of stationary storage units but also of EVs, the potential penetration of renewable energy technologies increases greatly. It is inevitable that storage costs will continue falling and so the transformative potential of new power technologies should also be seen as inevitable.

When could storage, plus EVs, plus renewable energy be cost-competitive?

The bank UBS note the near-term potential for an overhaul of power systems centred on energy storage. Their proprietary model considers the synergistic effects of solar PV plus battery storage and the impact for the EV market to drive down Li-ion battery prices through economies of scale. They see combined EV, solar PV and battery systems having a payback time of between 6 and 8 years by 2020 on an unsubsidised basis (Figure 6.12).

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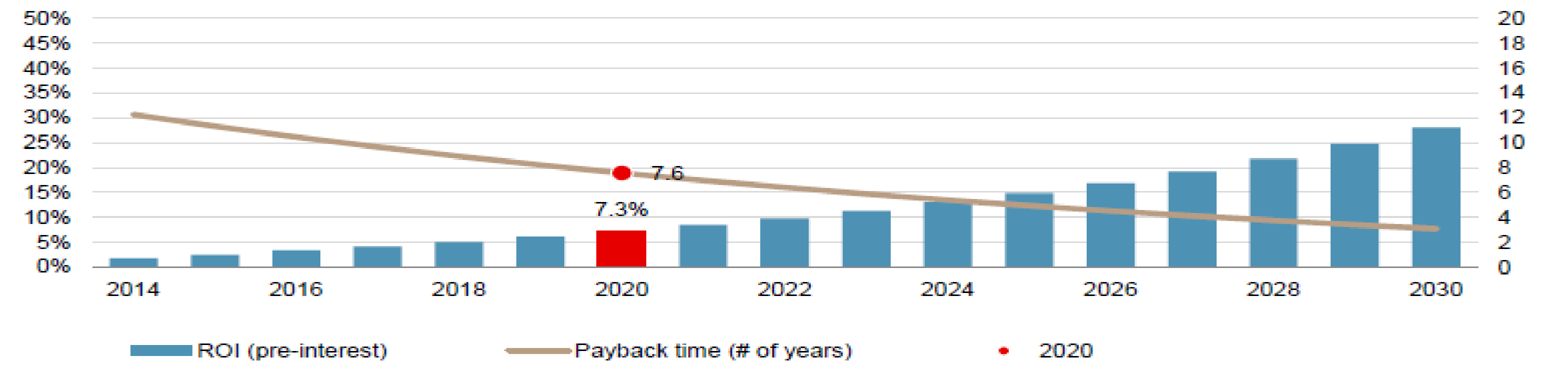
[107] http://ecowatch.com/2014/05/13/nissan-solar-energy-storage-system/
[108] http://www.nytimes.com/2015/06/17/business/gm-and-nissan-reusing-old-electric-car-batteries.html
[109] http://www.technologyreview.com/news/538541/nissan-gm-give-ev-batteries-a-second-life/
[110] http://www.navigantresearch.com/newsroom/vehicle-to-grid-frequency-regulation-revenue-will-surpass-190-million-annually-by-2022
[111] http://www.navigantresearch.com/newsroom/more-than-250000-vehicle-to-grid-enabled-electric-vehicles-will-be-sold-from-2013-to-2022

Figure 6.12: In 2020, solar + battery + EV is competitive in certain countries. Economics continue to improve



Source: UBSe. Note: Chart shows economics in Germany.

Based on an assumed 20-year technical lifetime, this means the buyer receives at least 12 years of free electricity. It is the feedthrough effects between the three technologies that makes this new power system commercially attractive by 2020, by their estimation.[112] In isolation, it would take each technology longer to become as commercially attractive as conventional alternatives. This encapsulates the synergistic relationship between storage, renewable energy and EVs, the impact of which is unpredictable. One thing is for sure, the potential exists for these new technologies to transform the power markets and fundamentally challenge the business models of fossil fuel companies.

Energy is no longer an engineering sector, but a 'new technology'

Discussions of the technical workings of renewable energy alternatives and battery storage options reveals the paradigm shift that is occurring in global energy markets – technological solutions are the future. Energy technologies are freer from the constraint of commodity prices so can achieve much deeper cost reductions than conventional energy sources. No longer are society's energy needs going to be solved by engineers but by tech scientists instead. The world's leading technological innovators see the transition that is occurring and understand that big money can be made by those early-movers. That is why Google has committed $1.8bn to renewable energy projects[113] and why Apple has invested $3bn in solar facilities.[114] These 'disruptors' will be shaping the

[112] UBS (2014) *Will solar, batteries and electric cars re-shape the electricity system?*
[113] http://www.bloomberg.com/news/articles/2015-02-26/google-makes-biggest-bet-on-renewables-to-fund-solarcity
[114] http://www.triplepundit.com/2015/02/apple-goes-invest-3-billion-solar-energy/

energy systems of the future, not the fossil fuel companies and the conventional utilities. “The enormous, disruptive creativity of Silicon Valley is unlike anything since the genius of the great 19th-century inventors,” according to the Economist[115], meaning these incumbent, disrupted companies must adjust to the business models of the future or be left behind and die.

Conclusions

- Transformative factors have the potential to create significant paradigm shifts in the energy sector. These technologies typically penetrate markets in an S-curve, i.e. with a period of exponential uptake. Current energy models do not factor in any non-linear change, hereby neglecting the potential of new energy technologies.
- Energy storage is one possible transformation technology that is rapidly becoming more competitive as costs fall. Tesla’s Powerwall demonstrated that storage cost reductions are 7 years ahead of the 2014 industry average forecasts and 25 years ahead of the US EIA estimate.
- Energy storage has the potential to be a ‘gamechanger’ in energy systems by facilitating the large-scale integration of renewable energy sources.
- IEA reference points demonstrate that 200GW of energy storage helps facilitate the addition of approximately 2500TWh of solar PV power.

[115] http://www.economist.com/news/leaders/21659745-silicon-valley-should-be-celebrated-its-insularity-risks-backlash-empire-geeks?fsrc=scn/tw/te/pe/ed/EmpireOfTheGeeks

BAU Assumption 7: Demand for coal continues to increase

"Given our expectations of long-term strength in coal demand fundamentals, the present conditions offer a window of opportunity for both suppliers and buyers" – Wood Mackenzie, 2015.[116]

Whilst in the short term, cheap coal prices make it more competitive, this is not sustainable for the mining sector. Analysis shows that the majority of the seaborne coal market is already barely covering costs, let alone making a profit for shareholders. Coal mining companies trying to hold out for higher prices may never see the prices they need to be profitable again. Many analysts see thermal coal in particular facing structural issues, rather than just being at the bottom of a commodity cycle.

Key findings

- Almost all industry scenarios see coal demand still growing, hereby exceeding the policy signals given in current INDC commitments.
- Even WoodMackenzie, one of the most bullish coal forecasters, cut its projection for Chinese coal demand to 2030 from 3.9% CAGR to 0.8% in 2014.
- Many of the mining companies simply cite convenient growth scenarios from the IEA, EIA and WoodMackenzie.
- Most financial analysts covering the sector see thermal coal being in structural decline, impacting the future market of seaborne coal.
- BHP Billiton has indicated its coal EBITDA could half if there is a sudden switch to a 2^{o}C scenario.
- Coal demand growth in the future could stutter because:
    - Off-grid and mini-grid renewable energy solutions out-compete coal in areas of energy poverty;
    - China is a key growth market, but the direction of policy suggests an acceleration of the energy transition is possible. Higher than expected renewable energy penetration could displace coal demand equal to half of 2012 export levels in the short-term.

[116] http://www.woodmac.com/analysis/global-coal-future

What is the range of coal demand forecasts

Structural decline or cyclical low?

Over the past 12 months, a number of market analysts and investment banks have publically warned the future of coal demand is uncertain. This is particularly the case with regards to thermal coal for power generation. Perhaps the most vocal of these has been Goldman Sachs who have declared thermal coal is at the 'retirement age', in terminal decline and will peak before 2020.[117] Prospects for metallurgical coal are slightly different because of its use in the production of steel. Some analysts see metallurgical coal as having less risk from substitution and so could offset some of the poor expected performance for thermal coal.

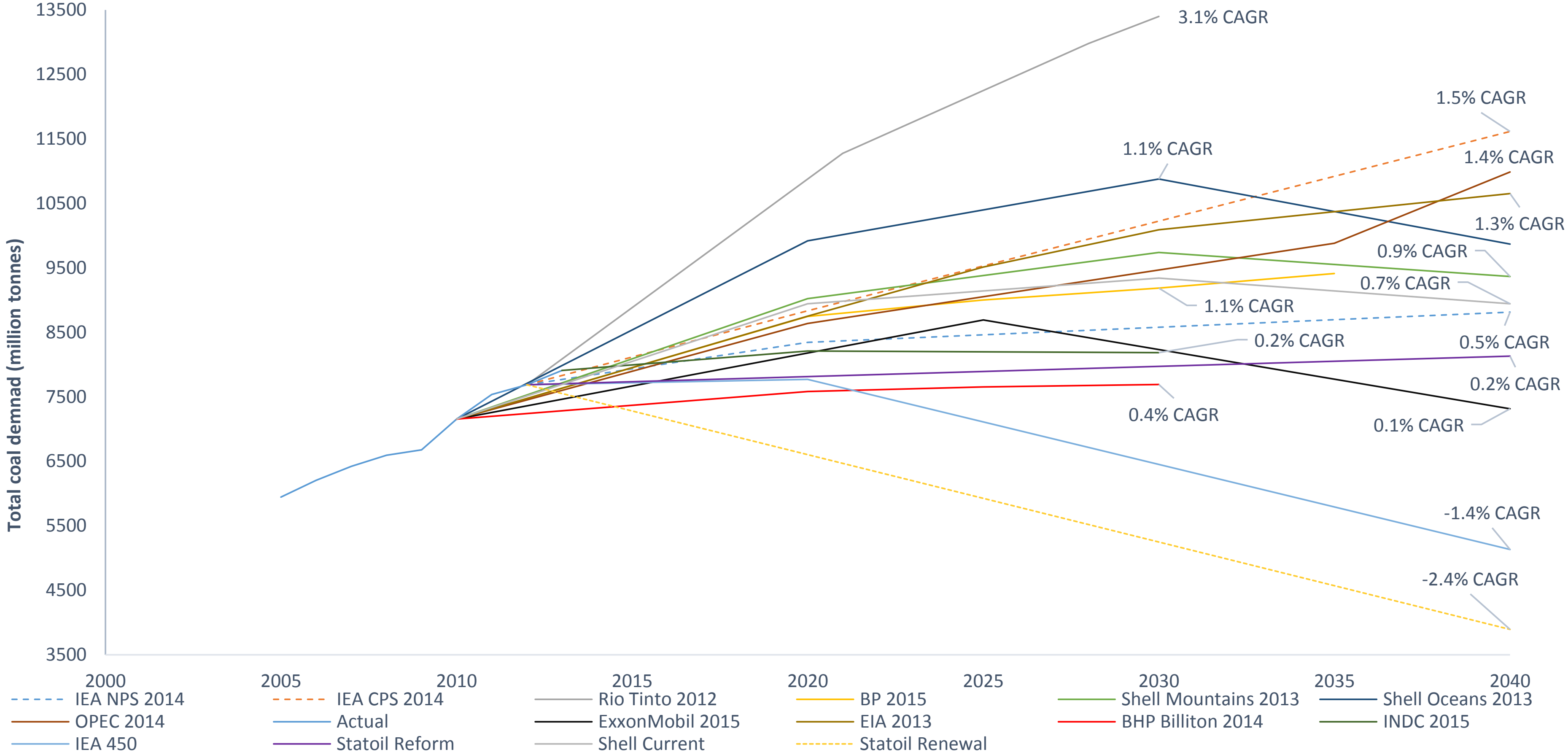
Figure 6.1 compares forecasts for total coal demand[118] across fossil fuel companies and energy analysts. It includes a forecast growth rate from Rio Tinto in 2012 that is approximately 2-3 times what most commentators are now expecting in the long-term. This reference points reveals exactly how quickly the coal market's prospects have shifted.

- Aside from 2°C scenarios, BHP Billiton's forecast to 2030 is the most bearish. It sees coal demand plateauing from 2020 onwards and correlates with BHP's recent efforts to reduce their coal exposure.
- The IEA's 2015 INDC scenario also sees coal demand plateauing from 2020, the year the next international agreement on climate change is set to take force. Figure 7.1 shows that the conservative commitments integrated in the INDC scenario achieve lower coal demand than envisaged in the IEA's NPS in 2014. It also shows that coal demand needs to fall significantly from current INDC commitments to meet the IEA 2ºC scenario (450 scenario).
- The oil majors have diverging expectations about future coal demand. Both Shell's bullish and bearish energy demand scenarios have coal demand that cumulatively exceeds that of the IEA's CPS to 2030, before declining in the decade after. However two of the more recent scenarios perhaps reflect the growing narrative from the oil majors that coal consumption has to reduce if we are to prevent climate change. ExxonMobil's expectations have coal demand growing to a peak in 2025 which declines steadily to a level in 2040 that reflects only 0.1% CAGR over the entire forecast period. Statoil's latest central Reform scenario sees steady 0.2% CAGR to 2040 putting them on a lower trajectory than the IEA's INDC, whereas their Renewal scenario sees -2.4% CAGR over the same period. This is a substantially greater demand decline than even the IEA 2ºC scenario. Note, Statoil explicitly highlight they do not attribute probabilities to any of their forecasts. In other words, this scenario is as likely as its central Reform scenario.

[117] http://www.reuters.com/article/2015/09/23/coal-markets-slump-idUSL5N11T01420150923

[118] Note, this includes metallurgical and thermal coal.

Figure 7.1: Comparison of total coal forecasts across fossil fuel companies[119]

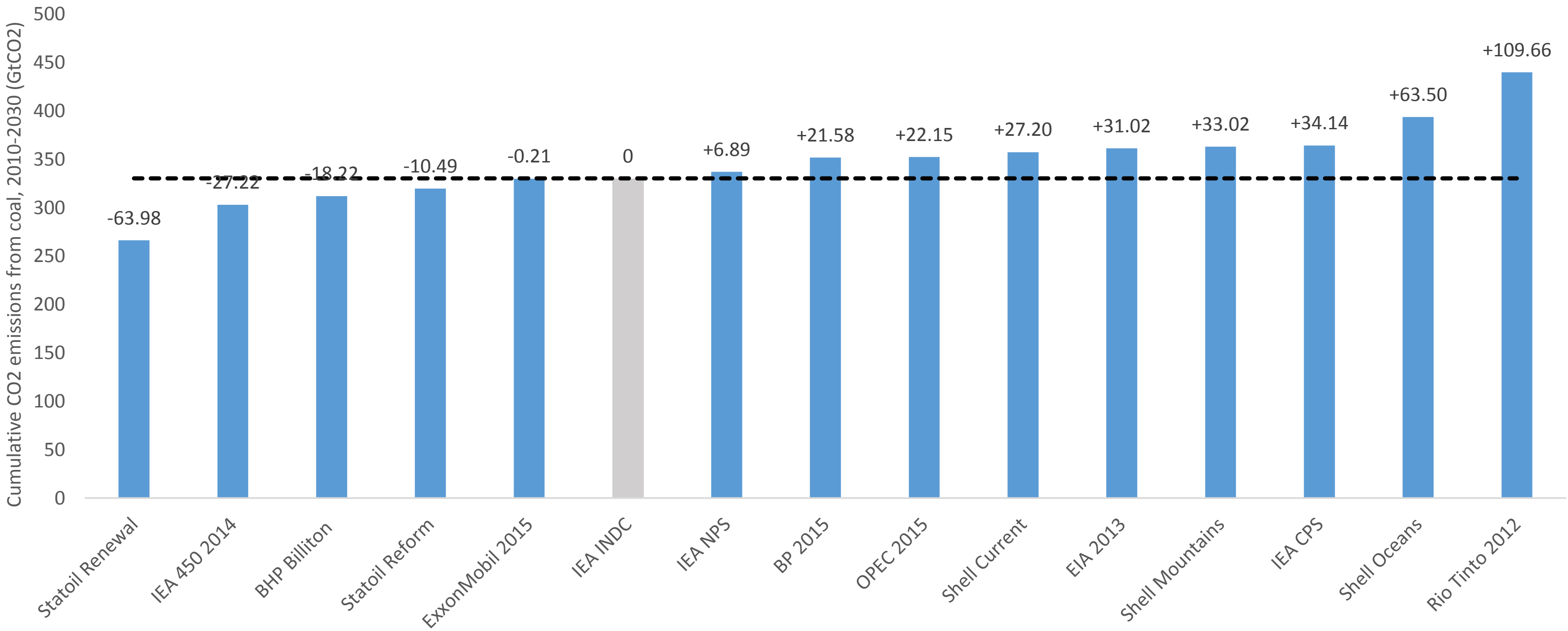


[119] Note forecast curves have different start dates between 2010 and 2013, depending on data given by the forecaster. This impacts CAGR calculations. All calculations are consistent with growth rates stipulated by the companies themselves. Forecasts are adjusted to IEA Coal Information 2014 data. Adjustment factors are in Appendix 2. There is variation in historic coal consumption data between institutions due to units, definitions and conversion factors. As such, this graph gets historic coal consumption data from the IEA's Coal Information 2014 document and adjusts all other forecasts to consistent units. It is worth noting the forecasts of Rio Tinto and BHP Billiton are our approximate readings from graphs found in investor presentations and therefore will not reflect exactly the expectations of these companies.

The CO_2 implications of different demand levels

In preparation for the COP21 climate conference in December 2015, countries are submitting Intended Nationally Determined Contributions (INDCs) to the UNFCCC. These commitments publicly outline what post-2020 climate actions each country intends to achieve under a new international agreement. As such, the INDCs represent the latest and most significant indication of political intention on climate policies. The IEA INDC scenario attempts to forecast what these commitments could mean for the global energy system to 2030. Figure 6.2 shows how fossil fuel scenarios for coal demand translates into CO_2 emissions compared to the level expected to result from the INDCs.

Figure 7.2: Cumulative difference in CO_2 emissions from coal consumption to the IEA INDC scenario (2010-2030) ($GtCO_2$)[120]



[120] Carbon calculations apply a bituminous conversion factor to all coal because it supplies more of coal demand than other coal types currently. This is: 1 tonne of coal = 2.439 tonnes of CO_2.

Most fossil fuel scenarios exceed the IEA's INDC scenario. As one would expect, these additional demand figures equate to meaningful amounts of CO_2 emissions. It is interesting that Shell's Current scenario results in lower CO_2 emissions than both their Mountains and Oceans scenarios. Also that the two diversified miners are entirely antithetical in their expectations – BHP see coal declining while Rio Tinto's 2012 outlook foresaw strong growth.

Perhaps the most important group of companies are missing from this forecast summary; that is the pure coal play companies. Instead of running their own demand scenarios like the oil majors, pure coal companies tend to use and publically reference IEA scenarios. They almost exclusively refer to the IEA's Current Policies Scenario (CPS), however, which is clearly more bullish than most. To 2030 the IEA's CPS foresees 34.14GtCO_2 more coal consumption than the INDC scenario. This is a business-as-usual forecast, which very much goes against the public messages coming out of investment bank and market analysis.

There is only a downside from the bullish IEA CPS scenario for pure coal companies

If the coal industry misreads future demand for its products by planning for the IEA CPS, they will increasingly diverge from market trends. In Peabody Energy's disclosure the company indicates that the IEA CPS does not take into account any new policies being introduced or changes to underlying trends and that it believes this to the most appropriate scenario for investors to consider. It would be interesting to hear from investors whether they believe the CPS is the right policy to base their view of the future energy market on. It could be argued there is a clear direction of travel for more measures to reduce greenhouse gas emissions and improve air quality, which should be factored in to the base scenario presented. Or at least a range of outcomes should be presented to show how resilient the business is to lower demand.

Peabody's disclosure on coal demand in its 2014 Annual Report:[121]

"*We project that approximately 225 gigawatts of new global coal-fueled generation, as well as industrialization and urbanization trends in China and India, will drive aggregate global thermal and metallurgical coal demand growth of approximately 500 million tonnes between 2014 and 2017. Though we anticipate that seaborne coal supply will also continue to grow during that period, we expect that growth to be outpaced by improved seaborne demand.*

The International Energy Agency (IEA) estimates in its World Energy Outlook 2014, Current Policies Scenario, that worldwide primary energy demand will grow 50% between 2012 and 2040. Demand for coal during this time period is projected to rise 51%, and the growth in global electricity generation from coal is expected to be greater than the growth in oil, natural gas, nuclear and solar combined. China and India are expected to account for nearly 75% of the coal-based primary energy demand growth projected from 2012 to 2040.

The Current Policies Scenario, which is one of three scenarios presented in the IEA World Energy Outlook 2014, considers government policies that had been enacted or adopted by mid-2014 and does not take into account government policies that may be enacted or adopted in the future. It is prepared by the IEA

[121] https://mscusppegrs01.blob.core.windows.net/mmfiles/files/investors/2014%20peabody%20annual%20report.pdf

as a baseline that shows how energy markets would evolve if underlying trends in energy demand and supply are not changed. We believe that the Current Policies Scenario is the most appropriate scenario for our investors to consider based on the substantial uncertainty as to the nature, extent and timing of possible new laws or regulations regarding the extraction or use of our products."

The impact of a 2^{o}C scenario

BHP Billiton has just produced a portfolio analysis of what a 2^{o}C scenario would mean for its business.[122] The analysis indicated that thermal coal is expected to provide a 20-year average of 4% of EBITDA revenues in its base case – this could fall to only 3% or 2% in orderly or shock transitions to a 2^{o}C world. As BHP Billiton has already started to move away from coal as a diversified mining business, the group level impact of a halving of coal revenues over the next 20 years is not a major impact, especially if offset by other commodities. However if the same were to apply to a pure coal company – a 50% drop in revenues over the next 20 years could well be terminal for the company.

Coal demand dominos keep falling

Between 2000 and 2012, coal consumption in the OECD has fallen by 5% due to substitution for alternatives and air quality and environmental regulation. This has meant producers have sought to diversify to export markets in a bid to reach non-OECD nations, which they expect to grow. This is especially true in the US who join other big exporters including Australia, Indonesia, Russia, South Africa, Colombia. This means there is more competition to serve the countries importing coal from the seaborne market. This seemed like a good strategy, as long as growing Asian economies continued to bolster demand for exported coal. China was the primary option, as its coal demand outstripped domestic supply in recent years. However this dynamic is shifting, with imports falling, leaving the potential for China to become an exporter within a few years. This would be like changing the direction of an escalator without warning – likely to result in casualties amongst those not expecting the reversal.

The next great hope for coal exporters is India. In contrast to China, the track record on delivery of policy is not convincing. This raises questions about which infrastructure will get delivered – either to increase overall demand, or to improve domestic supply of coal. Perhaps even more poignant is whether the Indian state can afford to subsidise importing coal which is expensive relative to its domestic product – if this cost is instead passed on to consumers it would cause an unacceptable increase in the price of electricity. Beyond this is Japan, where much will depend on the ability of the government to turn its nuclear capacity back on, rather than continue importing more coal. In Europe, after a brief period of sweating coal assets and using up carbon permits whilst coal was cheap, the direction of travel away from coal generation is clear. This leaves other south-east Asian economies as the next in line to support demand, but the bulk of the market has big question marks over its growth potential. This brief summary of regional markets hints at the struggle coal producers are facing to find coal demand dominoes that are yet to topple over.

[122] http://www.bhpbilliton.com/~/media/bhp/documents/investors/reports/2015/bhpbillitonclimatechangeporfolioanalysis2015.pdf

The poor won't save coal demand

The coal industry has developed a narrative around its role in providing the world with access to energy, but having had over a century to reach the world's population, it is hard to see it spreading much further, especially in tomorrow's energy market.[123] Africa is one of the regions with the lowest levels of access to energy, but the geography of coal supply makes it difficult to envisage widespread use of coal across the continent. Firstly the majority of the coal in Africa is concentrated right in the south of the continent. Secondly the lowest levels of energy access are in the rural areas which are not connected to power grids. This means that either the coal or the electricity would have to be transported to the people needing energy if coal is used as the power source. In sub-Saharan Africa, for example, only 7% of those without suitable access to energy live in the handful of countries with coal producing assets.

Carbon Tracker's detailed *Energy Access* analysis found that investing in off-grid and mini-grid renewables, as solar costs fall and battery technology improves, were by far the most cost-effective solutions in rural Africa.[124] Coal is therefore not the cheapest or most appropriate option for many of those without access to energy as its proponents claim. The coal industry regularly cites the IEA's "New Policies Scenario" as driving huge growth in demand and solving energy access problems in the developing world. However, that scenario only sees an 18% global increase in coal demand, and still leaves nearly three-quarters of the energy poor still without suitable energy access. In contrast, the IEA's scenario of universal electricity access by 2030 estimates three to five of households will source electricity via mini/off-grid solutions – a forecast in which coal demand increases less than 2%.[125]

How coal demand may be eroded in China

China's 12th Five-Year Plan (FYP) (2011-2015) was endorsed on 14 March 2011. It plainly outlined a move away from coal consumption by targeting: i) a 16% reduction in energy intensity of GDP; ii) increasing non-fossil fuel energy consumption to 11.4% of total; and iii) a 17% reduction in carbon intensity of GDP.[126] Further, the 12th FYP targeted an increase in service sector contribution to GDP from 43% to 47%. China has already exceeded its service sector target and looks likely to meet its energy targets - between 2011 and 2013 China achieved 9.03% energy intensity and 10.68% carbon intensity improvements.[127] In other words, China is on course to do what it said it would.

China's INDC climate pledge to the UNFCCC set a national target to peak CO_2 emissions by 2030. In an official submission to the UN, China stated it will 'work hard' to peak emissions before then.[128] Figure 7.3 shows a range of thermal coal demand forecasts in this scenario against other thermal coal

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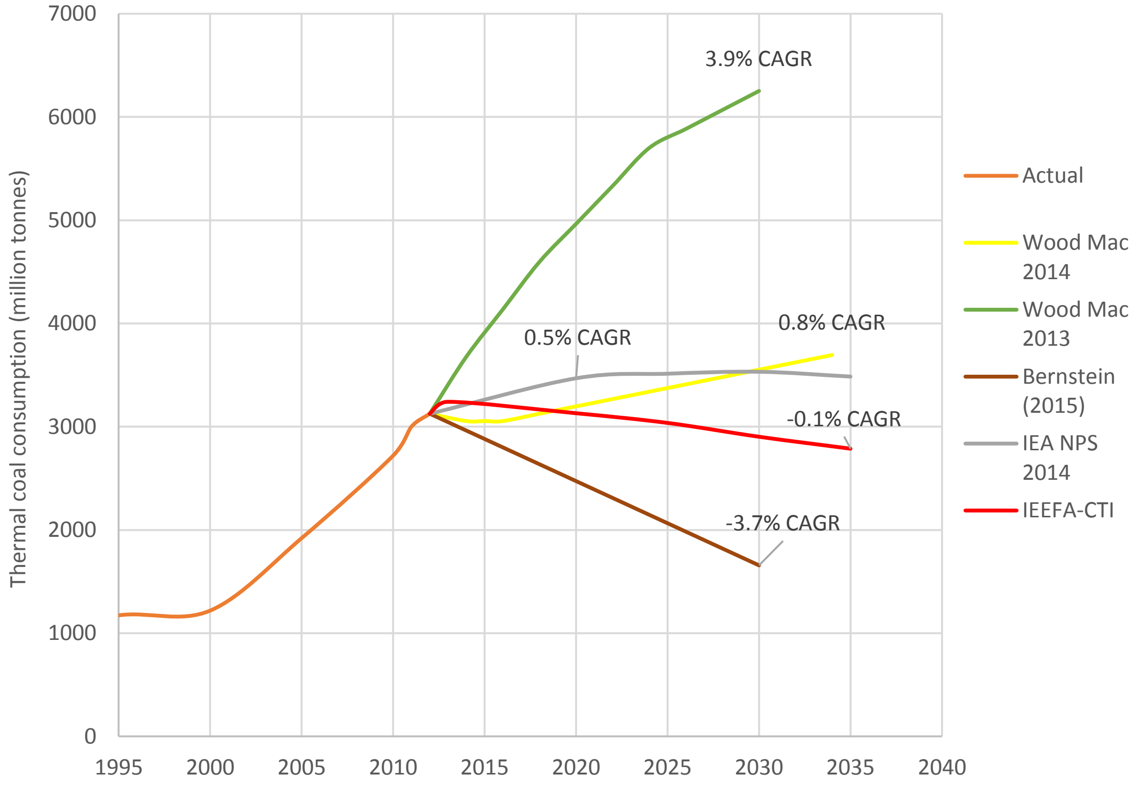
[123] https://www.advancedenergyforlife.com/
http://www.worldcoal.org/coal-energy-access/
[124] http://www.carbontracker.org/wp-content/uploads/2014/11/Coal-Energy-Access-111014-final.pdf
[125] http://www.carbontracker.org/report/energyaccess/
[126] http://www.c2es.org/international/key-country-policies/china/energy-climate-goals-twelfth-five-year-plan
[127] http://www.ipeec.org/blog/view/id/797.html
[128] http://www4.unfccc.int/submissions/INDC/Published%20Documents/China/1/China's%20INDC%20-%20on%2030%20June%202015.pdf

forecasts – China's thermal coal consumption accounts for roughly half of global total coal consumption and so is the single most important sector of the global coal industry.

Figure 7.3: Forecasts for thermal coal demand in China[129]



Official statistics showed that Chinese thermal coal demand fell by 2.9% in 2014 and that in the first half of 2015, this had fallen further to -5% on the previous year.[130] These statistics follow the path of the self-proclaimed 'extreme scenario' of the Bernstein 2015 report, 'Asia Strategy: Shouldn't we all be dead by now?' – shown in Figure 7.3.[131]

Few in the market predicted the shift in demand for coal in China. The rhetoric that China was building a coal-fired power plant every week still prevailed. This was typified by the now famous Wood Mackenzie report from 2013 entitled 'The illusion of peak coal'. Here Wood Mackenzie state that a decline in coal demand would not be seen until 2030, by which point consumption will be almost double that of 2011.[132] This forecast has since been revised downwards, but still does not see a demand peak occurring now. Such a large readjustment from 3.9% CAGR to 0.8% by WoodMackenzie shows how quickly the outlook for these markets can change.

[129] Where total coal demand forecasts are provided, the ratio of thermal coal demand to coking coal demand in China in 2012 (85%:15%) is used to convert these forecasts into thermal coal estimates. All forecasts are adjusted to historic data from the IEA's Coal Information 2014 report. These adjustment factors are in Appendix 2.
[130] http://ieefa.org/new-china-data-shows-how-australias-coal-industry-is-at-risk/
[131] Bernstein (2015) Asia Strategy: Shouldn't we all be dead by now?
[132] Wood Mackenzie (2013) *China: The illusion of peak coal.* April 29, 2013

The gap here also highlights that market analysts are tracking these trends and entertaining some bearish scenarios, even if the market consensus is higher. There has been a growing body of broker research calling the structural decline of the thermal coal market. However this is not reflected in the bullish views of some coal industry commentators and companies. In researching the projections used by the large diversified mining companies, many cited WoodMackenzie or IEA data which indicated continued high growth rates.[133] For example in an April 2015 presentation, Rio Tinto referenced the IEA WEO 2012, to indicate an expected growth rate of Chinese coal-fired power generation of 4.1% for 2009 to 2030. This seems a strange choice, given that an updated IEA WEO was available, in which the NPS has a rate of 0.8%. Furthermore, at that time there was already data emerging about the potential for 2014 to be a peak demand year for Chinese coal.

High renewable energy penetration in China could displace coal

In April 2015, the China National Renewable Energy Centre (CNREC) and the Energy Research Institute of the National Development and Reform Commission (NDRC) released a study exploring the feasibility of different renewable energy deployment scenarios.[134] It is significant that this study came from sources with a prominent voice in the economic planning of China. It concludes that it is both technically and economically feasible that renewable energy accounts for over 85% of China total electricity consumption in 2050. In this scenario they foresee strong solar PV electricity generation growth and particularly bullish growth in onshore wind generation. To 2020 alone, these high penetration rates of renewable energy technologies displaces approximately 160mt of cumulative coal demand against the CTI-IEEFA 2014 low-demand scenario. This is equivalent to approximately half of all China's coal imports in 2012.

Indian power demand may disappoint miners

With doubts surrounding future growth of Chinese energy and coal demand, fossil fuel companies have turned their eye to India as the next short-term growth market.[135] Indeed, when considering India against a number of the demand drivers cited in this report, it is easy to see why; the UN expect India to become the most populated country in the world by 2022, most likely increasing the number of people without access to electricity from approximately 300 million in the process. Furthermore, India is widely perceived to be at an earlier stage of economic development than say China and other BRICS nations. As such, strong, industry-led GDP growth is expected… but not guaranteed.

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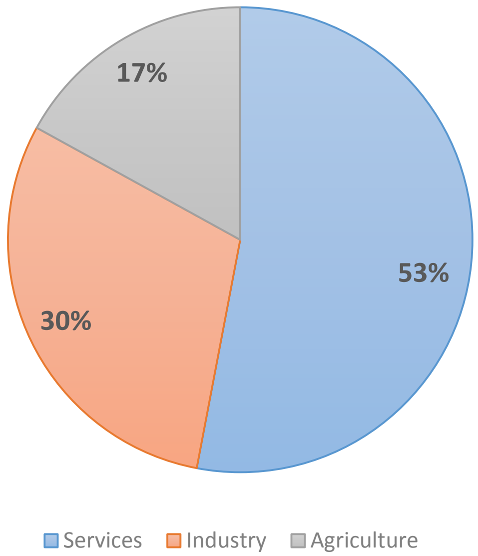
[133] For example see Rio Tinto presentations: http://www.riotinto.com/documents/150601_Presentation_-_Copper_and_Coal_roadshow_JS_Jacques.pdf ; http://www.riotinto.com/documents/201504_RT_Chartbook.pdf
[134] http://www.efchina.org/Attachments/Report/report-20150420/China-2050-High-Renewable-Energy-Penetration-Scenario-and-Roadmap-Study-Executive-Summary.pdf
[135] http://www.ft.com/cms/s/0/daab3774-d927-11e4-b907-00144feab7de.html#axzz3icOxgqi8

For example, the Wall Street investment bank Bernstein believe ‘industrialisation with Chinese characteristics is not going to be repeated by any market over the next 10 or 25 years’.[136] Many would point to India to argue against such a belief. However, looking at the sectoral breakdown of where India derives its GDP casts doubt on the nature of future economic shifts (and subsequent impacts on energy demand) India will undergo.

Figure 7.4: India’s GDP split by sector, 2014



Source: World Bank

Figure 6.4 shows that in 2014, India derived over half of its GDP from the service industry. This is a greater share than the service industry provides in China. India will seek to protect this industry in the future, so it is unlikely industry will take share from the service sector. Consequently, it is easy to make the argument from an economic perspective that India will not follow the hugely energy-intensive trajectory China is currently coming down from.

The rise of renewable energy threatens demand for coal in India

On October 1st 2015, India announced its INDC which set the target of 175GW installed renewable energy capacity in 2022. Approximately 100GW of solar power is expected and 60GW from wind power.[137] This is hugely ambitious given the total capacity between the two was 22GW in 2013.

Table 7.2 shows that assuming average utilisation rates, achieving these targets could displace 158mt of Indian coal demand. This is almost exactly the size of India’s coal imports in 2012. Clearly, if this target is realised, coal demand from the seaborne market will fall dramatically as the government favours and protects domestic producers first. These targets are substantial risks to global coal exporters.

[136] Bernstein (2015) Asia Strategy: Shouldn’t we all be dead by now?
[137] http://pib.nic.in/newsite/erelease.aspx?relid=123607

Table 7.2: India's new renewable energy target could hit the coal sector

	SOLAR PV			WIND POWER		
	Capacity (GW)	Electricity generation (TWh)	Coal equivalent (Mt)	Capacity (GW)	Electricity generation (TWh)	Coal equivalent (Mt)
2013	2	3	2	20	44	22
2022	100	175	86	60	147	72

Coal exporters to India will lose to domestic producers in a fight for demand

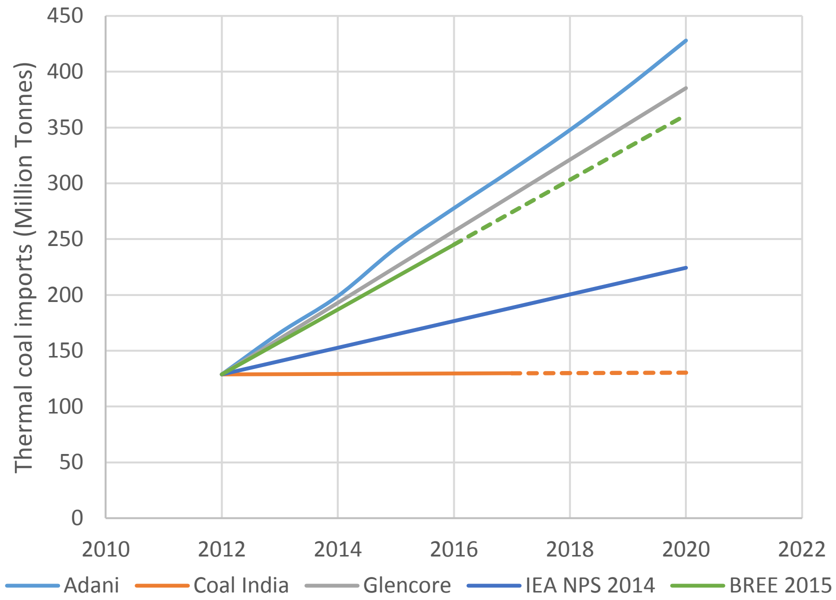
With future coal demand growth in China in doubt, the battle for import demand from seaborne market players is already fierce. In a future in which higher renewable energy penetration constrains absolute Indian demand for coal, that battle will intensify. Crucially, coal exporters are not only competing with others on the seaborne market but also domestic Indian coal producers. In recent history, supply bottlenecks in the Indian domestic market opened the door to overseas producers as the need for coal imports grew. This has been extremely costly and served to focus efforts on relieving production constraints domestically. With this aim firmly in the crosshair, India revealed in 2014 their aim to stop imports of power-generating thermal coal in the next three years:

"I'm very confident of achieving these targets and am very confident that India's current account deficit will not be burdened with the amount of money we lose for imports of coal" – Piyush Goyal, Power and Coal Minister.[138]

Whether or not one believes Mr. Goyal is fundamental to forecasts of coal being demanded either from domestic or overseas companies. Whether Mr. Goyal is proved right or not is almost wholly dependent on production levels of the state-owned Coal India. In their latest annual report, Coal India express their belief that India's total coal demand will be 980.5mt by 2017 of which 795mt will be produced domestically, meaning 185.5mt of coal will be imported.[139] They also state that 70% of this demand will be thermal coal for power supply. Figure 7.5 applies this percentage to Coal India's forecasts and compares this projection for thermal coal imports against the expectations of fossil fuel companies operating in that market.[140]

[138] http://in.reuters.com/article/2014/11/12/india-coal-imports-idINKCN0IW0FJ20141112
[139] https://www.coalindia.in/DesktopModules/DocumentList/documents/Coal_India_AR_2013_-_14_Deluxe_final_23092014.pdf
[140] Where only forecasts for 'total coal' were provided, Coal India's expectation for 70% to be thermal coal demand has been applied to give an estimate.

Figure 7.5: Coal India is bullish on its production of thermal coal...exporters don't believe them[141]



Coal India's forecast shows virtually flat demand for imported thermal coal – very much aligned with the targets of the Government of India. Instead, domestic total coal production increases from 604mt in 2012 to 795mt in 2017 to meet demand. Prime Minister Modi has announced that to 2020 India's target is to produce 1.35bn tonnes, (1.5bn tons).[142]

Adani, Glencore Xstrata and the Australian Bureau of Resources and Energy Economics (BREE) clearly do not foresee Coal India's predictions materialising. Adani are the most bullish, forecasting in a 2015 presentation that India's thermal coal imports will treble from 2012 to 2020.[143] This is consistent with their $16.5bn investment-to-date in the Carmichael mine; an estimated 60 million tonnes per annum project aimed almost solely to supply India.[144]

On average over the past five years, India has only managed 1.5% annual increases in coal production so it is easy to see why these companies and institutions are aggressive in their import forecasts. More recent production data coming out of India, however, suggests this approach may be misguided. In 2014/15 Coal India reported a 6.9% year-on-year increase in coal production. April 2015 production levels were 10.7% up on the previous year and April-June 2015 volumes were up 12% year on year.[145] In short, India is being successful in relieving their supply bottlenecks. As a result, India's coal imports were flat in June 2015, hinting at what lay in store for coal exporters should India continue progressing its domestic production.

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[141] All forecasts have been adjusted to India's 2012 coal import levels as published in the IEA's Coal Information 2014 report. The adjustment factors can be found in the Appendices.

[142] http://asia.nikkei.com/Politics-Economy/Policy-Politics/Modi-looks-to-double-coal-production-by-2020

[143] http://www.adani.com/Common/Uploads/InvestorRelationTemplate/19_InvBotDL_Adani%20Group%20Presentation%20Apr%2015.pdf

[144] http://www.mining-technology.com/projects/carmichael-coal-mine-and-rail-project-queensland/

[145] http://www.firstpost.com/fwire/india-coal-imports-flat-in-june-as-local-supply-jumps-trade-reuters-2324530.html

Demand – price relationship

Carbon Tracker's analysis of the cost curves of coal supply and its interaction with demand have demonstrated that lower demand levels in the future would be expected to lead to lower long-term equilibrium prices. In the short-term whilst the market rebalances there may be even lower prices seen due to oversupply –as is currently being experienced in the seaborne market. If coal exporters develop production on the basis of high future demand expectations they may be disappointed in a low demand environment. Given much of the seaborne market is already only covering its costs rather than making a decent return for shareholders, there is little room for further softening of prices. For a while many in the coal industry may have expected this situation to merely be the bottom of the latest commodity supercycle.

Cheap isn't always good

The drop in volume sold is obviously a negative for producers, especially if they have already sunk capital into new marginal production. However a drop in prices has further knock on effects. It may well have a larger impact on revenues than the reduction on volume for a start. It will also feed through into asset valuations, which may restrict the asset base that can be borrowed against, as many coal producers seek to issue debt to ride out the current challenging market. This shows why both demand and price assumptions should be considered together in scenarios, as price is critical for investors to understand future value. It also demonstrates that having a cheap product may appear a positive characteristic to compete in the market – but not if the price achieved fails to generate profits for any sustained period.

IEA price forecasts

The relative bullishness of the IEA's NPS and CPS translates into their forecasts of associated thermal coal prices (Figure 7.6). The 2014 NPS sees OECD thermal coal import prices increasing steadily to $108/t in 2030 and $112/t in 2040. Price estimates in the CPS are approximately 8% higher than in the NPS. The IEA also provide a Coastal China import price estimate that splits these two forecasts with a similar growth rate. In the context of the current low price, these forecasts seem deeply optimistic – the FOB Newcastle average price helps illustrate this in Figure 7.6. The IEA's NPS thermal coal price forecasts have not shifted to any significant degree since 2009, in spite of undergoing price crash and even the 450 scenario thermal coal price estimate is higher in 2040 than current prices even though global demand is forecast to be 33% lower than 2012 levels. Again, this exemplifies the challenges of predicting prices and keeping annual models up to date. We see reasons to suggest global thermal coal demand could peak in 2016, for total coal demand to plateau soon after and for coal prices being suppressed as a result.

Figure 7.6: IEA thermal coal price forecasts across scenarios

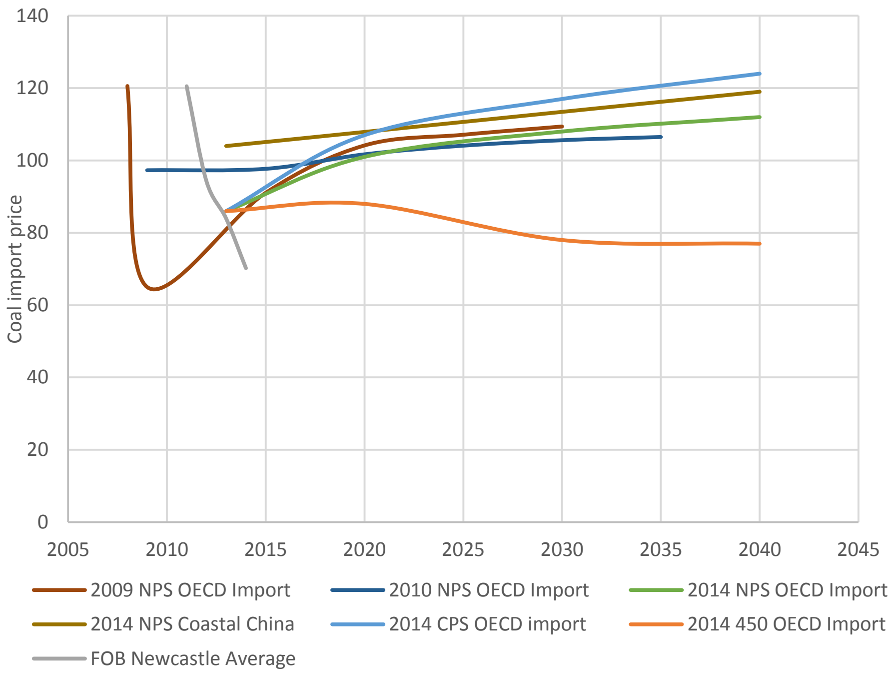
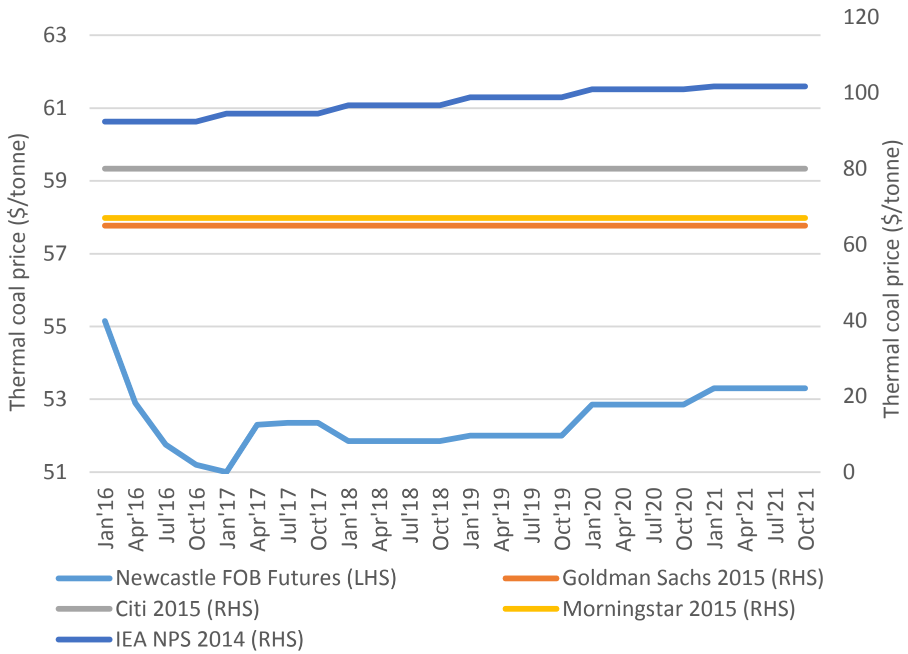


Figure 7.7: Market analysts get closer to futures prices[146]



Will coal prices rebound?

The IEA CPS and NPS see import coal prices recovering above $100 by 2020. Market analysts do not see such a recovery in their long-term forecasts. Over the past few years, investment banks have universally revised down their expectations for future coal prices. In 2015, Citi lowered their long-term price forecast to US$80/tonne, Morningstar to US$67/tonne and Goldman Sachs to US$65/tonne as they called the 'retirement age' for the thermal coal industry – refer Figure 7.7.[147] Futures coal prices suggest a lower price than even market expectations could materialise. One Newcastle Coal Futures database identifies coal price contracts between 2016 and 2021 trading between US$50 and US$55, almost exactly half the average price in the IEA NPS over the

[146] Graph assumes linear growth between given data points in the IEA NPS forecast.

[147] Citi (2015) *Survival of the fittest;* Goldman Sachs (2015) *Thermal coal reaches retirement age;* Morningstar, http://www.morningstar.co.uk/uk/news/135607/analysts-cut-price-forecasts-for-copper-coal-and-iron-ore.aspx

same period.[148] This is hugely significant because coal futures haven't traded at $50/t since 2003.[149] It is apparent market analysts are internalising clear constraints on future coal prices from potential demand destruction. Coal companies, however, continue to push a diverging message of demand and price growth by cherry-picking more bullish IEA scenarios.

Predicting prices – a mug's game?

It is easy to overreact to a discrepancy between scenario prices and current spot or futures prices. If there is increasing volatility in the market then a view of the longer term price trend is needed, rather than applying short-term price troughs. That said, in coal's case where the seaborne market shows signs of being in structural decline, prices may need recalibrating if they were previously based on the expectation of an upturn in the cycle. The speed at which scenarios can become out of date in terms of pricing levels represents another challenge in stress-testing business models against them. Companies need to ensure they are providing useful analysis, not just rigidly following scenarios.

Conclusions

- Almost all industry scenarios see coal demand still growing, hereby exceeding the policy signals given in current INDC commitments.
- Even WoodMackenzie, one of the most bullish coal forecasters, cut its projection for Chinese coal demand to 2030 from 3.9% CAGR to 0.8% in 2014.
- Many of the mining companies simply cite convenient growth scenarios from the IEA, EIA and WoodMackenzie.
- Most financial analysts covering the sector see thermal coal being in structural decline, impacting the future market of seaborne coal.
- BHP Billiton has indicated its coal EBITDA could half if there is a sudden switch to a 2^{o}C scenario.
- Coal demand growth in the future could stutter because:
    - Off-grid and mini-grid renewable energy solutions out-compete coal in areas of energy poverty;
    - China is a key growth market, but the direction of policy suggests an acceleration of the energy transition is possible. Higher than expected renewable energy penetration could displace coal demand equal to half of 2012 export levels in the short-term.

[148] http://quotes.esignal.com/esignalprod/quote.action?symbol=NCFQ-ICE
[149] http://www.reuters.com/article/2015/09/23/coal-markets-slump-idUSL5N11T01420150923

BAU Assumption 8: Demand for oil continues to increase

"The stone age didn't end for a lack of stones, and the Oil Age will end long before the world runs out of oil" – Ex-Saudi Oil Minister, Sheikh Zaki Yamani, 2000

Increasing efficiency of internal combustion engines (ICEs) continues to offset the growth in vehicle demand. EVs are starting to offer real alternatives and seeing significant uptake in countries like Norway, Netherlands, California where the incentives to buy EVs are right. Costs will only continue to fall, and battery technology improvements will make EVs more competitive.

"If electric vehicles *ever* reach 3% of global fleet additions: the next stop after 3% is 97%" – Bernstein Research.

Key findings

- Most oil demand scenarios show continued growth, with a few indicating a peak in demand in the next couple of decades. As a result most industry scenarios exceed the emissions trajectories from the oil sector indicated by INDCs.
- Oil demand growth is mainly expected in non-OECD markets where passenger vehicle fleets will grow.
- The technology used by the LDVs added in non-OECD markets will be critical to determining future demand.
- Growth in the number of EVs is already ahead of most energy industry scenarios, which foresee very low levels of penetration by 2040.
- Levels of oil demand from the HGV sector depend on economic growth rates and efficiency gains.
- The oil price is diffiult to predict with volatility and uncertainty having returned to the market. EVs offer protection from high oil import costs and energy security for importers.

As the profile of the risks of carbon-intensive assets has increased over the past few years, oil has been posited as a 'safer bet' than other fossil fuels because it is not easily substitutable. As investment guru Jeremy Grantham highlights in a quarterly newsletter, current oil wells deliver around 30 times the energy expended to obtain it; this is 'not easy to duplicate'.[150] The transport sector makes up 55% of all oil demand today and, according to some, there are no readily available and viable alternatives.[151] This may be about to change. In 2014, sales of hybrid vehicles passed the 7 million mark and over 665,000

[150] http://www.nasdaq.com/article/are-we-the-stranded-asset-and-other-updates-cm472723
[151] http://realmoney.thestreet.com/articles/06/18/2014/theres-still-no-substitute-oil

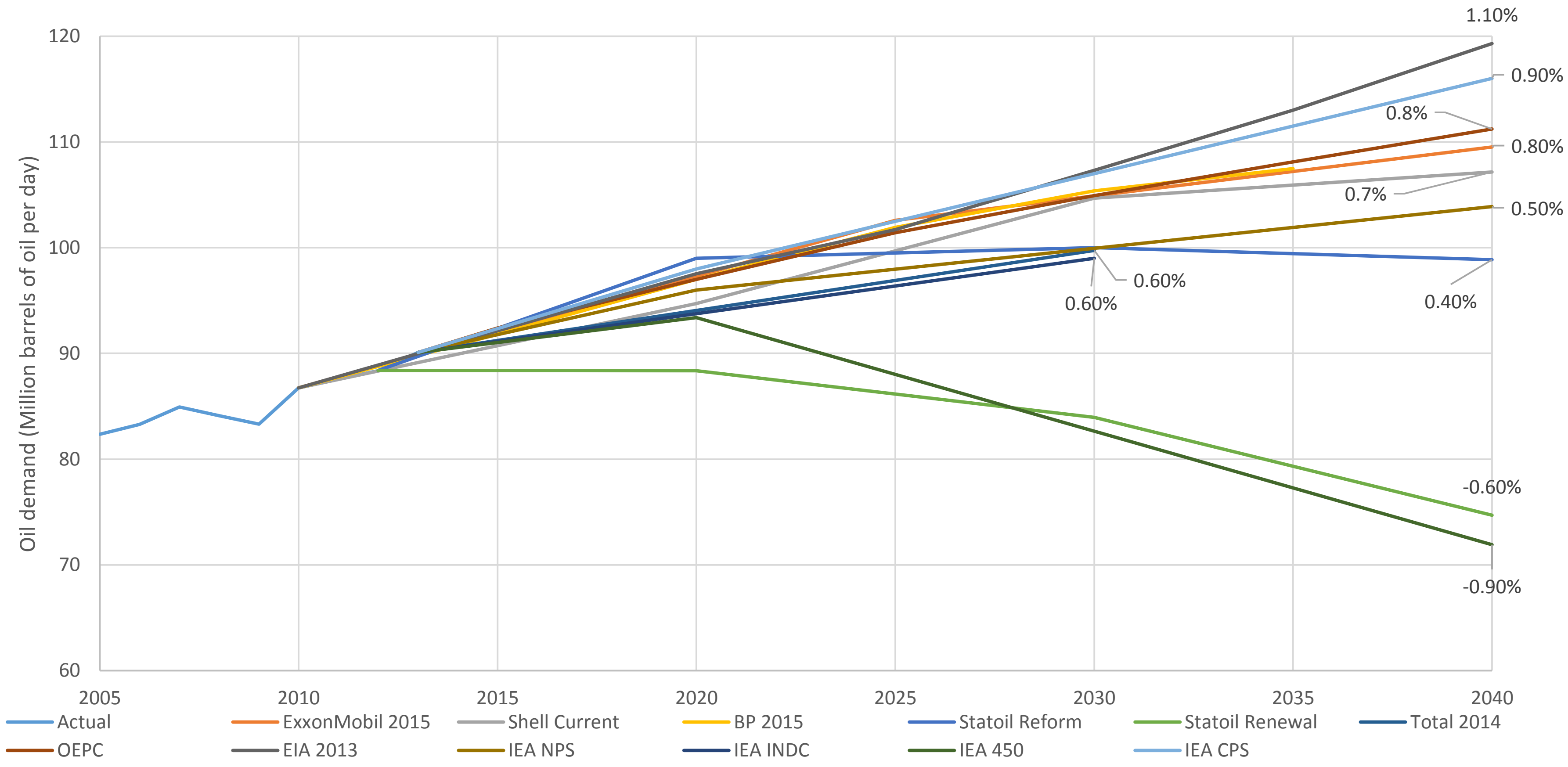
battery electric vehicles (BEVs) exist in the global fleet.[152] Technological improvements and innovations mean penetration of these alternatives will accelerate, a point not lost on Mr. Grantham. In the next two years, 'not 5 or 10 years from now', he sees the introduction of 'the fast charging of batteries, up to and including car batteries, in 2 to 10 minutes…and substantially longer lives and lower costs for all batteries'.[153] This could fundamentally challenge future oil demand for the transport sector. As highlighted in Assumption 6 on transformation factors, once penetration of technologies passes a certain threshold, their saturation of the market is inexorable.

The range of oil demand forecasts

Figure 8.1 shows forecasts of future oil demand growth across a number of oil companies, OPEC, the US EIA and IEA. Most corporate scenarios range between approximately 0.6% and 0.8% CAGR.[154] Statoil's Renewal scenario stands out as an alternative to consider with falling oil demand averaging -0.6%. We have used all available data to depict any curvature as accurately as possible in Figure 8.1.

[152] http://www.iea.org/evi/Global-EV-Outlook-2015-Update_1page.pdf
[153] http://www.nasdaq.com/article/are-we-the-stranded-asset-and-other-updates-cm472723
[154] Presented compound annual growth rates are consistent with those published by the company.

Figure 8.113: Forecasts of future oil demand[155,156]



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[155] Methodological differences in defining oil as part of the total liquids supply complicate comparing the level of projected oil demand across different sources. To aid comparability we have subtracted biofuels where possible, i.e. ExxonMobil and BP, in an attempt to give a more accurate 'oil' forecast. ExxonMobil was converted from QBtu to mbd and BP from mtoe to mbd. The conversion factors for these calculations can be found 2. Historic data is from the IEA's online database and adjusted to the 2013 total oil demand figure given in the IEA World Energy Outlook 2014. All forecasts were then adjusted to this historic data set using the more recent consumption figure given by the company or institution themselves. Adjustment factors can be found in Appendix 2.

Table 8.114: Comparing CO_2 implications oil forecasts against the IEA INDC scenario, 2012-2030 ($GtCO_2$)[157]

	EXXONMOBIL 2015	SHELL CURRENT	BP 2015	STATOIL REFORM	STATOIL RENEWAL	TOTAL 2014	OPEC 2015	EIA 2013	IEA NPS	IEA 450	IEA CPS
2012-2020	2.6	0.7	2.4	3.8	-3.9	0.2	2.4	2.7	2.7	-0.3	3.1
2020-2030	8.6	6.0	8.8	5.7	-18.7	1.0	8.4	11.0	2.9	-15.3	11.2
TOTAL	**11.2**	**6.7**	**11.1**	**9.5**	**-22.6**	**1.2**	**10.7**	**13.8**	**5.7**	**-15.5**	**14.3**

Are the scenarios INDC-ready?

In Table 8.1 we compare these forecasts against the IEA's 2015 INDC scenario because we see this forecast as it is the minimum shift that could occur as a result of climate policy. All oil demand forecasts exceed this benchmark, except the two 2ºC scenarios (Statoil Renewal and IEA 450). ExxonMobil is the most bullish on oil demand of the oil companies, with cumulative consumption between 2012 and 2030 approximately 61mbd higher than in the INDC scenario. In CO_2 emissions this is equivalent to 11.2$GtCO_2$ higher than in the INDC scenario. All forecasts, except that of Total, also exceed the IEA's NPS scenario, which implies at least a 3.6°C long-term rise in global temperature.

Forecasts from ExxonMobil, BP, OPEC and the EIA are in fact closer to the IEA CPS than the NPS. The CPS is 78mbd/14.3$GtCO_2$ higher than the INDC scenario between 2012 and 2030 and broadly a 5.5ºC scenario. The CPS is a business-as-usual future that only takes into consideration policies being implemented as of mid-2014 and assumes countries 'do not introduce any other policies that affect the energy sector'.[158] This is not a realistic proposition over the next 26 years and is not intended to be used as such but rather as a benchmark. Companies aligning their oil demand projections with this forecast are not adopting a true reflection of future policy and market risks.

ExxonMobil in particular have stated in the last year that governments acting to prevent dangerous climate change does not fall within the 'reasonably likely to occur' range. Instead their Energy Outlook 'demonstrates that the world will require all the carbon-based energy that ExxonMobil plans to produce' during this period.[159] The INDCs represent exactly those steps towards tackling climate change that ExxonMobil consider 'highly unlikely' and, according to the IEA scenario, will undercut ExxonMobil's expectations of oil demand by 55mbd cumulatively to 2030. In the decade starting 2020, this results in demand being around 4mbpd lower in the INDC scenario than ExxonMobil's.

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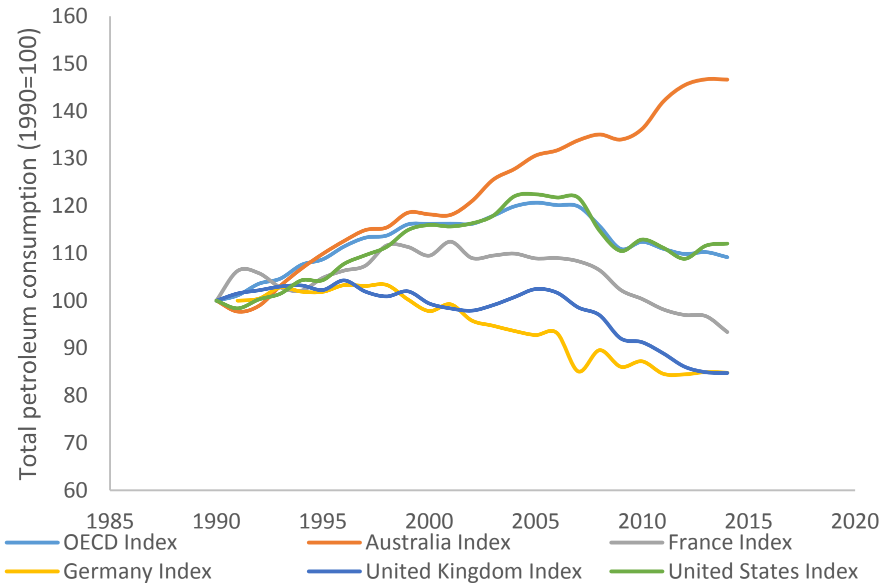
[157] Cumulative oil demand in million barrels per day was converted into CO_2 using the following conversion factor: 1bbl = 0.5tCO_2.
[158] http://www.worldenergyoutlook.org/publications/weo-2014/
[159] http://cdn.exxonmobil.com/~/media/global/files/other/2014/report---energy-and-carbon---managing-the-risks.pdf

We focus on road transport

Transportation is the largest sectoral consumer of oil, and involves combustion of the oil, as opposed to some of the chemical and physical applications of other petroleum products. Within the transport sector, oil is consumed in road, rail, aviation and navigation sub-sectors. The IEA's NPS forecasts approximately two-thirds of transport oil demand growth to 2040 will come from the road transport alone and exclusively in non-OECD countries.[160] As such, we focus on the potential for oil demand destruction in the road transport sectors specifically. First, there are important geographical and technical distinctions to outline:

- **The significant difference between LDVs and HDVs:** When talking about oil demand from road transport, one must distinguish between light-duty vehicles (LDVs), predominantly made up of passenger vehicles, and heavy-duty vehicles, which tend to be trucks for commercial use. Most oil companies see slower oil demand growth for LDVs, where efficiency measures are more progressed and the risk of product substation is greater, than for HDVs.

Figure 8.2: Petroleum demand in OECD nations[161]



Prospects for oil from transport differ by location:

OECD nations tend to have large existing fleets and limited expected growth in vehicle numbers in the future. Some even believe with investments in public transport, the increased use of communications technologies to substitute for travel and consumer preferences moving away from driving have meant OECD nations have reached 'peak car' – the notion that the cumulative distanced travelled per capita has peaked. Consequently, petroleum demand in OECD countries has been on the decline since 2005 (Figure 8.2). To date, petroleum demand is 10% down on the 2005 peak. Unlike OECD countries, the same level of existing road fleet does not exist in non-OECD regions. These countries have only more recently seen vehicle numbers start to rise so this is where growth is expected to be focused and, therefore, where there is greater potential for demand destruction and to avoid emissions.

[160] http://www.worldenergyoutlook.org/publications/weo-2014/. Says that transport oil demand in OECD countries declines across all sub-sectors apart from aviation.
[161] http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm

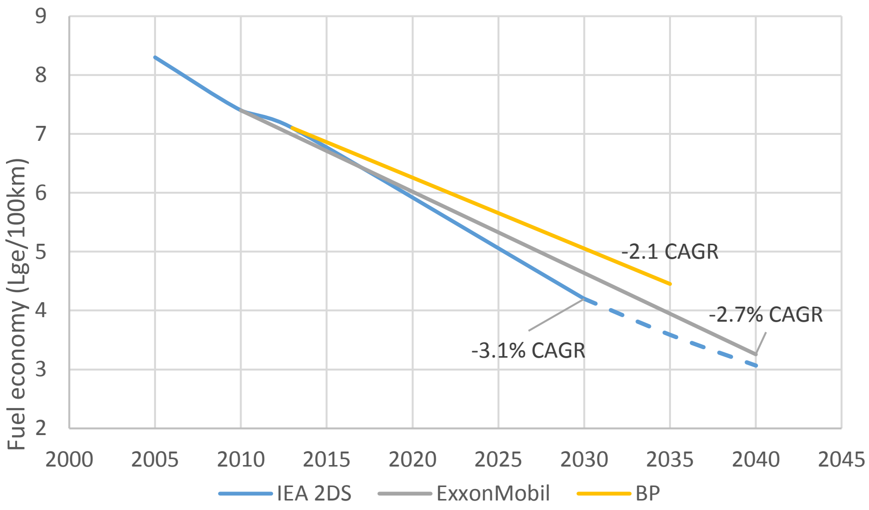
Demand for petroleum from LDVs depends on efficiency and substitutes

Only ExxonMobil and the IEA go into any detail about their expectations for oil demand from LDVs and both see it making modest growth in the future. The IEA NPS sees LDV oil demand rising 2mbd to 2040, while ExxonMobil are less optimistic seeing approximately 1mbd more growth before LDV demand peaks in 2020. Evidently, the important considerations are: i) whether LDV oil demand increases and by how much; and ii) how much LDV oil demand could decline in the forecast period.

This will largely be determined by future **efficiency gains** - typically only 15-20% of the chemical energy contained within oil ends up driving the wheels – and the potential for EVs to substitute for internal combustion engine (ICE) vehicles in the longer-term. The potential for **EVs to substitute for internal combustion engine** (ICE) vehicles is typically seen as a longer-term demand risk than efficiency gains. It is in this chronological order these drivers will be examined.

Oil companies forecast missed LDV efficiency targets

Figure 8.3: Fuel economy of global vehicle fleet forecast to improve[162]

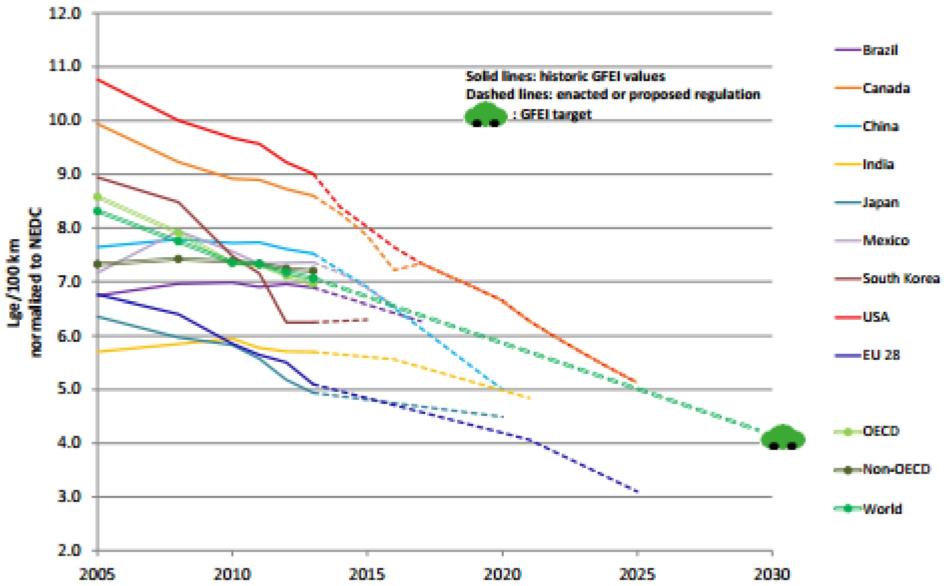


The IEA and UNEP's Global Fuel Economy Initiative (GFEI) set a target to reduce fuel economy from 8.3 Lge/100km to 4.2 Lge/100km in new LDVs between 2005 and 2030. This target is 'ambitious yet realistic' according to the IEA and aligns with their 2015 ETP 2DS scenario.[163] This target assumes 3.1% average annual efficiency improvements globally between 2014 and 2030. As Figure 8.3 shows, ExxonMobil and BP are the only oil companies to disclose their forecast assumptions for efficiency gains and neither achieve the GFEI's target. BP in particular are particularly conservative. This is likely to result from observed gains recorded between 2005 and 2013. In this period, annual improvements in fuel economy globally averaged 2.0%.[164] Evidently, efficiency gains must be accelerated. This will be determined by the net-effect resulting

[162] Dotted line extrapolates the IEA 2DS assuming the same CAGR decline. ExxonMobil value calculated from their assertion that fuel economy of global fleet will improve from 25 mpg to 45 mpg by 2040.
[163] http://www.iea.org/etp/etp2015/
[164] http://www.fiafoundation.org/media/45112/wp11-iea-report-update-2014.pdf

from OECD and non-OECD regions, between which progress varies substantially, as summarised in Figure 8.4.

Figure 8.4: Average new LDV fuel economy evolution by country[165]



Fuel efficiency set to halve consumption in 20 years

Oil demand in the road transport sector in OECD countries is plateauing and declining. It is following the same downward trajectory as population change, energy demand and coal demand that results from ever-maturing economies.

Between 2005 and 2013 the fuel economy in OECD countries improved by 2.6% each year on average (Figure 7.5).[166] Many OECD countries achieved well over 3% improvements over this period, led by the EU and Japan. The application of greenhouse gas and fuel economy corporate average fuel economy (CAFE) standards saw improvements accelerate in the US. This chart shows how in 20 years from 2005 onwards, many countries could halve the amount of fuel used for a given distance. This means that if the vehicle fleet size in these countries stays the same, oil demand could be 50% lower. Figure 8.4 shows the fuel efficiency of passenger cars and light-duty vehicles in a number of OECD countries already exceeds the GFEI/2DS target and are foreseen to improve.

Efficiency gains in non-OECD countries could surprise on the upside

Approximately 90% of global additional LDVs are expected to be purchased in non-OECD countries.[167] The efficiency of this additional fleet, therefore, is critical to the future oil demand and CO_2 emissions from the road transport sector.

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165 http://www.globalfueleconomy.org/media/45112/wp11-iea-report-update-2014.pdf
166 http://www.fiafoundation.org/media/45112/wp11-iea-report-update-2014.pdf
167 http://www.bp.com/en/global/corporate/energy-economics/energy-outlook-2035.html

In the period from 2010 to 2013, non-OECD countries achieved annual fuel economy improvements of 0.8% each year. Since then, major vehicles markets include Mexico and Saudi Arabia have introduced fuel economy standards, while India introduced a fuel efficiency target in 2014 of 4.8 lge/100km by 2021/22 – this would surpass the standards expected in the US at this time. China is the most important single driver of non-OECD fuel economy progress, however. In 2013, China accounted for 58% of all new vehicle sales in non-OECD countries and over a quarter worldwide. Oil companies like ExxonMobil are expecting the size of China's vehicle fleet to grow to 400m by 2040 – 40% larger than in the US. As of 2013, the fuel economy in China was one of the highest of non-OECD countries studied by the GFEI standing at 7.6 lge/100km.[168] However, China has issued big targets to catch up with the developed world as fast as possible.

China's plan proposes an average fuel combustion target of 6.9 lge/100km in 2015 and 5.0 lge/100km for new LDVs by 2020. These levels exceed standards in the US over this period and roughly equate to 2.2% annual improvement to 2015 from a 2010 level and then more ambitious 6.2% annual gains to 2020.[169] Over the 10 year period this equals annual average efficiency gains of -4.2%. This policy is largely in response to the air pollution crises in China's cities that have prompted political action. Air pollution is now at the top of China's political agenda leading many to believe this target will be met – China has confirmed they will punish any carmakers who do not meet the fuel economy standards.[170] To get the ball rolling, China supported this policy by announcing 5 million of the most polluting cars that fail these fuel standards will be scrapped. If China meets these standards and continues making LDV efficiency gains through to 2030 while the size of the fleet increases, the GFEI target will most likely be met on a global level.

Carbon savings exist between the oil company forecasts and IEA 2DS

The fuel economy forecasts of BP and ExxonMobil quoted earlier assume greater consumption of petroleum in the LDV sector than if the GFEI/2DS target of 4.2 Lge/100km is achieved. Table 8.2 illustrates how much additional CO_2 emissions this assumes to 2035 (the end of BP's forecast period). These totals assume a reduction in CO_2 emissions of 34Mt for every 0.1 Lge/100km drop in fuel economy calculated from the IEA 2DS between 2012 and 2030.

Table 8.2: Annual CO_2 emissions from LDV sector[171]

Year	2DS 2015 Fuel Economy (Lge/100km)	Annual LDV emissions (Mt CO_2)	ExxonMobil 2015 Fuel Economy (Lge/100km)	Annual LDV emissions (Mt CO_2)	BP 2015 Fuel Economy (Lge/100km)	Annual LDV emissions (Mt CO_2)
2013	7.1	4350.8	7.1	4350.8	7.1	4350.8
2030	4.2	3379.0	4.7	3539.6	5.1	3664.9

168 http://www.fiafoundation.org/media/45112/wp11-iea-report-update-2014.pdf
169 http://www.theicct.org/sites/default/files/publications/ICCT_PVfe-feasibility_201308.pdf
170 http://cleantechnica.com/2014/10/22/china-punish-automakers-dont-meet-fuel-economy-standards/
171 Extrapolates the 2DS scenario to 2035 assuming the 2013-2030 rates of -3.1%. Applies ExxonMobil forecast rate of -2.7% between 2010 and 2040. Applied given -2.1% rate for BP forecast.

2035	3.6	3173.9	4.0	3301.0	4.5	3463.2
Cumulative difference to IEA 2DS 2015 (2013-2035)				+2148.5		+4012.9

Table 8.2 shows that improved fuel efficiency of LDVs in line with GFEI targets will reduce emissions by 2.1GtCO_2 below ExxonMobil's current expectations to 2035 and by 4.0GtCO_2 below BP's. This may seem a modest contribution over this time period, but this is just one driver within the LDV sector. The medium-term driver of EVs and non-petroleum alternatives substituting for ICE vehicles could compound downside transport oil demand risk.

EVs could displace ICE LDVs – but how many?

There are many different types of 'electric vehicles' (EVs) on the market now, each consuming different amounts of oil, that need to be defined. Full battery powered electric vehicles (BEVs) use no oil. Plug-in-hybrid electric vehicles (PEVs) have an ICE as well, but can recharge the battery by plugging into an outlet, in theory negating the need for the engine on short journeys. A traditional hybrid vehicle (HEVs) has both an electric motor and an ICE, but cannot be plugged in, instead charging the battery off the ICE's wasted energy. The industry standard, and the classification that we use from now on, is that the term 'electric vehicles' comprises BEVs and PEVs but not HEVs.

Table 8.3: EV stock in EVI members and the global total

EV Stock	2012	2014	% Change
China	11573	83198	619%
France	20000	30912	55%
Germany	5555	24419	340%
Japan	44727	108248	142%
Netherlands	6750	43762	548%
Norway	10000	40887	309%
Sweden	1285	6990	444%
UK	8183	21425	162%
US	71174	275104	287%
Global	180000	665000	269%

There were approximately 665,000 EVs on the roads globally as of the end of 2014, an impressive number given they have only been on the market since 2009. Growth has been particularly pronounced in countries that are members of the Electric Vehicles Initiative (EVI) – refer Table 8.3 - an intergovernmental programme dedicated to accelerating EV adoption to 20m vehicles by 2020. Industry forecasts either articulate their expectations for EV growth as a percentage of the total global fleet or as a percentage of new sales. We attempt to build up a comprehensive picture of EV prospects from these two approaches.

Figure 8.5: EV sales as % of annual PLDV sales

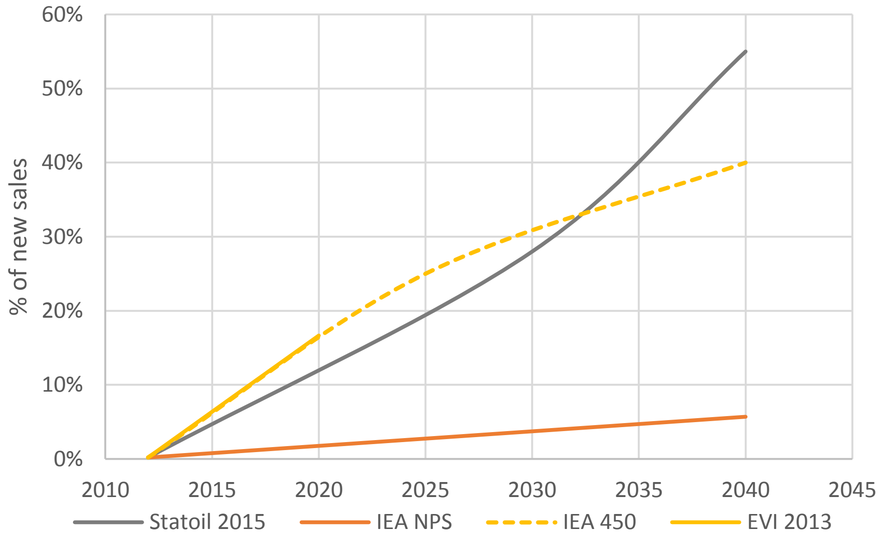

Figure 8.6: Forecast of EV totals as % of global fleet

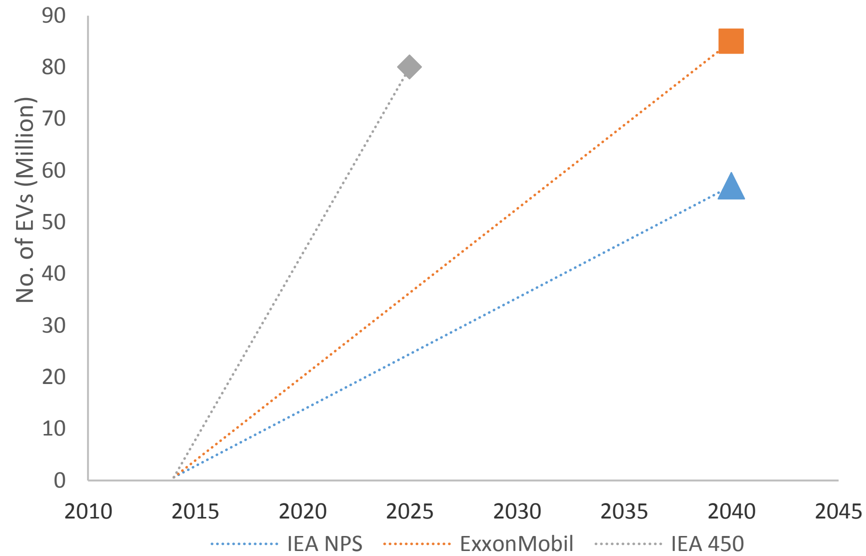

Figure 8.5 focuses on the proportion of new cars sold in a year that are electric vehicles. Figure 8.6 indicates how this translates into total EV fleet size. Both oil companies and the IEA are conservative on the potential of EVs:

- **EV proportion of sales:** The IEA NPS sees EV sales increase to 5.7% of total LDV sales in 2040 – refer Figure 8.5. This is exceptionally conservative in light of both the EVI target and Statoil's central Reform scenario, which sees EVs account for 55% of annual sales in 2040.
- **Total EVs in the global LDV fleet are conservatively forecast:** As one would expect, low sales translated into low numbers of EVs on the roads in the IEA's NPS. They foresee EVs making up 3% of the global car fleet by 2040 – approximately 57million units. This penetration of EVs displaces 800k/bpd of oil demand by 2040 in the NPS. ExxonMobil are slightly more ambitious, yet still conservative, with EVs making up 5% of the global fleet, approximately 85m EVs. This is approximately the level of EV sales expected by roughly 2025 in the IEA 450 scenario.

ExxonMobil explains explain their forecasts are because 'even though battery costs are likely to fall in coming decades… penetration remains very low due to their high cost'.[172] This goes against the scenarios of Statoil and the targets set by the members of the EVI who aim to achieve 20 million EVs in the global

[172] http://cdn.exxonmobil.com/~/media/global/files/outlook-for-energy/2015-outlook-for-energy_print-resolution.pdf

fleet by 2020, which will rise to 80 million by 2025 if the EVI remains consistent with the IEA's 450 scenario. If the EV assumptions of the IEA 450 scenario is achieved this will displace nearly 6mbd in 2040.[173] This is equal to 25% of forecast LDV oil demand in 2040 in the IEA's NPS, a significant sum that oil companies like ExxonMobil and BP are ruling out as a possibility.

Potential for greater EV penetration

As we demonstrated in Assumption 6 on transformation technologies, it is the early stages of technological uptake that are both the most difficult and the most crucial. Bernstein believe that 3% of global fleet additions is the threshold at which EVs will begin the 'virtuous spiral' where demand and supply are large enough to instigate cost-reduction feedbacks that lead to market saturation – 'the next stop after 3% is 97%'.[174] In this context, therefore, achieving the Electric Vehicles Initiative's target of 20m EV in the global fleet by 2020 is hugely important and, for a number of reasons, not implausible:

- **Historic growth rates suggest we are on track:** Between 2012 and 2014, the global EV fleet grew by 92% each year on average. To meet the EVI target, a lower percentage growth rate of 76% is required each year. To subsequently meet the IEA 450 scenario 2025 target of 80 million vehicles in the global fleet, a 32% CAGR is required from the EVI's 2020 target.
- **EVs to be cost-competitive by 2025:** 665,000 EVs are in the global vehicle fleet without being at cost-parity with ICE's. Costs are only coming down, however, and so consumers will be increasingly incentivised to switch to EVs. Figure 8.7 shows a consensus among all analysts that the costs of EV batteries is only travelling downwards. Statoil acknowledge and integrate this cost-down curve. Statoil's 2015 Energy Perspectives quotes extensively the source of this graph, a Nature paper by Nykvist and Nilsson (2015), on the cost-reductions of battery costs of EVs. This report finds that battery costs have come down from 1000USD/kWh in 2007 to around 300USD/kWh in 2014 (Figure 8.7 – the black line).[175] Statoil go on to assert that 'battery costs can come down towards 150-200USD/kWh' by 2030[176] – the threshold generally considered at which EVs are cost-competitive with ICE's.[177] Statoil's awareness of this cost-down trajectory explains their higher forecasts of EVs share of future LDV sales, and sets them apart from other industry players. We think 2030 for cost-parity between EVs and ICEs is very likely, but there are grounds to think this cross-over will arise as early as 2025 globally and possibly earlier in certain markets.

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173 Note, this is as well as efficiency gains; the IEA 450 scenario assumes on-road emission targets for PLDVs in 2040 of 45gCO_2/km. In non-OECD countries this level stands at 65gCO_2/km.
174 Bernstein (2015) Asia Strategy: Shouldn't we all be dead by now?
175 Nykvist & Nilsson (2015) 'Rapidly falling costs of battery packs for electric vehicles', *Nature Climate Change,* 5:329-332
176 http://www.statoil.com/en/NewsAndMedia/News/2015/Pages/04Jun_Energy_perspectives.aspx
177 http://www.transportation.anl.gov/pdfs/TA/149.pdf, p.41

Figure 8.7: Summary of EV battery cost reduction studies

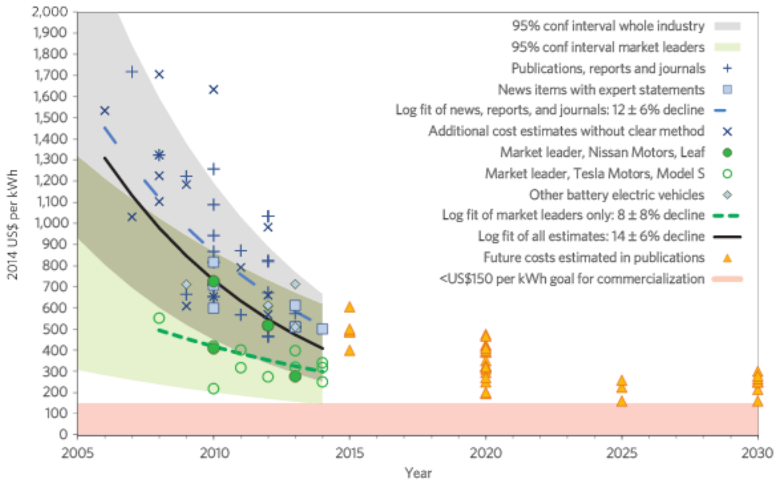
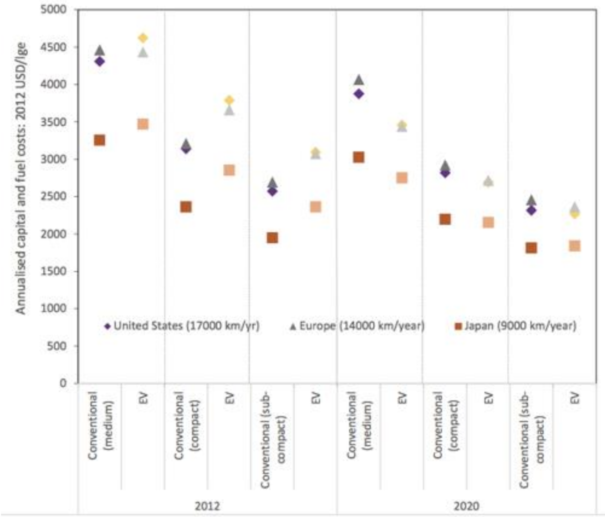


Figure 8.8: IRENA show EVs are cost competitive in some countries by 2020



It is emerging as a theme that cost-reductions of those technologies that are fundamental to the energy transition are exceeding in rate and scale industry forecasts. For example, 2014 cost estimates for Tesla's Model-S vehicle are approximately US$41/kWh less than the average estimates for costs in 2020 (Figure 8.7). This is at least five years ahead of schedule. Therefore, assuming learning rates are maintained, US$150/kWh could be hit as early as 2025. Alliance Bernstein's 2015 forecast concurs that cost-parity will be met by 2025.[178] Figure 8.8 shows that the International Renewable Energy Agency (IRENA) sees 2020 being the year that total ownership costs for EVs fall below that of ICEs in Japan, Europe and the US. Crucially, once cost-competitiveness is achieved, the cost of EVs will continue declining because it is a technology and not a commodity. Whereas ICE's have a price floor because of their reliance on fossil fuels, EVs will only get cheaper with time.

- **EVs in China, 'one of the wild cards':** This is according to Statoil and reflects the central role China will play in determining whether the EVI target is met. China has set itself a target of 5 million EVs by 2020[179] – one quarter of the EVI target. China's leaders want to 'leapfrog' the advanced automotive industries of other countries to seize the growing 'new energy vehicles' market.[180] Given China accounted for 30% of all new LDV sales

[178] Bernstein (2015) Asia Strategy: Shouldn't we all be dead by now?
[179] http://belfercenter.ksg.harvard.edu/publication/24345/electric_vehicles_in_china.html
[180] http://belfercenter.ksg.harvard.edu/publication/24345/electric_vehicles_in_china.html#_ftn2

in 2014, this is a significant hint towards the future of PLDV oil demand.[181] EVs are perfectly suited to the environment expected to emerge in China. For example, rapid urbanisation is expected in China (which incidentally is expected to increase energy demand as discussed in Assumption 1). These areas are characterised by higher population density than rural areas – China's megacities are particularly densely populated. As such, low power, low range EVs are more appropriate for this environment than full ICE passenger vehicles. Furthermore, the government offers subsidies to EV producers that, combined with the fuel economy standards discussed above, are intended to reduce the air pollution crises hitting China's urban areas. One final incentive for incentivising the scale-up of EVs in China is to reduce the current oil import bill. At the start of 2014, China overtook the US as the largest importer of oil. Cultivating a domestic EV industry will not only contribute to GDP growth in China but save on import costs and improve national energy security. Back in 2013, investment bank Kepler Cheuvreux said that 'the single biggest risk posed to long-term demand outlook for oil is China's policy stance on EVs'. Setting the target of 5 million vehicles in 2020 is the start of a coherent policy framework on the issue, and while some obstacles remain to be overcome, the potential is there for China to singlehandedly drive the global EV market and deal a huge blow to future oil demand.

- **Policy support is in place in some countries and proving effective:** An increasing number of countries are applying incentives to buy electric vehicles (e.g. grants to lower the initial purchase price). It is being effective in these countries which are now demonstrating the highest level of EV penetration. For example, in 2015 so far, 22.9% of all car sales have been EVs in Norway – 18.4% BEVs and 4.5% PEVs.[182] This is by far the highest of any country. This is the result of numerous incentives which fiscally add up to about EUR11,500 per BEV. These incentives caused a 90% market share increase in BEVs from 2012 to 2013.[183] The Netherlands is another example of a country with a relatively high percentage of sales from EVs – in 2014 EVs made up approximately 4.3% of all cars sold.[184] The fiscal incentive in the Netherlands is about EUR38,000 for PHEVs and resulted in a 1,900% market share increase from 2012 to 2013.[185]
- **Air quality and carbon regulations are helping shift supply:** In OECD countries, regulation is progressing to such stringency levels that EVs could soon become the most sensible car for manufacturers to supply. For example, EU carbon emission limits from road vehicles are expected to be pulled down further in revisions out to 2025. This has led luxury car manufacturer BMW to declare that all its models will be electric within 10 years.[186] If this is a sign of things to come, supply side constraints will be significant in driving the shift from ICEs to EVs.
- **Consumer trends and perceptions can result in rapid uptake of EVs:** Which cars people want is influenced by their perceptions, fashions and information in the media. There is a perception that the shorter range of current electric vehicles is a major obstacle to buying a vehicle – yet they would cover 95% of journeys, and certainly most people's daily commute. EVs are also partly a lifestyle choice. Those that have converted like the

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[181181] http://www.oica.net/category/sales-statistics
[182] http://cleantechnica.com/2015/07/16/23-of-new-cars-in-norway-now-electric-cars/
[183] http://www.theicct.org/sites/default/files/publications/ICCT_EV-fiscal-incentives_20140506.pdf
[184] http://cleantechnica.com/2014/12/10/ev-hybrid-car-sales-high-netherlands/
[185] http://www.theicct.org/sites/default/files/publications/ICCT_EV-fiscal-incentives_20140506.pdf
[186] http://www.nasdaq.com/article/bmw-all-models-electric-within-decade-20150629-00597

fact they don't have to go and fill up at a petrol/gasoline station any longer. They will be enjoying the savings of not having to pay out for expensive petroleum products every month. The interest of tech companies like Google in transportation shows the potential for transformation of how we get around. No-one can predict which way consumers will go, but if EVs are the next smart phone then cars could change pretty radically. Travelling round the world, one can also see that there is significant nationalism when it comes to buying cars. This may be due to availability / import taxes / national pride. However if for example Chinese manufacturers develop some good EVs that become the car to have in China, then this will dominate the market. There are significant opportunities in growth vehicle markets to secure market share.

Heavy duty vehicles (HDVs) to supply two thirds of transport demand growth for oil

In their 2015 Outlook, ExxonMobil hail 'the rise of heavy-duty vehicles'. Part of the reason why ExxonMobil manage to marry a bullish global oil demand forecast and near-team peaking of LDV oil demand is because they see HDVs as a key growth sector in the future. They see total energy demand for HDVs increasing by 65% to 2040, of which 80% is met by diesel. The IEA NPS forecasts that roughly two thirds of oil transport demand growth will come from HDVs, particularly in developing countries, to 2040. This is equivalent to approximately 6mbd. LDV demand for petroleum is on a downward trend. Consequently, the debate around future road transport oil demand can be framed as the degree to which any fall in LDV oil demand could negate HDV growth.

Efficiency gains will hit oil demand from HDVs

Growth in the HDV sector is forecast by some to be the main future growth transport market for the oil industry because HDVs are more energy-intensive than LDVs and, at present, available non-diesel substitutes seem a long way away. The IEA note that in their NPS, diesel overtakes petroleum as the major oil product in transport during the 2030s. ExxonMobil are more bullish, stating this will occur in 2025. There are short-term risks to this demand growth transpiring, however, chiefly in the form of improved efficiency.

Fuel economy standards for HGVs are far less progressed than those for LDVs, largely because HDVs are more diverse in terms of vehicle size and configuration than LDVs. Progress is being made now though, predominantly in OECD nations. Most significantly, in the US, the largest oil demand centre for the HDV sector, things are about to change. Standards that require a 20% reduction in fuel consumption for medium- and heavy-duty vehicles by 2027 come into force in 2015. The EPA's draft for follow-up efficiency regulations between 2021 and 2027 look to enforce an additional 24% improvement.[187] Japan and Canada have also implemented regulation starting this year, while the EU is running a test protocol.[188] These efficiency regulations could mean we see demand oil savings from HDVs in OECD nations follow the same path of LDVs in the near-term.

[187] http://www.wired.com/2015/06/making-trucks-efficient-isnt-actually-hard/
[188] http://transportpolicy.net/index.php?title=Global_Comparison:_Heavy-duty_Fuel_Economy_and_GHG

ExxonMobil and the IEA, however, don't see the bulk of demand coming from OECD nations, but the developing world. ExxonMobil for example, attributes 30% of all HDV oil demand growth coming from China and India alone. Fuel economy standards are progressing in both of these markets. India is preparing a rule proposal that is likely to be finalised next year with implementation following in 2018.[189] China are already into their second phase of HDV fuel economy regulation. This second phase came into effect on July 1, 2015, and applies to all new commercial trucks, dump trucks, tractors, coaches and buses. Studies show that the Chinese restrictions are on average between 10.5% to 14.5% tighter than the Industry Standard (Figure 8.9).[190] In other words, the Chinese standards are more strict than most OECD regulations. This will undoubtedly apply downside pressure on future HDV oil demand in China. Figure 8.10 reflects HDV fuel economy improvements from OECD and non-OECD nations assumed in the IEA's Bridge scenario. This takes current announcements and forecasts their continuation through to 2030. On the whole the selected countries achieve an average 30% efficiency gains in their HDV fleet to 2030.

Figure 8.915: Fuel consumption limits in Phase 2 China National Fuel Combustion Standard

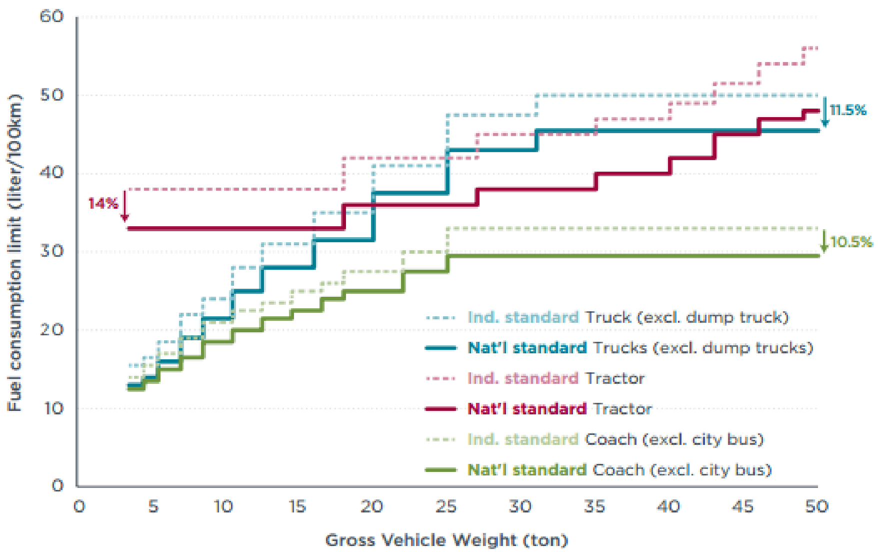
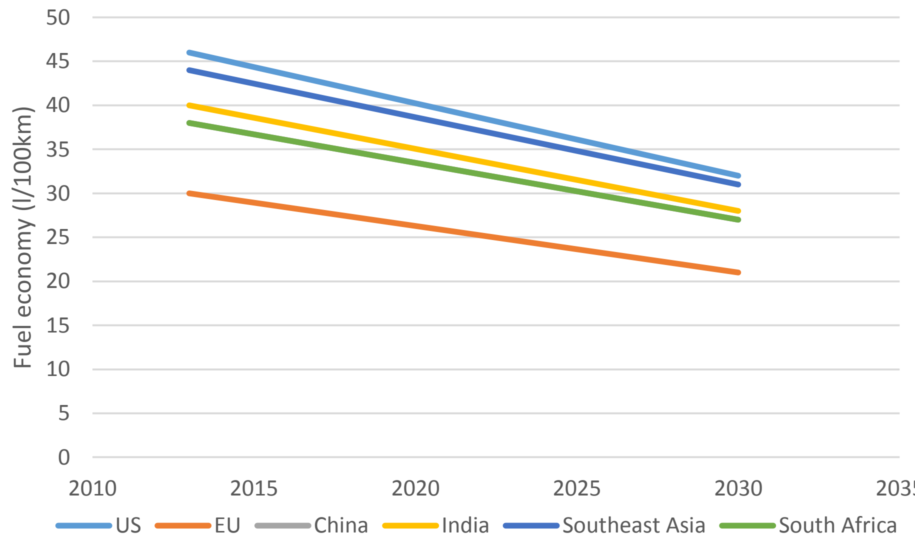


Figure 8.1016: Assumed HDV efficiency gains in the IEA Bridge scenario



[189] http://transportpolicy.net/index.php?title=Global_Comparison:_Heavy-duty_Fuel_Economy_and_GHG
[190] http://www.theicct.org/sites/default/files/publications/ICCTupdate_ChinaPhase2_june2014.pdf

Sources: The ICCT

Substitution risk exists for HDVs

The companies that run the world's largest commercial HDV fleets are constantly working to drive fewer miles on increasingly efficient engines. Technologies are already being showcased that are increasingly electrified. This is directly at odds with the interests of oil companies and serves as a medium-term risk to demand. For example, Walmart has one of the largest HDV fleets in the US and is making great strides to cut back costs on oil consumption. In 2013, it announced a 84% efficiency improvement of its fleet against a 2005 baseline.[191] It has further efficiency targets out to 2015 and beyond. Further, in 2014 the company unveiled its 'Walmart Advanced Vehicle Experience' (WAVE), a truck featuring a series of battery powered components and aerodynamic improvements that could improve fuel efficiency dramatically if rolled out across the whole fleet.[192]

Another near-future technology that is relevant to oil demand for commercial purposes is the emergence of drone delivery services. In July 2015, the first successful drone delivery was made in the US.[193] As viable delivery ranges extend, this technology could pose a substitution risk to conventional HDV methods of delivery. Amazon are investing heavily in this technology and estimate that 86% of all Amazon deliveries could be carried by drone.[194] Certainly, as the world becomes more urbanised as expected by oil companies, the subsequent higher concentration of demand and road congestion will increase the commercial appeal of technologies like drone delivery that can bypass such obstacles.

Both the Walmart and Amazon-led initiatives are currently in the very early stages of development and might not come to fruition. They do, however, offer a glimpse into the future of commercial transport and what that could mean for demand for oil from HDVs.

HDV demand for oil relies on GDP growth

For the sake of simplicity, in this report we have predominantly addressed key demand drivers in isolation. However, as our earlier comment on the link between urbanisation and LDV oil demand suggests, there are many interlinkages at work as well. One relationship that is critical to future oil demand from HDVs is on GDP. As ExxonMobil note, the need for commercial transport is reliant on economic growth. This is why demand for HDVs is expected to grow much faster in non-OECD countries.

In Chapter 2 of this report we highlighted the potential for slower global GDP growth if the OECD forecasts transpire. At a more regional level we focused on the potential for Chinese economic slowdown to continue undercutting forecasts. If lower economic growth trajectories come to fruition this will result in

[191] http://news.walmart.com/news-archive/2014/03/26/walmart-debuts-futuristic-truck
[192] http://www.wired.com/2014/03/walmart-big-rig/
[193] http://qz.com/458703/the-first-successful-drone-delivery-in-the-us-has-taken-place/
[194] http://www.theverge.com/2015/6/3/8719659/amazon-prime-air-drone-delivery-profit-free-shipping-small-items

oil demand from HDVs disappointing on current forecasts. Given the consensus around low prospects for oil demand growth in the LDV sector, this shift would undermine oil demand growth prospects from the road transport sector on the whole.

Oil price volatility reminds companies the market can change

Over the past year, the oil price has demonstrated its great sensitivity to supply-demand shifts. In the six months from mid-2014 to the year-end, the oil price more than halved to approximately $50/bbl. Despite a minor revival, the price is back below $50/bbl as of August 2015.[195] Such a collapse would have been considered a low likelihood, 'tail-risk' prior to the 2014 drop-off. However, it is these lower probability events that are the most destructive should they arise. Models which use recent historical statistics to forecast the future are particularly susceptible to this – as the market saw three years of oil prices around $110/bbl before the drop in 2014.

Until recently it was assumed that OPEC producers would prefer to maintain the price around $100/bbl. The rise of US shale production and the trend for OPEC not to act as a co-ordinated group has shifted the dynamic, with Middle East producers making it clear they will now prioritise retaining market share over short-term price levels. This leads to the potential for supply outstripping demand, leaving the marginal barrels exposed. This puts some pressure on current production, but also challenges future projects that need higher prices than we have seen so far in 2015. Management need to take a long-term view of what prices might be when sanctioning projects that will produce over decades. However the current volatility is a reminder of what could prevail in a market that is difficult to predict, and has already had a chilling effect on capex. The fall in oil price has so far resulted in $200bn of projects being shelved by oil companies according to Wood Mackenzie, a consultancy.[196]

Price assumptions need reviewing

Oil companies on the whole do not publish oil price forecasts. Many, however, publish the oil price against which they judge short term project production, which to some extent gives an indication of future expectations. Until mid-2014, there was a consensus around $100/bbl over coming years. In investor presentations in 2012, 2013 and 2014, ExxonMobil were testing project production against Brent prices to 2017 of $111/bbl, $112/bbl and $109/bbl respectively. Total concluded in a 2014 investor presentation that oil market fundamentals support a $100/bbl scenario to 2030.[197] Following engagement over Carbon Asset Risk, Shell disclosed they apply a range of $70-100/bbl oil prices to test the resilience of their project portfolio to 2040, assuming a $90/bbl base case (Figure 8.12).[198] The current deal to acquire BG Group is also predicated on a return to $90/bbl oil by 2018.

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[195] http://markets.ft.com/research/Markets/Tearsheets/Summary?s=IB.1:IEU
[196] http://www.ft.com/cms/s/0/d6877d5e-31ee-11e5-91ac-a5e17d9b4cff.html#axzz3h00CO8HW
[197] Total (2014) 2014: Outlook and objectives, Sept 2014.
[198] http://s01.static-shell.com/content/dam/shell-new/local/corporate/corporate/downloads/pdf/investor/presentations/2015/sri-shell-london-14042015.pdf

IEA scenarios and price

The IEA's scenarios were developed in a different context, (pre-US shale growth and switch in OPEC strategy mentioned above), and the IEA are expected to produce a new low oil price scenario in the next WEO. As a result they do not offer a useful stress test on price, as the levels in all the scenarios are higher than we are experiencing in 2015. In response to shareholder requests, Shell did offer some comparison to the IEA scenarios, but did not enter in the spirit of a sensitivity analysis to the down-side of price. This therefore shows that the Net Present Value (NPV) of its assets is higher in all of the IEA price scenarios. It is hardly surprising that assets are worth more if the oil prices are higher. Of more use to shareholders would be an indication of what the downside risk is if the oil price is $20 or $40 lower than expected. Figure 8.13 indicates that the impact of the oil price being at the low end of their price range ($70/bbl), rather than at the base case of $90/bbl is at least as large as the potential upswing in the other direction.

Figure 8.11: Shell Portfolio Potential Resilience to Scenarios

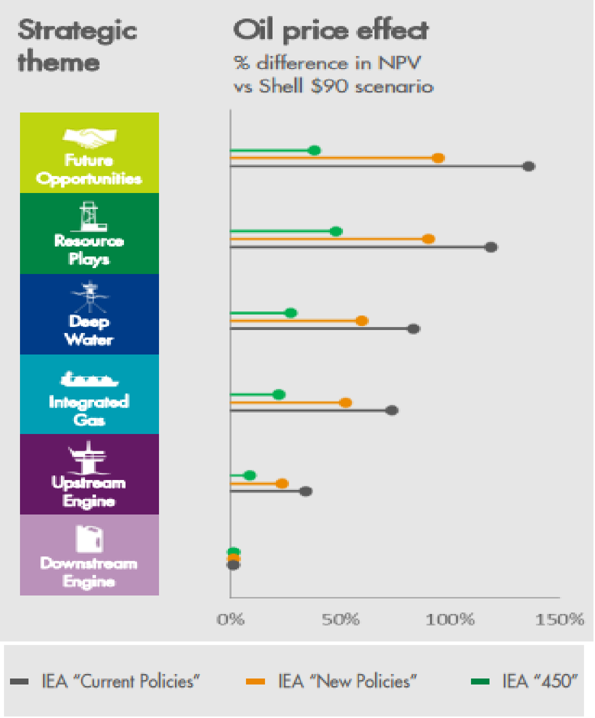


Figure 8.12 Shell & IEA price scenarios

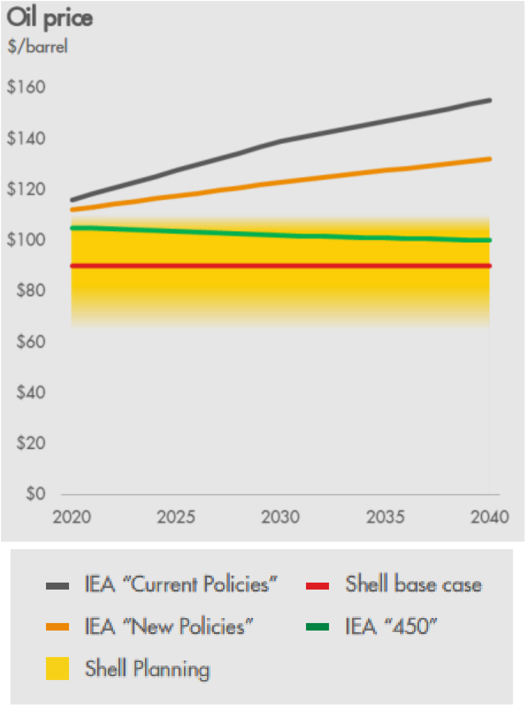
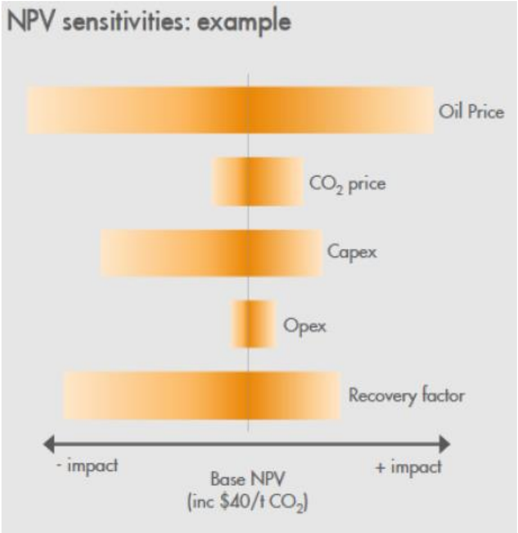


Figure 8.13 Shell NPV sensitivity



Price vs Volume

These charts demonstrate why price is a greater risk in the short-term than actual loss of volume in production. This was reflected in the HSBC analysis of the impact of a low demand, low price scenario for European oil majors. The modelling of the impact of a lower oil price ($50/bbl) resulted in 40-60% of the market value of these companies being at risk according to HSBC analysis in 2013.[199]

Conclusions

- Most oil demand scenarios show continued growth, with a few indicating a peak in demand in the next couple of decades. As a result most industry scenarios exceed the emissions trajectories from the oil sector indicated by INDCs.
- Oil demand growth is mainly expected in non-OECD markets where passenger vehicle fleets will grow.
- The technology used by the LDVs added in non-OECD markets will be critical to determining future demand.
- Growth in the number of EVs is already ahead of most energy industry scenarios, which foresee very low levels of penetration by 2040.
- Levels of oil demand from the HGV sector depend on economic growth rates and efficiency gains.
- The oil price is diffiult to predict with volatility and uncertainty having returned to the market. EVs offer protection from high oil import costs and energy security for importers.

[199] Oil & Carbon revisited, (January, 2013) HSBC

BAU Assumption 9: Demand for gas grows strongly

Gas has a number of regional markets which have been hard to predict. The much-heralded coal to gas switch has never quite materialised in the EU. Few commentators saw the US shale gas boom coming. LNG has grown to an increasingly global trade. Gas is the fossil fuel that still sees growth in some low carbon scenarios, but demand is still lower than business as usual. The competition between coal and gas is heating up to secure the remaining carbon budget.

Key findings:

- The role of gas in the energy transition may have been overplayed by some commentators. Whilst there is still growth in gas demand in 2°C scenarios, it is not as large a market as in other scenarios.
- Low carbon scenarios see a peak in gas demand around 2030, as all fossil fuel emissions streams get squeezed.
- The power sector provides the greatest potential for gas demand destruction with, for example, nearly all of the growth expected in the IEA NPS wiped out in the IEA 450 scenario.
- The changing role of gas to provide back-up power to renewables at peak times in low carbon scenarios impacts the economics of gas plants and subsequently the business model of utilities.

What rate of gas demand growth do fossil fuel companies expect?

- **Demand projections forecast linear growth:** Existing projections and scenarios from the oil and gas majors as well as the IEA depict linear growth for future demand for gas. Fossil fuel company scenarios indicate that primary energy demand for gas will increase above the 2012 level by between 618 million tonnes of oil equivalent (MTOE) by 2040 in the IEA's 450 scenario and 2492 MTOE in Shell's *Mountains* scenario.[200] Most projections and scenarios of 2040 demand tend to collate around the IEA's CPS (4742 MTOE) and NPS (4418 MTOE) scenarios.[201] The question is therefore not about whether there will be growth, but how much.
- **Demand projections of oil and gas majors not focused on a 2°C future:** The existing projections and scenarios from the majors do not include modelling of future gas demand in a 2°C-constrained world. Statoil's 2°C Renewal scenario is the exception, but still sees some growth for gas, although

[200] The 2012 figure for Shell's data was derived from a linear interpolation between two data-points provided by Shell's New Lens report.
[201] To maintain as consistent and legible a comparison as possible, all figures are adjusted to the IEA's latest figures, provided in the 2014 WEO for the year 2012. BP's data for years 2036-2040 was extrapolated using same growth rate for their data between 2030-2035. See Appendix 2 for full details and adjustment figures for each scenario.

at only 18% growth it is substantially less than any other model, except the IEA's 450 scenario. Whilst there is still room for growth in gas demand in a 2°C scenario, this is limited. This may leave some parts of the industry disappointed in the future level of growth in the market. By 2040, compared to the IEA's NPS scenario, the level of gas demand is 34% lower in the 450 scenario and 37% lower in Statoil's Renewal scenario.

- **Annual growth rates are relatively consistent[202]:** Figure 9.1 shows that calculated compound annual growth rates (CAGR) for industry scenarios and projections are not too disparate, unlike those for renewables, for example. There are roughly three groupings indicated: first, the 'low-growth' 2°C scenarios of Statoil's Renewal and IEA's 450 with CAGRs below 1%; second, 'medium-growth' CAGRs between 1% and 2%, where most industry scenarios and projections fall; and third, the Shell's 'high-growth' Mountains scenario which projects more than a 2% CAGR as unconventional gas forms a 'gas backbone' to the energy system.[203]
- **Non-OECD countries fuel significant growth:** It is well documented that North America's coal-dominated power sector has been transformed by a glut of unconventional, cheap gas and the introduction of stringent emissions regulations for coal plants. However, under the IEA's NPS, 80% of gas demand from 2012 to 2040 will come from emerging market economies, with China and non-OECD Asian countries representing 22% and 41% of this demand, respectively.

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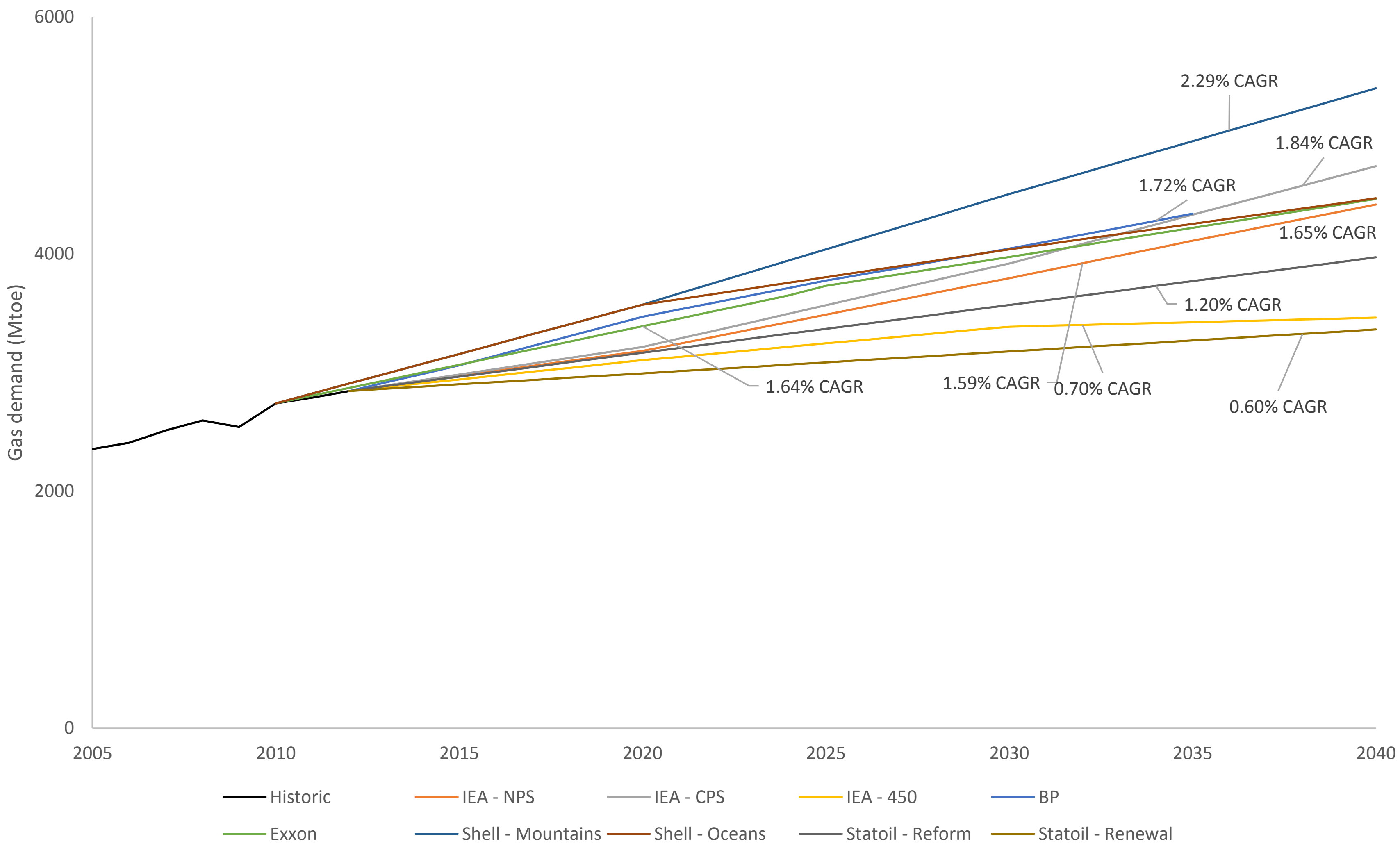
[202] CAGR for the period 2012-2040 for each line was manually calculated using the adjusted figures referenced in footnote 1. Therefore, there may be differences to CAGRs in company reports due to them being over different periods of time (e.g. BP's Annual Outlook only goes to 2035) or because our figures are adjusted to the IEA's for consistency.

[203] http://www.shell.com/global/future-energy/scenarios/new-lens-scenarios.html

Figure 9.1: Industry comparisons of future gas demand



How could demand destruction for future gas occur?

Power sector uncertainty continues

The ability of gas to quickly transform a power sector has been evident in North America over recent years. 2015 witnessed, for the first time, the United States producing more electricity from gas than from coal.[204] US EIA analysis documents that 33 GW of natural gas generating capacity is expected to be built in the US over the next few years, while coal-fuelled power plants are mostly being retired.[205]

Table 9.1: Comparing 2011 and 2014 IEA WEO gas demand expectations for OECD-Europe

	MTOE	2020	2025	2030	2035	2040
TPED	2011 WEO	515	528	547	551	-
	2014 WEO	438	460	472	490	503
	% Change	-15%	-13%	-14%	-11%	
Power Gen	2011 WEO	185	194	210	213	-
	2014 WEO	135	154	164	178	188
	% Change	-27%	-21%	-22%	-16%	

However, such developments have not led to a certainty of a wholesale expansion of gas markets. In 2011, the IEA released a report on the 'Golden age of gas'. Yet, as Table 9.1 shows, the 2014 WEO NPS scenario projects future demand for gas in the OECD-European power sector significantly below its comparative projections made in the 2011 WEO. The power sector is the focal point of many of the uncertainties with regard future gas demand. This is due to the relative ease of fuel substitution within the power sector.

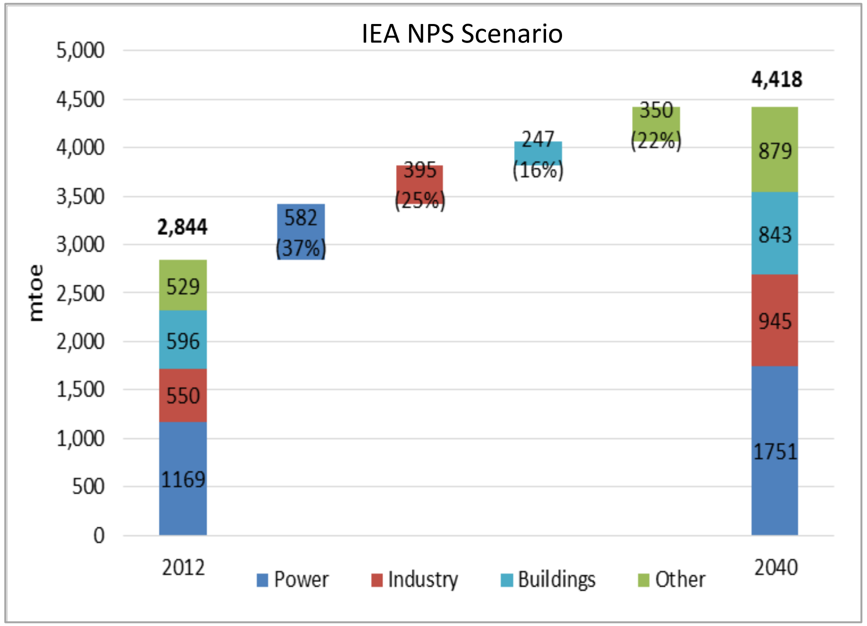
Sectoral drivers of natural gas demand destruction under 450 – power paves the way

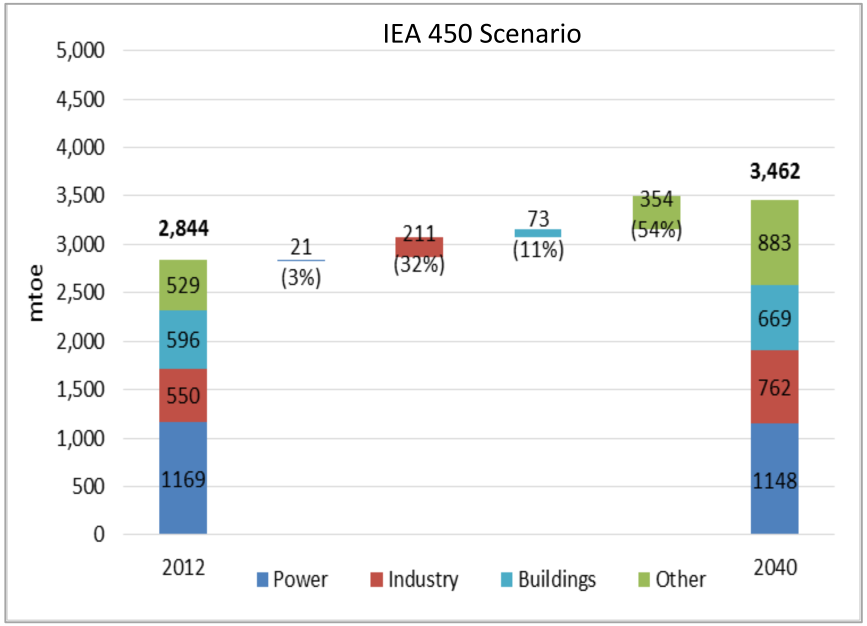
Under both NPS and 450 scenarios the power sector remains the single largest source of gas demand from 2012 to 2040 – refer Figure 9.2. Under 450, the increase in gas demand within the power sector is 96% lower relative to NPS, leaving only a 21 MTOE increase in demand to 2040. In terms of centralised generation (i.e. grid-connected), fuel use can be prioritized in terms of both cost and policy. Putting a price on carbon, for example, drives a wedge between the cost of coal and gas generation, as coal is more than twice as carbon-intensive as gas, and helps optimize plant fleet dispatch in terms of least emissions rather than least cost, i.e. nuclear and renewables first, followed by gas, and finally coal. Energy efficiency policies also reduce the need for power overall and gas as a source of heat for buildings.

[204] http://www.ft.com/cms/s/0/1d1e00fe-28a2-11e5-8db8-c033edba8a6e.html#axzz3m5Lf5Dl5

[205] United States Energy Information Administration, 'Planned generating capacity additions from new generators, by energy source, 2014-2018', http://www.eia.gov/electricity/data.cfm#gencapacity, 2015

Figure 9.2 The impact on sectoral demand for gas under NPS and 450

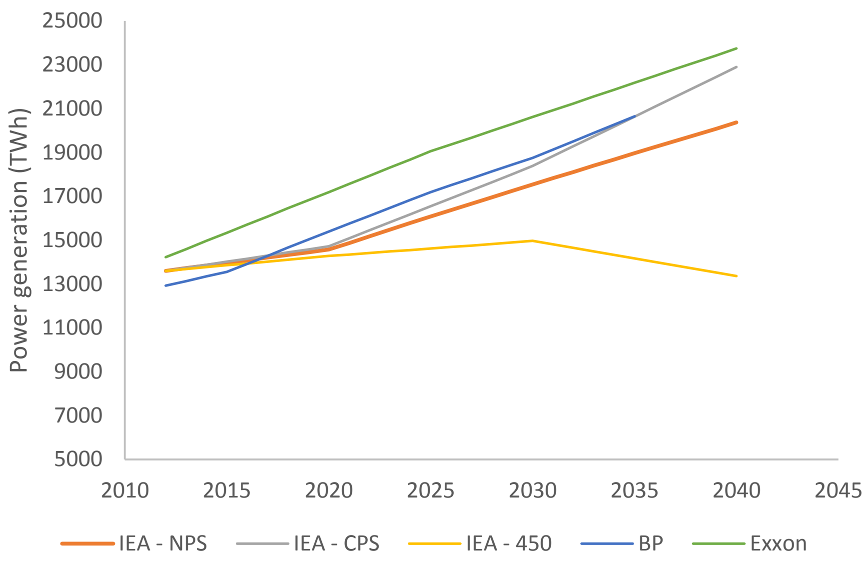




Peak gas demand in the power sector

One of the key differences between the IEA 450 scenario and the other scenarios is that it sees a peak in gas demand in 2030, with levels returning to 2012 levels by 2040 – refer Figure 9.3. This only gives a 15 year window for expanded gas-powered generation from today. BNEF have a similar peak in electricity generation from gas, although it is not shown on the chart as it is not a comparable metric.

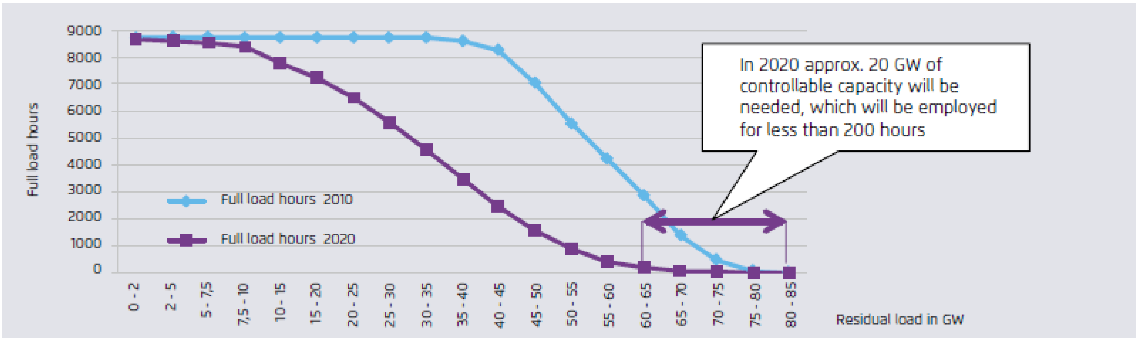
Figure 9.3 Comparison of power generation from gas expectations



From 'base-load' to controllable fuel

Due to the current variability of the supply from renewable power generation, fossil fuel power plants exist as the 'base-load' producers. This means that they continuously supply power to meet at least minimum levels of demand consumed throughout the year, with renewable energy providing more intermittent supply. However, the confluence of numerous factors – environmental regulation, decreasing renewables costs, and expanding storage capacity, to name a few – could lead to a reversal of this current structure. Germany's *Energiewende* policy seeks to implement precisely this.

Figure 9.4 Demand for controllable capacity to cover maximum peak loads in Germany[206]



Agora Energiewende, an organisation tracking this change, suggest that: (1) wind and solar PV could supply the 35 to 40 GW base-load required for Germany, meaning much less conventional capacity will be required to run throughout the year[207]; and (2) until cost-efficient storage technologies are widely installed, relatively small quantities of controllable fossil fuel capacity can be used to meet moments of peak demand.

[206] http://www.agora-energiewende.de/fileadmin/downloads/publikationen/Impulse/12_Thesen/Agora_12_Insights_on_Germanys_Energiewende_web.pdf

[207] Agora estimates that, with 40% of power generation supplied by renewables, only 10 to 25 GW of conventional capacity operating 6000 to 8000 hours per year will be still required.

Gas-turbines neatly fit this role

Gas-powered plants have better potential to meet the controllable capacity requirements set out by Agora than coal. Not only are they less susceptible than coal plants to increasing carbon regulation, but they also offer better technical potential for transitioning to an intermittent source of supply. Figure 8.5, shows that optimising existing gas plants can make them substantially better suited for shorter operational times.

Figure 9.5 Comparison of the flexibility potential of coal and gas power plants[208]

Optimization potential (first figure) and typical status today (figure in parentheses) per 1000 MW

		Hard coal power plant	Lignite coal power plant	Combined cycle power plant	Gas turbines
Minimum load	MW	200 (400)	400 (600)	300 (500)	200 (500)
Maximum change in load within 5 minutes	MW	300 (75)	200 (50)	400 (100)	750 (400)
Start-up time cold start	h	4 (10)	6 (10)	2 (4)	<0.1

Specifically, Agora contends that at a relatively low cost, open-cycle gas turbines (OCGT), which have low efficiency rates and high fuel costs but are able to reach full capacity very quickly, can adequately meet intermittent supply deficits. They estimate that, by 2020, Germany will require around 20 GW of controllable capacity – roughly 25% of total capacity – to meet this intermittent demand, with gas potentially supplying the majority of this.

'Virtuous cycle' threatens utilities' profit

This change in modus operandi challenges the economics of new gas plants without major restructuring of power markets. Utility companies continue to invest in fossil fuel power generation for its role as a 'dispatchable' power supply with high, dependable capacity factors (see Assumption 5). However, as renewable technologies with low marginal costs - namely wind and solar - increase their supply of the power, the capacity factors of coal and gas generation will be lowered having an adverse effect on their profitability. Bloomberg New Energy Finance illustrates this virtuous cycle: as more wind and solar is installed, coal and gas plants sit idle causing coal and gas power costs to increase.[209] This prioritising of increasingly cost-competitive renewable power generation should be factored into utilities' business models to avoid a situation of surplus fossil fuel supply creating negative wholesale prices.[210]

Carbon savings from gas can be substantial in 2°C world

Driven predominantly by coal to gas switching in the power sector and growth in emerging economies, even in a 2°C constrained future, there will remain underlying growth in the demand for gas. However, if the world moves to a 2°C future then substantial emissions savings can be made, assuming zero-carbon alternatives are used instead.

[208] http://www.agora-energiewende.de/fileadmin/downloads/publikationen/Impulse/12_Thesen/Agora_12_Insights_on_Germanys_Energiewende_web.pdf
[209] http://www.bloomberg.com/news/articles/2015-10-06/solar-wind-reach-a-big-renewables-turning-point-bnef
[210] http://www.carbontracker.org/report/eu_utilities/

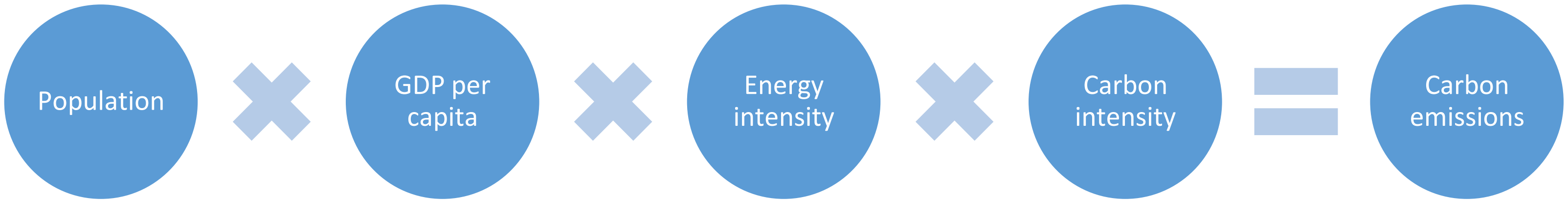
Conclusions

- The role of gas in the energy transition may have been overplayed by some commentators. Whilst there is still growth in gas demand in 2°C scenarios, it is not as large a market as in other scenarios.
- Low carbon scenarios see a peak in gas demand around 2030, as all fossil fuel emissions streams get squeezed.
- The power sector provides the greatest potential for gas demand destruction with, for example, nearly all of the growth expected in the IEA NPS wiped out in the IEA 450 scenario.
- The changing role of gas to provide back-up power to renewables at peak times in low carbon scenarios impacts the economics of gas plants and subsequently the business model of utilities.

10. Conclusion: Calculating downside CO_2 emissions with the Kaya Identity

As outlined in the introduction, the economic principal of the Kaya Identity provides a simple breakdown of the key components that determine CO_2 emissions from energy systems. Figure 10.1 provides a reminder of the Kaya Identity formula.

Figure 10.1: The Kaya Identity



In Assumptions 1 to 3, we presented the range of assumptions of population growth, economic growth and energy intensity being used in fossil fuel industry and energy analyst scenarios. Assumptions 4 to 9 analysed the range of carbon intensity assumptions being applied in these scenarios and the justifications for this by fuel type.

We now apply the downside assumption for each component of the Kaya Identity to understand the impact on CO_2 emissions of this alternate scenario – to recall, these are: i) population growing more slowly to 8.3bn by 2040 in line with SSP and SRES trajectories; ii) GDP growth to 3.1% in line with the OECD forecasts, affecting GDP per capita growth; iii) energy intensity falls accelerating to -2.8% in line with the IEA 450; and iv) carbon intensity falls accelerating to -2.3% in line with the IEA 450. We then compare this downside scenario against a base case, for which we have chosen the IEA NPS. Figure 10.2 and Table 10.1 summarise the workings and findings of our Kaya calculations with these assumptions. Note, in Table 10.1 cells coloured orange highlight the assumption that has been downgraded; those coloured green identify a variable that has been made higher.

Table 10.1: Downside components of the Kaya Identity progress us from the IEA NPS to a 2°C scenario, 2012-2040

		Population growth	GDP per capita growth	Energy intensity	Carbon intensity	CO_2 CAGR	Total CO_2 (2012-2040)	% gap to 450 covered
	IEA NPS	0.9%	2.5%	-2.2%	-0.5%	0.7%	1021.7	
NPS downside	Lower population	0.6%	2.5%	-2.2%	-0.5%	0.4%	978.6	19%

	Lower GDP per capita	0.9%	2.2%	-2.2%	-0.5%	0.4%	978.6	19%
	Low energy intensity	0.9%	2.5%	-2.8%	-0.5%	0.1%	931.5	39%
	Low carbon intensity	0.9%	2.5%	-2.2%	-2.3%	-1.1%	846.5	76%
2°C variations	IEA 450	0.9%	2.5%	-2.8%	-2.3%	-1.7%	792.0	100%
	2°C Low pop, GDP & energy intensity	0.6%	2.2%	-2.8%	-1.7%	-1.7%	792.0	100%
Beyond 2°C	Combined downside scenario	0.6%	2.2%	-2.8%	-2.3%	-2.3%	754.5	

Figure 10.2: Downside components of the Kaya Identity progress us from the IEA NPS to a 2°C scenario, 2012-2040

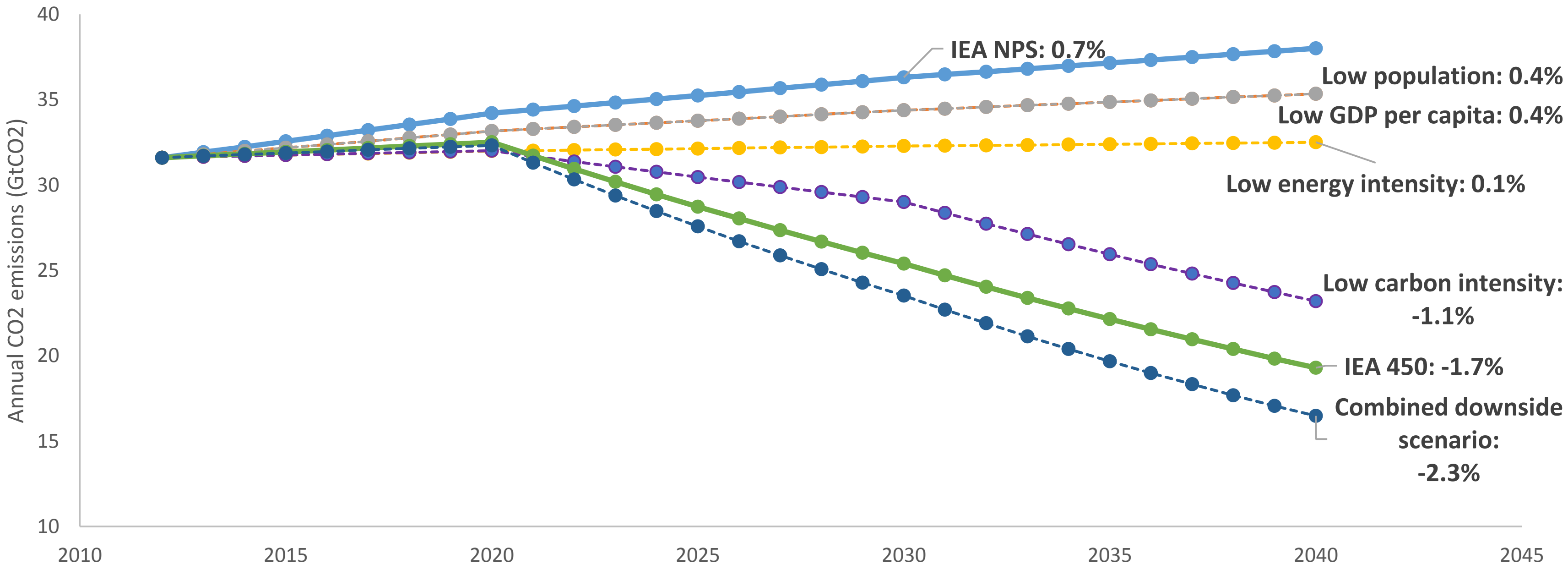


Table 10.1 and Figure 10.2 show, while keeping all else constant, that:

- **Reducing assumed population growth** to levels in SSP and SRES trajectories reduces annual CO_2 emissions growth from 0.7% in the NPS to 0.4%. This equates to CO_2 emissions that get you 19% of the way from NPS to the IEA 2°C 450 trajectory;
- **Reducing GDP per capita growth** in line with OECD forecasts has the same impact because CO_2 emissions are again 0.3% per year lower than NPS;
- **Accelerating energy intensity falls** to -2.8% in line with the 450 scenario as opposed to -2.2% reduces the compound annual growth rate of CO_2 emissions from 0.7% to 0.1%. This reduction gets you 39% of the way from the IEA NPS to 450 scenario.
- **Accelerating carbon intensity falls** to -2.3% in line with the 450 scenario as opposed to -0.5% reduces the compound annual growth rate of CO_2 emissions from 0.7% to -1.1%. This reduction gets you 76% of the way from the IEA NPS to 450 scenario.

One might observe from Table 10.1 that adding up the percentage growth rates of the four components of the Kaya Identity act as an accurate proxy for the subsequent growth rate in CO_2 emissions.[211] As such, one can attribute deeper cuts in ratios where desired and understand how this feeds through to less dramatic changes in other parts of the energy system. To demonstrate we ran a pathway that achieved the same -1.7% CAGR of CO_2 emissions as the 450 scenario, but via a different combination of assumptions:

- **If reduced population and economic growth as well as accelerated energy intensity falls** are achieved simultaneously, the carbon intensity of energy only has to fall by -1.7% each year to achieve 2°C, as opposed to the original -2.3% in the 450 scenario.

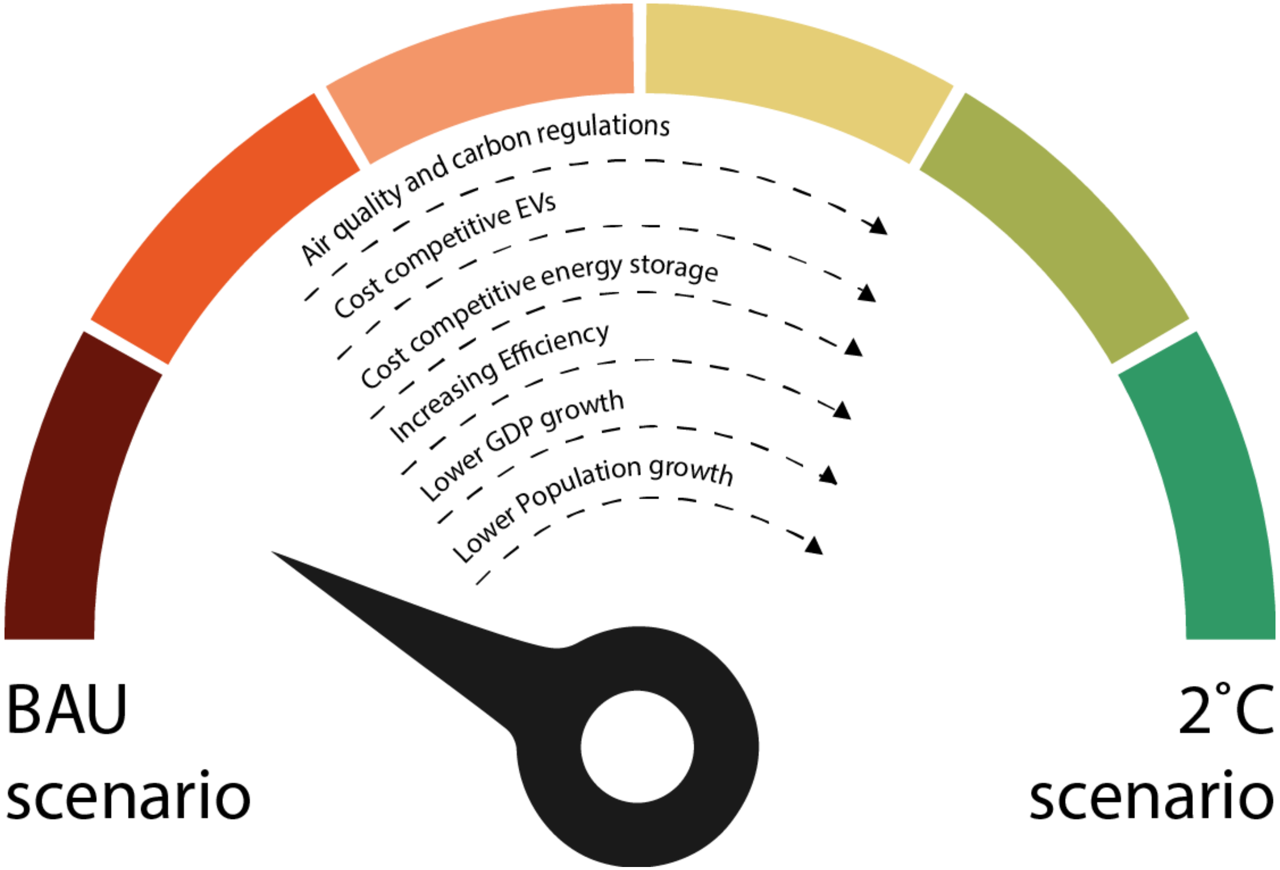
We also explored what would happen to CO_2 emissions if downside scenarios transpired for all four components of the Kaya Identity. In this 'combined downside scenario', CO_2 emissions fall by -2.3% per year on average and are 5% below the IEA 450 scenario.

[211] We tested the relationship for these CAGRs and this method of adding the four components holds true. This might not be as accurate for much larger CAGRs.

Recommendations

Investors need to understand where company scenarios are on the spectrum of demand assumptions.

Companies need to explain how their business model would change in a lower demand scenario



Appendices

Appendix 1: Which institutions produce energy scenarios?

The complexity of energy modelling and subsequent scope for inaccuracy means most industry forecasts are caveated to some degree. Here we discuss the ways in which scenarios examined in this report could be interpreted based on statements made by the publishing institution.

Energy analysts:

The **International Energy Agency (IEA)** is an intergovernmental organisation that publishes detailed global energy forecasts. These forecasts are readily referenced by fossil fuel companies. Those companies that do not directly reference the IEA's energy models will use their energy assumptions to inform their own energy modelling forecasts. The World Energy Outlook is the most referenced IEA publication. This contains: i) a 'Current policies scenario' (CPS) based on 'only those policies and implementing measures that have been formally adopted'; ii) a 'New Policies Scenario' (NPS) based on implemented policy measures as well as 'relevant policy proposals…yet to be fully developed'; and iii) a '450 Scenario' (450) that illustrates how a long-term average global temperature rise of 2°C can be achieved.

The IEA emphasise that 'none should be considered forecasts'. The CPS is intended 'to offer a baseline picture' if policy doesn't change in the future. Even the NPS which they focus on may deviate markedly from what actually transpires. Having said that, the fact that almost all fossil fuel companies refer to these scenarios in some form imparts a greater responsibility on these scenarios to be as accurate as possible. The IEA also publish an Energy Technology Series that publishes scenarios consistent with the CPS, NPS and 450 but out to 2050. These are referenced in places of this report as well.

The **US Energy Information Agency (EIA)** publishes an International Energy Outlook that looks at global energy markets through to 2040. The last version of this, however, was in 2013. Since then the EIA has focused on oil markets in its international scenario publications. They stipulate their projections are scenarios not forecasts and it is worth noting these are 'business-as-usual trend estimates', i.e. only assume current policies and technologies. As such, these scenarios should be read as very conservative.

Fossil fuel companies:

ExxonMobil published its 2015 'Outlook for Energy' at the end of 2014. ExxonMobil are the only fossil fuel company who explicitly state their publically available forecasts are used in their business planning - "*The Outlook provides the foundation for our business and investment planning, and is compiled* *from the breadth of the company's worldwide experience in and understanding of the energy industry*".[212] ExxonMobil indicated in a communication to shareholders that it thought the likelihood of a 2DS was zero.[213]

In 2013, **Shell** published its 'Lens scenarios' – 'Mountains' and 'Oceans'. They emphasised that these scenarios '*are not intended to be predictions of likely future events or outcomes and investors should not rely on them when making an investment decision*'. Having said that, '*they are designed to stretch management to consider even events that may be only remotely possible*'.[214] We also refer to Shell's 'Current Outlook' in this report. This scenario draws on the single projection of future energy demand presented in Shell's investor note on the carbon bubble and stranded assets.[215] This scenario is described by Shell as '*our current outlook for global energy demand until 2050*'. (Specific data is not provided so approximate readings from graphs have been used).

BP describe their 2015 Energy Outlook as the '"most likely" trajectory of the global energy system'.[216] This suggests this single scenario is a base case for BP.

Statoil's 2015 Energy Perspectives presents three scenarios based on research from 'throughout the Statoil organisation'.[217] Probabilities are not assigned to any scenario but Statoil have included a new high renewables scenario this year.

At appropriate stages and where data is available, forecasts for future energy demand are referenced from **Total, BHP Billiton, Rio Tinto, Adani** and **Glencore Xstrata**. These forecasts tend to be sourced from investor presentations and, as such, should be interpreted to reflect the market expectations of the company. These tend to be approximate readings from graphs.

The oil majors have a history of producing energy data and scenarios – for over a decade in some cases. We observe that few assign probabilities to outcomes, and rarely is there an explicit link made to business planning. Low emissions scenarios went out of fashion, but appear to be coming back this year.

Alternative sources:

Where possible we have tried to find credible research and academic institutions that have produced alternative thinking on these issues. Interestingly it can be difficult to find many other organisations that have the resources to undertake this kind of detailed modelling at a global scale. We have managed to find alternative views for most of the variables looked at here, but this also shows how the energy sector view is dominating the public debate. Investment

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[212] http://cdn.exxonmobil.com/~/media/global/files/other/2014/report---energy-and-carbon---managing-the-risks.pdf
[213] Add reference
[214] http://www.shell.com/global/future-energy/scenarios/new-lens-scenarios.html
[215] http://s02.static-shell.com/content/dam/shell-new/local/corporate/corporate/downloads/pdf/investor/presentations/2014/sri-web-response-climate-change-may14.pdf
[216] http://www.bp.com/en/global/corporate/about-bp/energy-economics/energy-outlook.html
[217] http://www.statoil.com/en/NewsAndMedia/News/2015/Downloads/Energy%20Perspectives%202015.pdf

banks and brokers have research teams which are reviewing some of these areas from a financial perspective. However the majority of this research does not reach the public domain and therefore cannot feed into the public discourse in the same way.

Environmental NGOs such as WWF and Greenpeace do commission work in this area, which is at the other end of the spectrum.[218] Indeed it should be noted that a number of these projections have in fact turned out to be more accurate than the oil sector's attempts.[219] Given this indication that environmental experts have as much chance of getting this right as oil economists, we would suggest there is value in investors understanding the implications of the full range of potential outcomes.

Appendix 2: Adjustment factors

For certain graphs featured in the report we adjusted fossil fuel company data to a given historic data set, typically IEA data. This is to overcome methodological differences between fossil fuel companies in classifying fuel types. By adjusting the data in this way, we standardise scenario data to be able to more accurately compare across company projections. The following are adjustment factors used in the relevant graph:

Adjustment factors used to calculate Figure 7.1 – coal demand forecasts:

	Year Adjusted To	Factor
RIO TINTO	2012	1.13
BP	2010	1.04
EXXON	2010	1.06
SHELL	2010	0.95
OPEC	2010	0.93
EIA	2010	0.97
INDC	2013	1.00
BHP BILLITON	2010	1.00
STATOIL	2012	1.00
SHELL CURRENT	2010	0.94

[218] http://www.greenpeace.org/international/en/publications/Campaign-reports/Climate-Reports/Energy-Revolution-2015/
[219] http://cleantechnica.com/2015/03/30/greenpeace-aces-installed-renewable-forecasts-surprised/

Adjustment factors used to calculate Figure 7.3 – China thermal coal forecasts

RATE OF ADJUSTMENT		
	Year	Factor
IEA NPS	2012	0.94
WOODMAC 2014	2012	0.84
WOOD MAC (2013)	2012	1.08
BERNSTEIN 2015	2013	1.14
IEA NPS 2014	2012	1.01
IEEFA-CTI	2012	1.14

Adjustment factors used to calculate Figure 7.5 – Indian coal import forecasts

ALL ADJUSTED TO 2012	FACTOR
ADANI	1.43
GLENCORE	1.10

Adjustment factors used to calculate Figure 8.1 – Oil demand forecasts

COMPANY	YEAR	FACTOR
EXXONMOBIL	2010	0.99
SHELL CURRENT	2010	1.00
BP	2010	1.01
TOTAL	2013	1.00
OPEC	2013	1.00
EIA	2010	1.00

Adjustment factors used to calculate Figure 9.1 – Gas demand forecasts

SCENARIO ADJUSTED TO 2010	ADJUSTMENT FACTOR
IEA	1.00
BP	0.95
EXXON	0.94
SHELL	1.00
STATOIL	1.00

Adjustment factors used to calculate CO_2 projections from fossil fuel scenarios

ADJUSTMENT FACTORS		
SCENARIO	Year	Factor
SHELL OCEANS AND MOUNTAINS	2010	0.97
EXXONMOBIL	2010	0.98
BERNSTEIN	2010	0.92
EIA 2013	2010	0.97