Deutsche Bank
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Industry
Decarbonisation

Date
27 March 2017

DeCAF: Deutsche Carbon Alignment Framework

A new and clear way to think about decarbonisation

Long term decarbonisation is here to stay despite the pick-up in global growth and Trump presidency. This means less oil and coal, more solar and wind, and the electrification of transport and heat. Volume uncertainties remain for gas, while nuclear is assumed in scenarios but may not be delivered in practice. Up until now there has been no simple way for investors to think about generating returns from decarbonisation. DeCAF does just that. It is an intuitive, jargon-free framework based on the fact that the volume goals of policy makers and value goals of investors are not necessarily aligned.

The authors wish to acknowledge the extensive contribution of Caroline Cook to the origination and compilation of this report.

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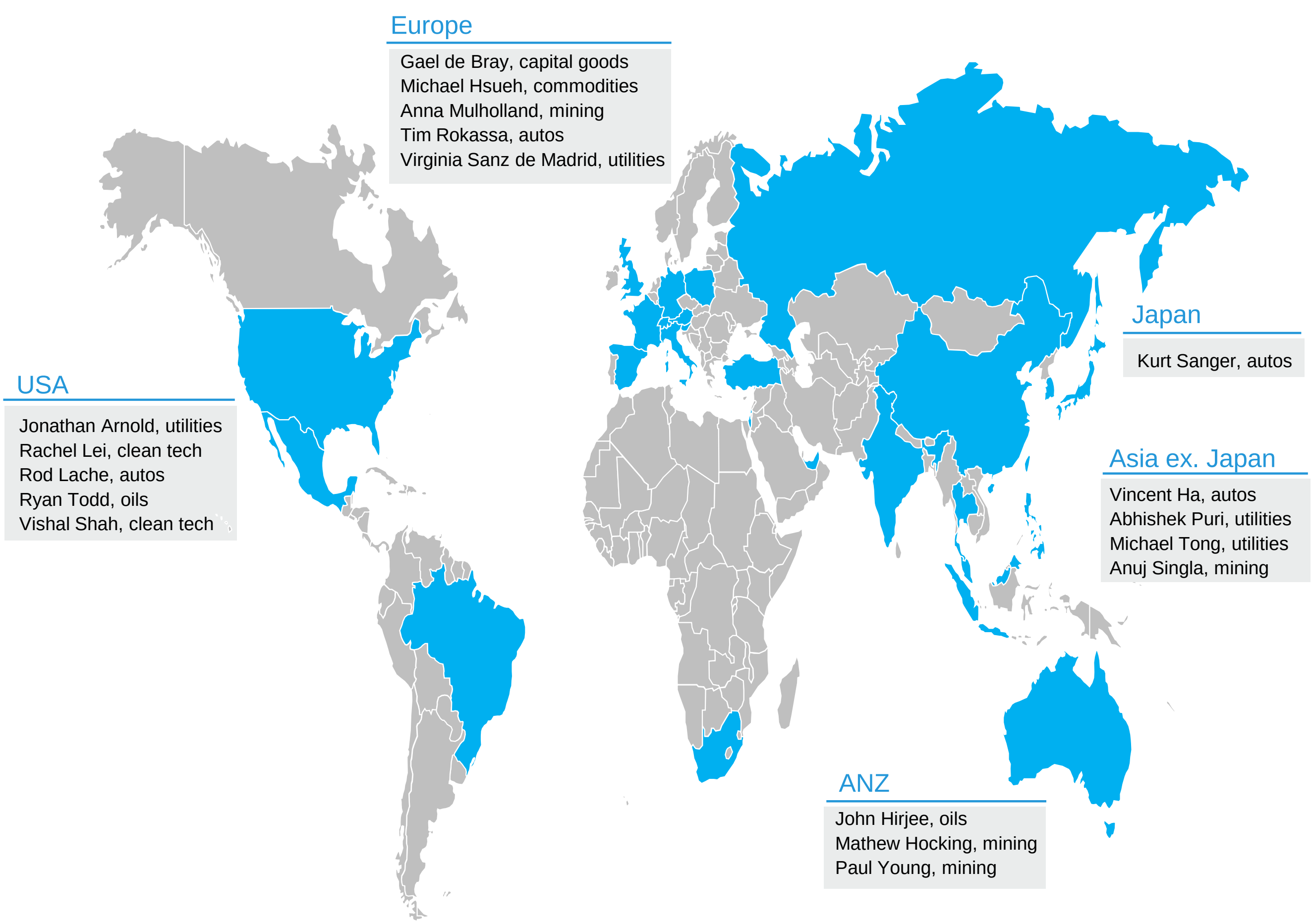

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Long term decarbonisation is here to stay despite the pick-up in global growth and Trump presidency. This means less oil and coal, more solar and wind, and the electrification of transport and heat. Volume uncertainties remain for gas, while nuclear is assumed in scenarios but may not be delivered in practice. Up until now there has been no simple way for investors to think about generating returns from decarbonisation. DeCAF does just that. It is an intuitive, jargon-free framework based on the fact that the volume goals of policy makers and value goals of investors are not necessarily aligned.

For example, falling output does not always result in stranded assets while clean tech is sometimes value destructive. In this report we introduce how DeCAF can be used by clients to analyse companies and show how some key stock picks fit into the framework. We then explain the volume outlook and assumptions behind the benchmark decarbonisation view. Also published today is our detailed guide to volumes entitled ***Decarbonisation: A guide to the language and assumptions***. Click here to view. In upcoming reports, our global research teams will use DeCAF to analyse individual sectors and stocks.

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Policy makers care about volumes

Discussion of action on climate change is understandably obsessively about volumes. Temperature is driven by the amount of carbon dioxide in the air. This is driven by the amount of fossil fuel burned. Scenarios and climate models thus tend to focus on volume as the end point, translated into different mixes of: coal, oil, gas burn; use of internal combustion engines versus electric vehicles; deployment of solar, wind and nuclear generation; implementation of energy efficiency measures and smart technology.

Once policy makers, modelers and analysts have decided on what volumes are needed, the choice of incentives and policy instruments are seen as a means to achieve this end. For climate change policy making, returns on private investment are just one mechanism for driving action, which drives the final outcome – the volume of carbon dioxide emitted.

Investors care about values

For investment professionals, on the other hand, valuations and returns are the ends not the means. Volumes are a crucial input – which is why we devote two thirds of this report plus an appendix to the topic – but they are just an input. The most important outcome for investors is whether their assets are becoming more or less valuable. Volumes are one part of that.

What is more, while volume is clearly an important driver of shareholder value, they are not necessarily aligned. By that we mean that value can be either created or destroyed under rising or falling volumes. Green companies can as easily squander money in a booming sector as carbon-heavy rivals can ramp up payouts in a declining one. This clear two-by-two matrix allows DeCAF to sort companies into those where value and volume are aligned or misaligned. Only by trying to understand where companies sit within this framework can investors fully appreciate the opportunities or risks of decarbonisation to their portfolios.

Examples of aligned and misaligned investment plays

In a series of global sector deep dives in the coming months, analyst teams from multiple sectors and geographies will show how DeCAF can be used to better understand how carbon volume risks and opportunities translate to investor values. For some stocks it will be clear whether they are likely to be aligned or misaligned beneficiaries from decarbonisation. For most stocks, however, the potential gap between volume and value is large.

DeCAF provides a framework for clarifying under what circumstances a company can benefit or suffer in a rapid decarbonisation scenario. Our matrix divides them into four quadrants. Where volume and value are aligned companies either fall into the Green Growth or Stranded Carbon quadrants. Where volume and value are misaligned a firm either sits with the Carbon Cash Cows or in a Green Bubble.

In this introductory report, we pick out a few stocks from across global sectors to illustrate how DeCAF can be used in practice. Examples include:

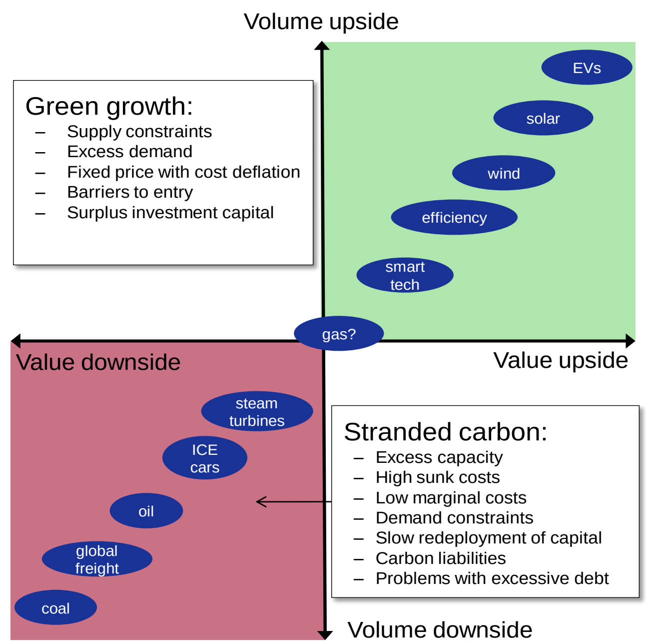
Green Growth: EDPR, Schneider and PG&E are examples of companies which look likely to be Green Growth stocks, with aligned volume and value upside.

Stranded Carbon: Petrobras and Glencore look to be at risk in a rapid decarbonisation world, with prices and margins under pressure. Volume and value aligned.

Carbon Cash Cows: Rio Tinto, CR Power and BP are possible candidates to be Carbon Cash Cows in a rapid decarbonisation world, with volume downside but where volume and value may be misaligned. Exelon looks to be turning into a Cash Cow in generation by focusing on margins not volume.

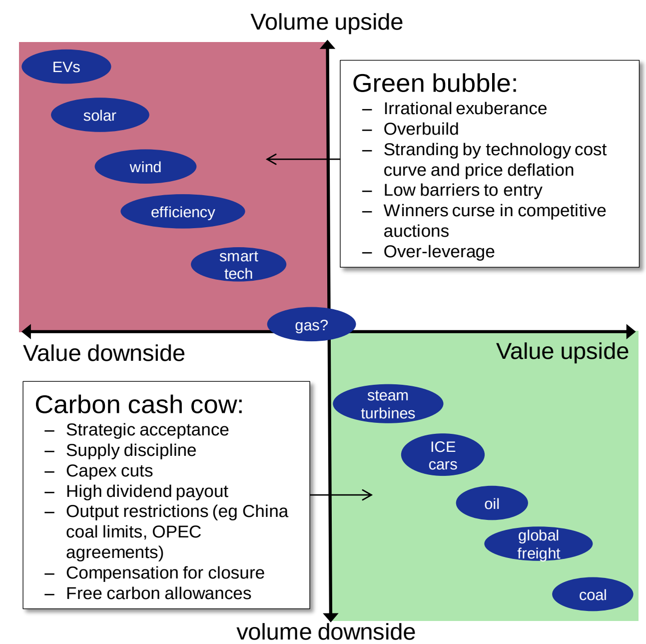
Green Bubble: EDF and Enphase Energy are examples of stocks involved in clean energy investment where returns on capital have been or look likely to be disappointing. Upside on volumes may leave the shares looking expensive as volume and value are misaligned.

Figure 1: When volume and value are aligned



Source: Deutsche Bank

Figure 2: When volume and value are misaligned



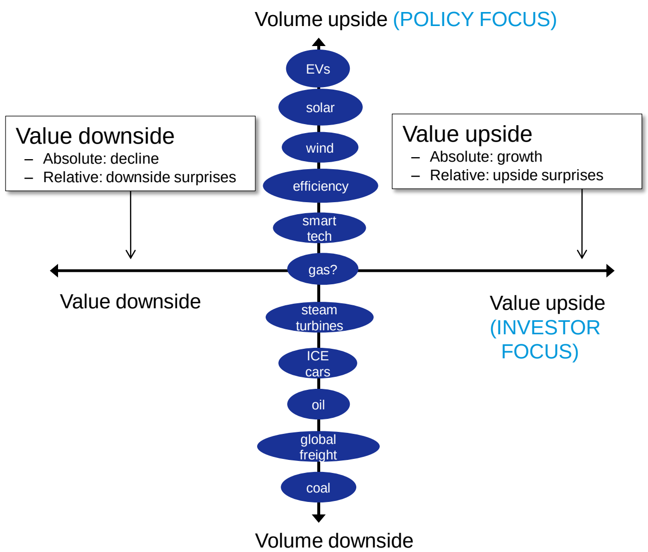
Source: Deutsche Bank

Introducing DeCAF

Visual summary and key stock picks

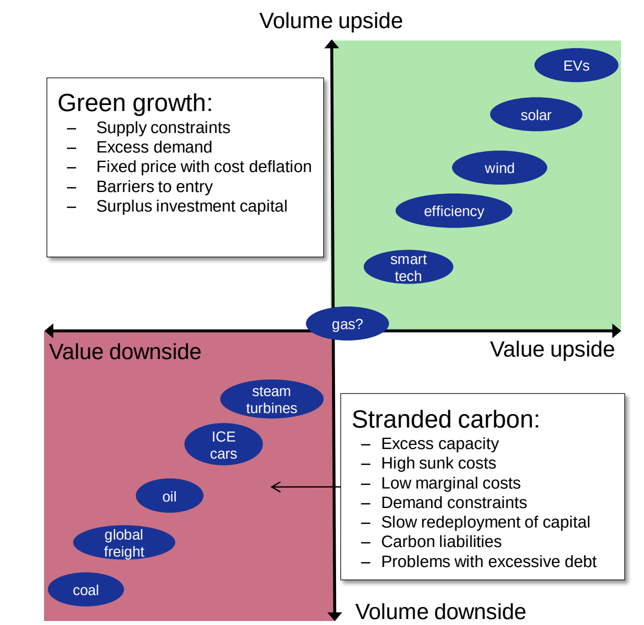
Policy makers care about volumes but investors care about value. DeCAF addresses this by asking: are volumes and value aligned or misaligned?

Figure 3: Carbon risk: volume versus value



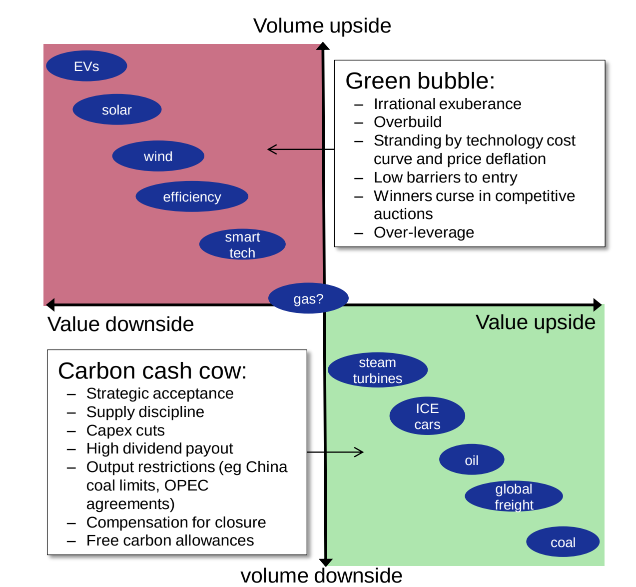
Source: Deutsche Bank

Figure 4: When volume and value are aligned



Source: Deutsche Bank

Figure 5: When volume and value are misaligned



Source: Deutsche Bank, Company data, Ofgem

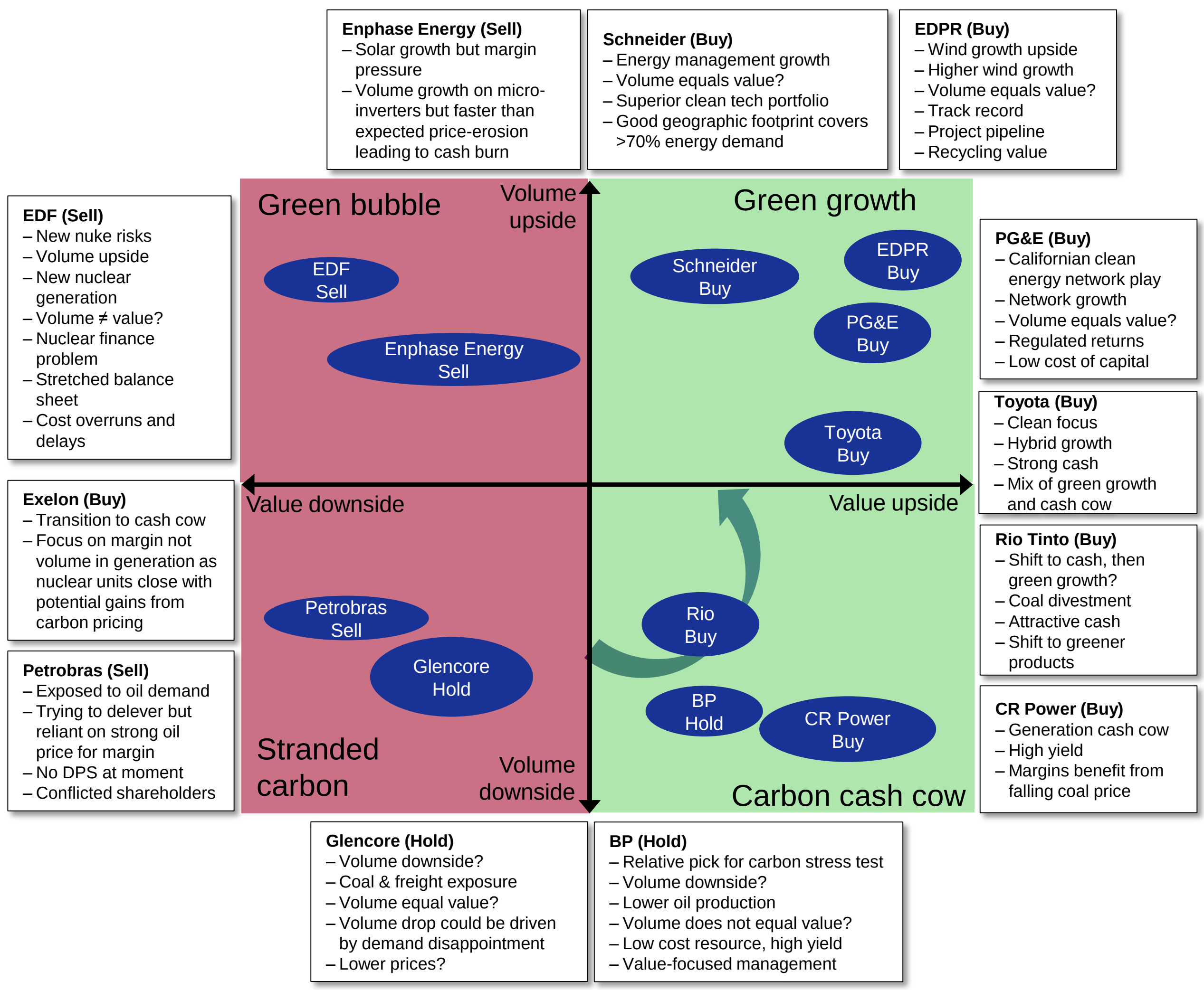
Figure 6: Key implications

- **Investors**: should look for indicators associated with a misaligned world. Be wary of high carbon companies where decarbonisation may be demand-led. Prefer fossil companies where decarbonisation is supply driven. Focus on green companies where supply constraints exceed demand constraints.
- **CEOs**: low carbon stress tests to be robust to the impact of different mechanisms on margins, not merely volumes; impact on sunk investment may sometimes be more important than on new investment.
- **Policy makers**: should focus on aligning volumes with value. Misaligned policy mechanisms may be counterproductive in the long term.

Source: Deutsche Bank

Key stock picks using DeCAF

Figure 7: Illustration of some DB stock picks using the Deutsche Carbon Alignment Framework



Source: Deutsche Bank

Figure 8: Key global recommendations consistent with a rapidly decarbonising scenario

Quadrant in carbon stress test	Company	Sector	Country	Rec	Price (local)	Mkt cap (USDbn)	P/E (2018E)	Div yield (2018E)	Comment
Green growth	EDPR	Utilities	Portugal	Buy	6.1	5.8	28.1	1.1	Wind growth play
	Schneider	Cap goods	Germany	Buy	66.4	39.8	16.7	3.4	Energy management services
	PG&E	Utilities	USA	Buy	67.5	34.5	18.5	3.1	Green infrastructure growth
	Toyota	Autos	Japan	Buy	6161.0	166.7	10.5	3.4	Lower carbon vehicles
Stranded carbon	Petrobras	Oil & gas	Brazil	Sell	14.2	59.0	-84.9	0.0	Margin drop on oil price
	Glencore	Mining	Switz	Hold	329.6	73.4	798.6	2.9	Coal price exposure
Green bubble	EDF	Utilities	France	Sell	7.7	19.9	13.6	4.2	New nukes unfinanceable?
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Carbon cash cow	Rio Tinto	Mining	UK	Buy	3309.5	92.7	745.5	6.8	Divestments and cleaner focus
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	CR Power	Utilities	HK	Buy	14.6	8.9	11.2	5.8	Margin upside from cheap coal
	Exelon	Utilities	USA	Buy	36.3	34.4	13.7	3.6	Power margins not volume

Source: Deutsche Bank

DeCAF: Deutsche Carbon Alignment Framework

The problem for investors when thinking about decarbonisation is that they care about value not volume. Taking action on climate change is a 'volume game' in the sense that success will be determined by reducing the volume of carbon dioxide released into the atmosphere. However, traditional carbon risk analysis assumes volumes and value are aligned. For example, a green company surprising on growth also generates upside surprises on valuation. Likewise, high carbon footprint companies are expected to deliver downside surprises on volumes and therefore also on value.

But volumes and value are often misaligned. DeCAF clearly sets out the relationship between volume and value, with important implications for investors, CEOs and policy makers. In this section we explain the framework, in more detail and present some examples of key aligned and misaligned stock ideas. We also include a useful sample of relevant questions for companies based on the framework.

Volume and value: the end versus the means to the end

Discussion on climate change is obsessively about volumes. That is not surprising. After all, temperature is driven by the amount of carbon dioxide in the air, which is influenced by the amount of fossil fuel burned. Scenarios and climate models thus tend to focus on volume as the end point. This can be translated into different mixes of: coal, oil, gas burn; use of internal combustion versus electric vehicles; use of solar, wind and nuclear generation; implementation of energy efficiency measures and smart technology.

For policy makers investment returns are just a means to an end

Once policy makers have decided on what volumes are needed, the choice of incentives and instruments are merely seen as a means to achieve this end. For them, returns on private investment are just one mechanism for driving action, which drives the final outcome – the volume of carbon dioxide emitted. There are many other mechanisms available for driving changes in action and therefore changes in volume. Policy makers may feel themselves committed to the outcomes (lower emissions) but open minded to the policy instruments and implications for asset values and returns on new investment.

For investors, investment returns are the ends and the volumes are the means

For investment professionals, valuations and returns are the ends not the means. Of course the trend for volumes over the coming decades is of crucial importance. But what matters most for them is whether their investments are becoming more or less valuable. Volumes are just one of the potential means to creating value.

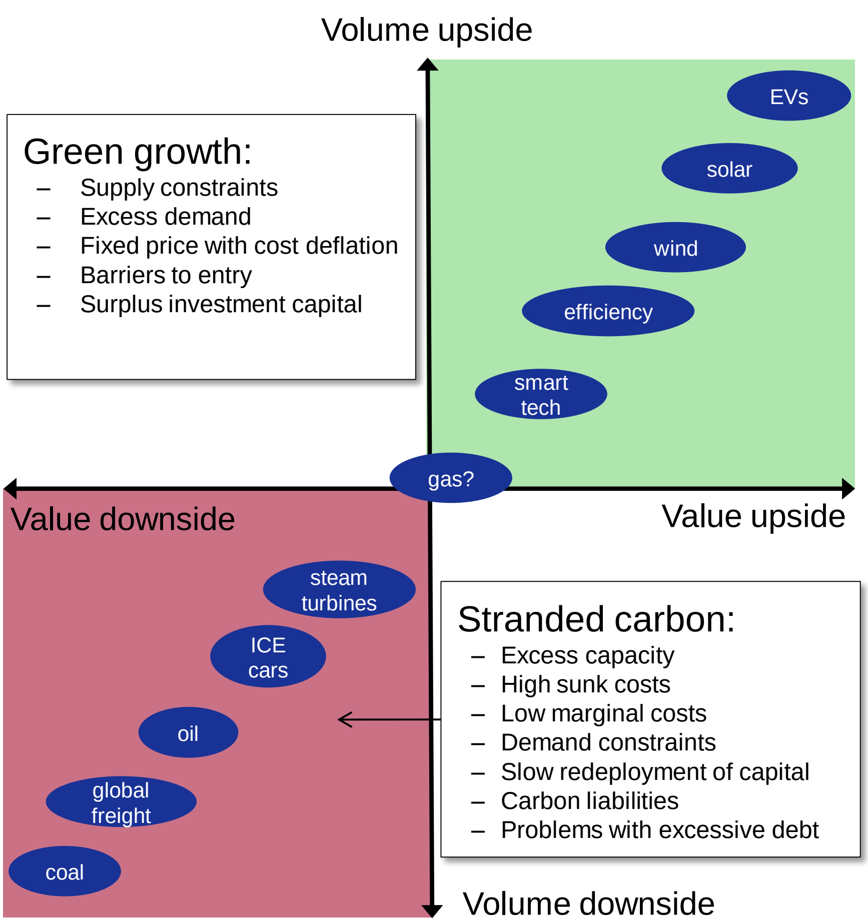
By that we mean that value can be either created or destroyed under rising or falling volumes. Green companies can as easily squander money in a booming sector as carbon-heavy rivals can ramp up payouts in a declining one. This clear two-by-two matrix allows DeCAF to sort companies into those where value and volume are aligned or misaligned. Only by trying to understand where companies sit within this framework can investors fully appreciate the opportunities or risks of decarbonisation to their portfolios.

Of course in the long term, given that climate change is damaging to the environment and ultimately the global economy, emitting too much carbon dioxide will reduce aggregate value. However, this is unlikely to be a compelling driver for investment decisions in companies and assets today. Impacts can, however, be brought forward through the actions of regulators and the preferences of consumers.

Aligned world: volumes and value go together

Traditional analysis of carbon risks and opportunities often implicitly assumes that volumes and value go hand in hand. If this is the case then investors should indeed spend much of their time thinking about volume risk. A scenario with aggressive reductions in carbon emissions means less coal, oil, combustion engine and possibly gas usage and more deployment of solar, wind, energy efficiency, smart technology, batteries and electric vehicles. In an aligned world this is straightforwardly bad news for investors exposed to coal, oil and internal combustion engines and good news for investors exposed to renewable generation, electric vehicles and battery technology.

Figure 9: Volume and value in an aligned world



Source: Deutsche Bank

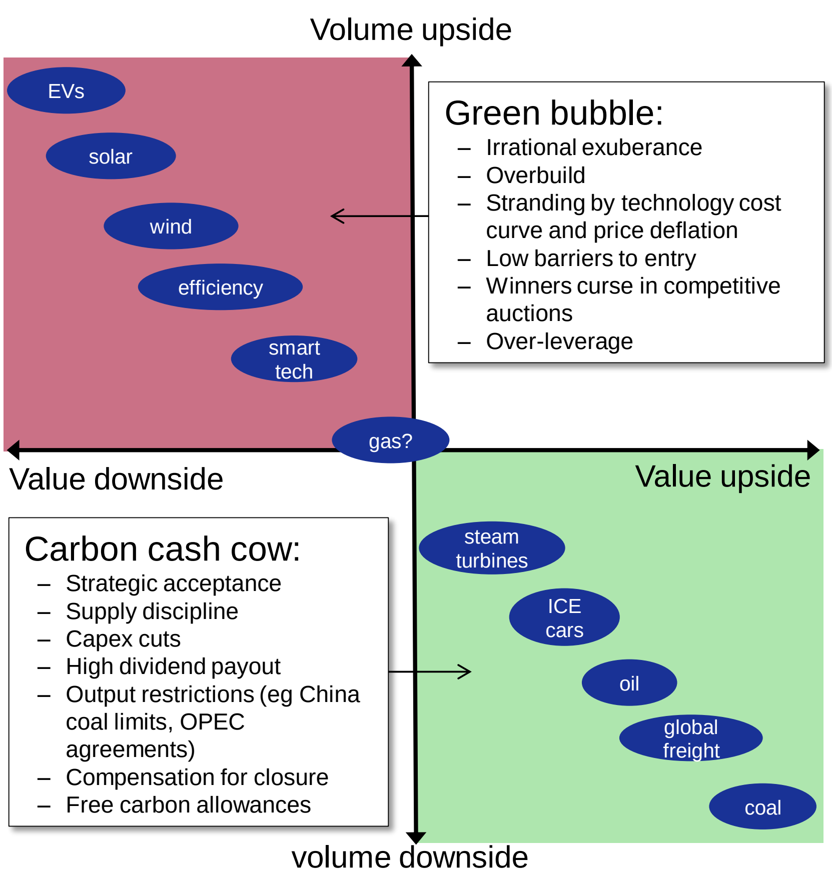
Characteristics of companies which benefit (or not) in a green-aligned world:

- **Stranded carbon** – carbon intensive companies find themselves in a world with excess capacity as volumes disappoint, led by lower demand; they may have high sunk costs while low marginal costs drive market prices down; they can only redeploy capital slowly due to long asset lives; leverage proves a problem as lower volumes and margins hurt financial ratios.
- **Green growth** – companies positioned in low carbon activities find themselves in a rapidly growing market, with supply constraints sustaining high margins. Early movers secure advantages while technological progress drives down costs. The growth allows for leverage to help finance whilst policy announcements favour companies as the regulatory backdrop becomes greener.

Misaligned world: volume and value negatively linked

Investors, CEOs and policy makers need to consider cases where volume and value are misaligned. Simply showing that a company is in a market with rising volume does not always show that there is value creation, or upside surprises on value. Equally, sometimes companies or sectors which are shrinking in volume terms may be under-valued or may be able to create value as they get smaller.

Figure 10: Volume and value in a misaligned world



Source: Deutsche Bank

Characteristics of companies benefitting (or not) in a green-misaligned world:

- **Green bubble** – green companies may be over-valued or be earning returns below their cost of capital even as they grow. Excess optimism may drive a rapid build-up of excess capacity, leading to low margins even as volume grows. Technological progress may leave past investments stranded. Low barriers to entry and deployment of volumes through competitive auctions could result in a winner's curse.
- **Carbon cash cow** – high carbon companies could adjust to a world of shrinking production, stopping new developments and restricting supply. Regulation could also restrict supply. This could allow high margins even as volumes drop. Companies might be compensated for closing dirty capacity while high dividend payouts may reward value investors.

Implications for investors, CEOs and policy makers

Investors

Investors should be particularly sensitive to indicators that are associated with being in a misaligned world. This analysis can be applied both to sunk capital and new investment. For companies with low growth capex, margins on existing production will clearly be more important than incremental value creation or destruction on new investment. For high growth companies, returns relative to the cost of capital on new investment will be more critical.

Investors should be wary of high-carbon companies where decarbonisation is likely to be demand driven (for example coal generators facing lower production as subsidised renewable production is built). However there may be value opportunities where decarbonisation is supply driven (for example restrictions on coal production, or forced coal closures could increase margins on remaining capacity even while overall volumes drop).

Investors should look for low carbon companies in sectors where supply constraints are likely to be more significant than demand constraints as volumes grow. They should be wary of sectors where the mechanisms for growth are likely to drive down returns (for example long asset lives with technological progress and short-term market pricing).

By understanding the positioning of companies in the matrix of volume and value, investors can make an informed judgment. Market valuations can be set against current opportunities and future expectations. Shareholder engagement can help ensure the right corporate strategy.

Chief executives

CEOs need to perform decarbonisation stress tests not merely on volumes but more particularly on mechanisms and margins. Investments or holdings in high carbon projects could be justified even in some rapid decarbonisation scenarios if the way that decarbonisation is driven is likely to preserve margins (relative to the current market value of the asset).

While management attention may be focused on new investments, CEOs need to bear in mind that greater value may be tied up in sunk capital. Spending time understanding and shaping the policy landscape around margins may have a bigger impact on value than focusing on volume.

For green companies, CEOs need to focus investment on areas where they can be confident margins will be maintained even in a high volume scenario. Growth driven by open competitive auctions or by deployment of capacity with rapid technological progress might bring higher risks of green bubbles. This may be even more likely to be true in high volume scenarios (for example, high volumes go with more competitive auctions or more rapid cost deflation).

Policy makers

Policy makers should focus on making sure volumes and value are aligned. Returns above the cost of capital in green growth areas may be needed to attract capital in a sustainable way. Policies that drive down emissions but undermine returns for green companies may prove counterproductive in the long term given the capital intensity of long term decarbonisation.

Examples of aligned and misaligned investment plays

In a series of global sector deep dives in the coming months, we aim to show how DeCAF can be used to better understand how carbon volume risks and opportunities translate to investor values. For some stocks, it will be clear whether they are likely to be aligned or misaligned beneficiaries (or not) from decarbonisation. For many stocks however the potential gap between volume and value is large. They could flip between an aligned or misaligned outcome depending on policy choice, corporate strategy and technological progress.

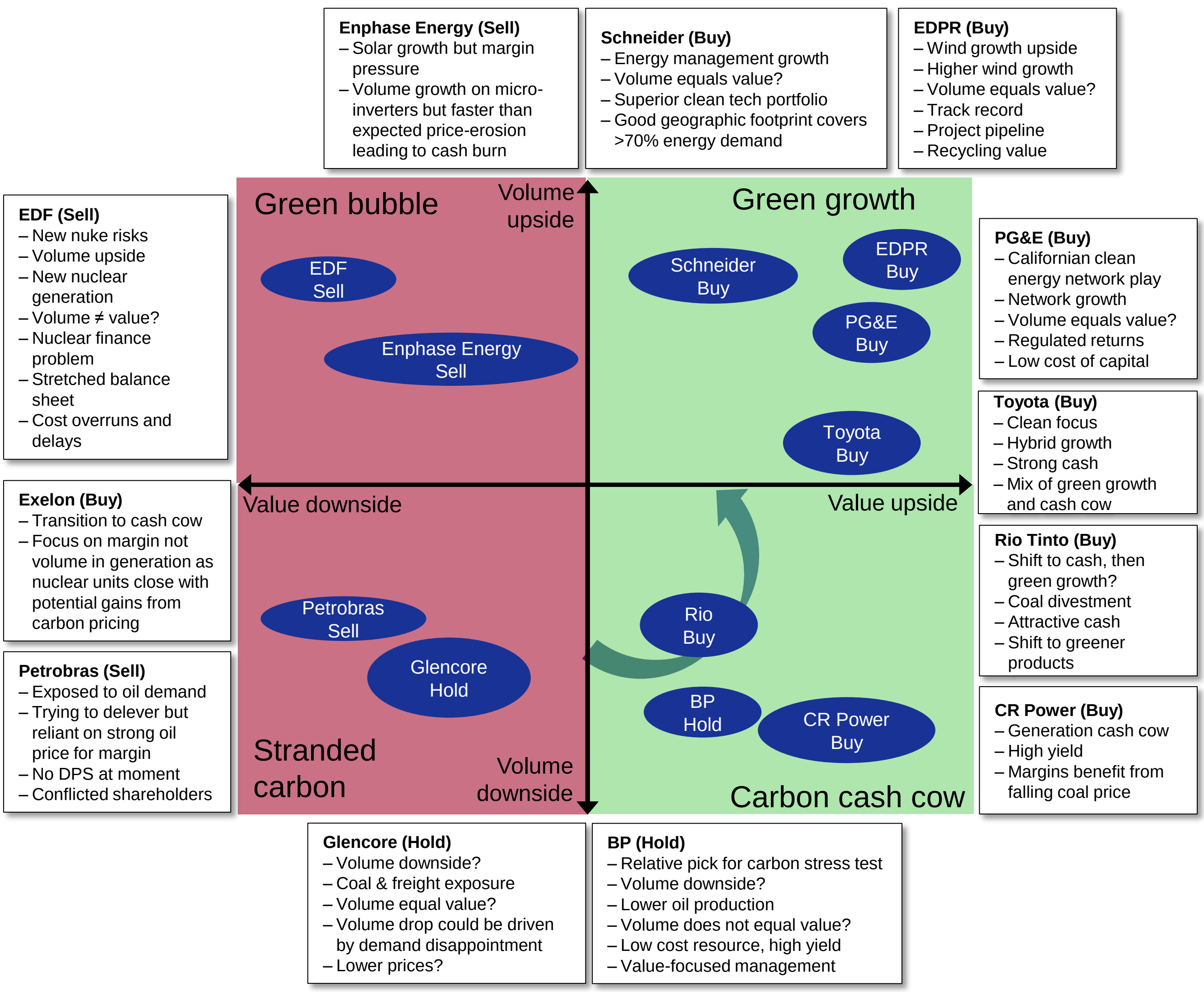
DeCAF provides a framework for clarifying under what circumstances a company can benefit or suffer in a rapid decarbonisation scenario. It can highlight potential undervalued carbon cash cows or potential overvalued green bubbles. The chart on the following page picks out a few stocks from across global sectors to illustrate how DeCAF can be used.

Green Growth: EDPR, Schneider and PG&E are examples of companies that look likely to be Green Growth stocks in a rapid decarbonisation, with volume upside and with volume and value aligned:

- **EDPR** (Buy) – A wind developer that has been de-rated on US wind growth fears following the US presidential election. We expect wind growth to prove robust, driven by state-led not federal incentives. We believe that EDPR could earn returns above its cost of capital on new projects due to its well developed pipeline and good track record. Therefore, we expect upside on volumes to drive upside on value.
- **Schneider** (Buy) – We reckon there is upside for energy management services and Schneider looks well positioned to benefit. Schneider operates in markets that represent 70 per cent of final energy use (buildings, industry, data centers, etc). We believe the group has the most comprehensive energy management platform, with a wide range of energy efficiency products and solutions (dimmer switches, timers, HVAC control, variable speed drives for motors, building management systems, microgrid management solutions, renewable connection systems, etc) and services (such as energy audits, demand reduction programs, optimisation of energy purchases, monitoring services, etc).
- **PG&E** (Buy) – is a California regulated utility with networks-focused infrastructure investment growth opportunities supporting rate base and earnings growth sustainably in the 6-7% range. Supportive state

legislation currently targets 50% renewable generation by 2030 with a 2030 carbon target of 40% below 1990 levels. With explicit state legislative and regulatory support for utility scale energy storage and transportation electrification, the state's utilities offer good exposure to emerging growth avenues well aligned with broader decarbonisation thematics.

Figure 11: Examples of possible company positioning in a rapid decarbonisation scenario using the DB Carbon Alignment Framework



Source: Deutsche Bank

Stranded Carbon: Petrobras and Glencore look at risk of being Stranded Carbon stocks in a rapid decarbonisation world, with prices and margins under pressure and with volume and value aligned:

- **Petrobras** (Sell) – An ambitious business plan leaves no room for disappointment, with the company's deleveraging objective heavily dependent on rising oil price and the company's ability to maintain premium product pricing on the domestic market and achieving its stated disposal objectives.

- **Glencore** (Hold) – A mining company and trader. Has a broad range of industrial assets with price exposure to a diversified basket of commodities including metals, agricultural products and energy products. Due to its elevated position along the cost curve, weaker commodity prices will have a significant negative sentiment impact in our view and provide a deterrent to a re-rating.

Carbon Cash Cows: Rio Tinto, CR Power and BP look possible candidates to be Carbon Cash Cows in a rapid decarbonisation world, with volumes downside but where volume and value may be misaligned: Exelon (Buy) looks have the opportunity to be a Cash Cow on a shrinking nuclear fleet if carbon pricing were introduced:

- **Rio Tinto** (Buy) – A mining company that has divested much of its thermal coal production and increased cash flows. It is now positioning itself as having the greenest iron ore, which may be more in demand in a rapid decarbonisation scenario. This could allow it to move from being a cash cow to a green growth company.
- **CR Power** (Buy) – A generator exposed to coal generation. Its margins improve as coal prices fall and it is becoming an attractive yield play.
- **BP** (Hold) – Exposed to oil production and therefore could face downside volume risk in a rapid decarbonisation scenario. However we believe it is better placed than most oil stocks to weather such a scenario. Its resource base also screens well relative to peers on emissions intensity (kilogram of carbon dioxide per barrel of oil equivalent). It is also an attractive yield play and could focus more on cash in a world of disappearing growth.
- **Exelon** (Buy) – Combines utility networks with the largest US nuclear fleet and a leading energy retailer. We believe that Exelon's focus on margin over volume is allowing it to become more of a Cash Cow on market exposed generation. If longer-term US decarbonisation eventually means pricing carbon, Exelon would be a prime beneficiary despite a shrinking nuclear fleet, and no such uplift seems to be priced in commodity markets or stock prices Meanwhile, the utilities offer a stable and growing regulated earnings base with ~75% of growth capital recovered under formulaic mechanisms.

Green Bubble: EDF (Sell) and Enphase Energy (Sell) are examples of stocks involved in clean energy investment where returns on capital have been or look likely to be disappointing. These are Green Bubble stocks where upside on volumes may leave the shares looking expensive as volume and value are misaligned:

- **EDF** (Sell) – A clean nuclear generator with a low carbon footprint but high exposure to market power prices. A rapid decarbonisation scenario is likely to be driven by a combination of further contracted / subsidised wind and solar generation and potentially by low coal prices, both of which would driven down power prices. If the French government presses ahead with new nuclear generation we believe this will likely prove unaffordable for EDF without a major (probably dilutive) financial restructuring.
- **Enphase Energy** (Sell) – Enphase was the first to successfully commercialize the solar micro-inverter. However, even as solar installation volume grew, faster-than-expected price erosion had an

outsized negative impact on margins and earnings. Enphase Energy is still the higher-cost producer against its competitors. Until further signs of pricing environment stabilization and strong execution on cost reduction, we maintain a Sell rating.

Figure 12: Key global recommendations consistent with a rapidly decarbonising scenario

Quadrant in carbon stress test	Company	Sector	Country	Rec	Price (local)	Mkt cap (USDbn)	P/E (2018E)	Div yield (2018E)	Comment
Green growth	EDPR	Utilities	Portugal	Buy	6.1	5.8	28.1	1.1	Wind growth play
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	Exelon	Utilities	USA	Buy	36.3	34.4	13.7	3.6	Power margins not volume

Source: Deutsche Bank estimates

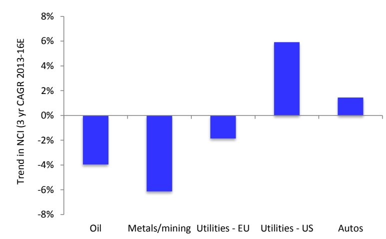
Questions for companies based on DeCAF

Public policy pressure is on institutional shareholders to engage with corporates. Meanwhile, the environmental lobby wants companies to drive forward energy transition and institutions to divest ownership of certain sectors. Thus the interests of policy makers and lobbyists are by definition not driven by shareholder returns. This is the volume-value gap. Investors must question companies to make sure they understand whether they operate in an aligned or misaligned world and hence know how to maximise shareholder value.

Key questions for company management

- *What are your expectations for energy demand and supply over the next 10-15 years? How do these vary from the IEA benchmarks?*
- *How do you embed transition thinking in investment decisions? Who has responsibility for energy transition at Board level?*
- *What is your energy transition future? What products and services will you sell? What products or geographies will you now avoid?*
- *To what extent is the business ready to apply growth capital to new opportunities as opposed to replacement capital to existing ones?*
- *How do you assess the prospects for comparative financial returns? What is the appropriate pace of capital reallocation? How is this influencing your decisions on shareholder payout?*
- *How are the markets or companies you sell into changing? Are your major customers becoming more fragmented?*
- *How do you expect energy prices to move as a result of the transition trends over the next ten years? To what extent will that impact margins?*
- *What level of financial disclosure can we expect about new business streams? Will we see an "energy transition" division that enables us to track capital and returns?*
- *Do you disclose your direct GHG emissions? Do you provide information on indirect emissions embedded in the ultimate use of your products?*
- *Do you have a carbon dioxide price/tax assumption? How do you apply that to the business in terms of investment decisions? Would a global carbon pricing regime be positive?*
- *What assumptions do you make about abandonment and remediation of production facilities? How do you provide for these future liabilities?*
- *How do you assess the likelihood of physical damage to your facilities, or liability for damage caused to others by your GHG emissions?*
- *What are your priorities in discussions with regulatory authorities? Where would you like to see change or greater clarity?*

Figure 13: Annual change in net capital invested 2013-16E: incumbent declines



Source: Deutsche Bank

Sector volume outlook and challenges

Global oil & gas

- ***Less***: oil; frontier exploration; OECD refining
- ***More***: consolidation; low-cost resource access; natural gas; supply (trading and retail solutions)
- ***Risks***: gas squeeze between renewables and coal; abrupt late-2020s policy dislocation versus oil/gas
- ***Q****: What will drive the roll-over in oil demand? Can gas grow against coal and renewables?*
- ***Q****: Should the majors expand in new energies?*
- ***Q****: How and where will carbon taxes influence prices and margins?*

Global utilities

- ***Less***: fossil-fuel power; traditional utility business model; centralisation
- ***More***: wind and solar; demand side management (controls and services); distribution assets
- ***Risks***: fragmentation, increased competition; gas squeeze; nuclear build
- ***Q***: *Should OECD utilities prioritise new capacity growth over dividends?*
- ***Q***: *Can listed equities deliver nuclear growth?*

Global mining

- ***Less***: coal, oil, seaborne trade
- ***More***: green metals, consolidation, high quality metallurgical coal
- ***Risks***: new competitors in growth metals; abrupt late-2020s policy dislocation versus coal
- ***Q****: Can new capacity be added fast enough in green metal mining and processing?*
- ***Q****: Is there a bull case for coal supply?*
- ***Q****: How significant will the burden of carbon taxes be on traditional miners? What are the amelioration options?*

Global autos

- ***Less***: fleet growth; competitive advantage in combustion engines
- ***More***: tech content (autonomous, electric); advanced ICEs into trucks; increased fleet turnover
- ***Risks***: fragmentation, increased competition; lost potential market-share in EMs; access to IT skills
- ***Q****: What will drive the shifts in transport intensity?*
- ***Q****: When will EVs be the more competitive option for producers and consumers?*
- ***Q****: Can the incumbents develop and retain an IT-led offering?*

Capital goods

- ***Less***: steam/gas turbines; transmission network growth; freight volumes (trucks, ships)
- ***More***: distribution networks; smart grid controls and infrastructure; controls/motor tech; energy services
- ***Risks***: weaker global trade volumes; gas-power squeeze; fragmentation, EM domestic alternatives
- ***Q****: Can increased pricing power overcome more fragmented competition in manufacturing?*
- ***Q****: To what extent can power-distribution products replace those in bulk transmission?*

Clean tech

- ***Less***: tax credits, generic OECD component manufacturing
- ***More***: wind, solar, marine, energy storage, power demand management tools
- ***Risks***: diminishing early-cycle returns; fragmented competition; policy reversals; cyber failure
- ***Q****: What is the scale of the energy productivity available through cyber-control and differentiated pricing?*
- ***Q****: What will a mature clean tech sector look like?*

Decarbonisation view

We believe the Paris agreement in 2015 was a key breakthrough with policymakers agreeing to restrict global warming to less than two degrees centigrade this century. The post-Paris scenario work of the International Energy Agency offers investors a roadmap of where various industries could be headed in terms of volumes over the next 25 years.

The big picture: 2040 carbon emissions need to halve versus current trend rate

Global carbon dioxide emissions have risen from 20 gigatonnes to over 30 gigatonnes in 25 years and could exceed 40 gigatonnes by 2040 on this growth path. But emissions need to but cut to less than 20 gigatonnes by 2040 if we are to have a chance of restricting global warming to less than two degrees centigrade this century.

So what does halving carbon emissions by 2040 imply?

It implies an acceleration of energy productivity and a transformation in carbon intensity. Energy intensity relative to gross domestic product has been improving at 1.5 per cent a year since 1990. If this can accelerate to three per cent, the absolute volume of energy demand growth to 2040 could be restricted to ten per cent and still generate global economic development. Fossil fuels have supplied 80-85 per cent of our energy needs for decades. New technologies need to cut this to under 60 per cent by 2040.

Volumes imply massive shifts in energy-related revenue and capex

Top-down projections for a two degree path show $15tn less capital investment in fossil fuel production and power, but an extra $25tn required in alternative fuels, technologies and control systems. Global oil production would need to fall towards 70m barrels per day by 2040, 35 per cent below many major oil company projections (Figure 31). This is equivalent to $11tn of lost revenue. Coal use needs to halve by 2040, with 20 per cent of China's 2020 coal generation capacity needing to close early.

More wind, solar, EVs; fragmentation in integration and engine tech

Current global solar and wind additions of 140 gigawatts per year are only about two-thirds what is required for a two degree run-rate. The minimum ten per cent per year net growth is a $6-7tn investment. If only eight per cent of transport demand is electrified by 2040, it would still mean 700m electric vehicles and sales of almost $20tn. Also required are products to integrate and control the new power profile, and disseminate transport engine efficiencies.

$2tn gas revenue uncertainty, $1tn nuclear finance gap

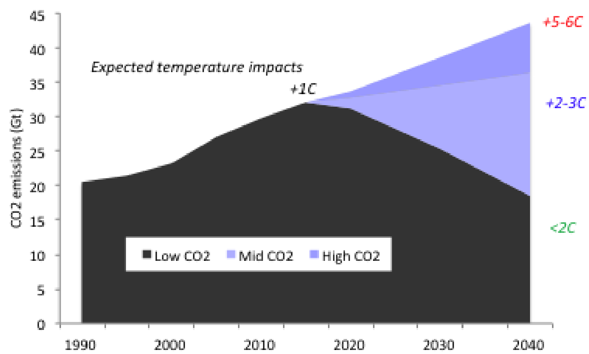
Nuclear generation is assumed to grow in top down projections but equity investors show no appetite to finance this. Gas use looks certain to rise to 2030, but a switch straight from coal to wind and solar could cut its role as a 'bridge fuel'. Even infilling for less nuclear, a low-gas scenario could reduce 2040 demand by ten per cent compared with a high-gas scenario.

Policy and regulation: possible carbon dioxide prices of $45/bbl, $300/t coal

The rapid elimination of cheap fossil fuels and imbedded infrastructure looks impossible absent carbon pricing or straight fuel prohibition. The IEA assumption of a carbon price of $140 per tonne by 2040 equates to $2.5tn gross cost per annum.

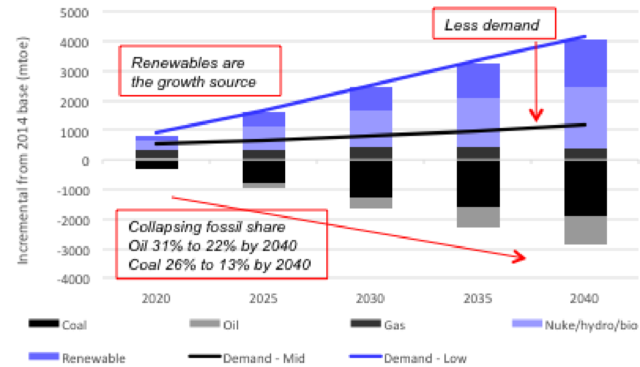
The volumes behind decarbonisation: key charts

Figure 14: CO_2 emissions are driving up temperatures
Need to half by 2040 to keep change under control



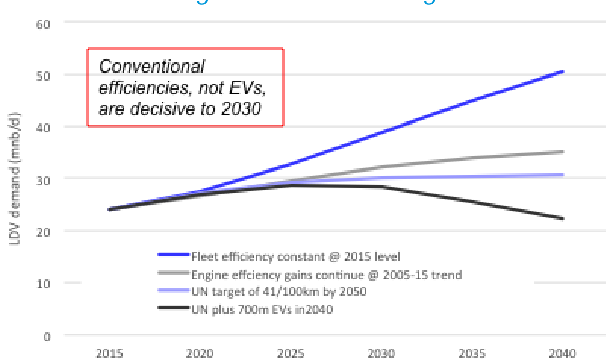
Source: IEA WEO 2016, Deutsche Bank estimates Note: Scenarios defined on p19. High-mid-low equate to IEA Current Policies, New Policies and 450S

Figure 15: CO_2 abatement means less demand, less fossil
Incremental demand vs decarbonising energy to 2040



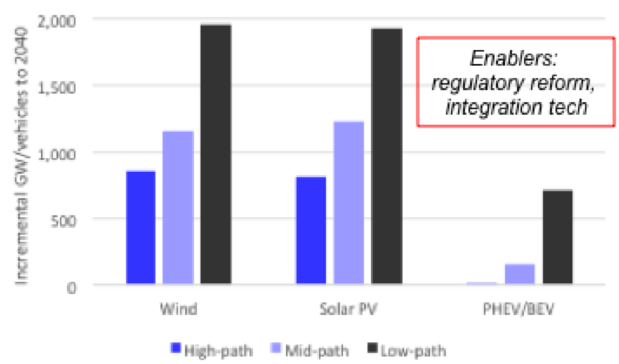
Source: IEA WEO 2016, Deutsche Bank estimates. Note: Period fuel change is Low-path case

Figure 16: *Efficiency is the biggest single contributor to decarbonisation. E.g. oil demand from light vehicles*



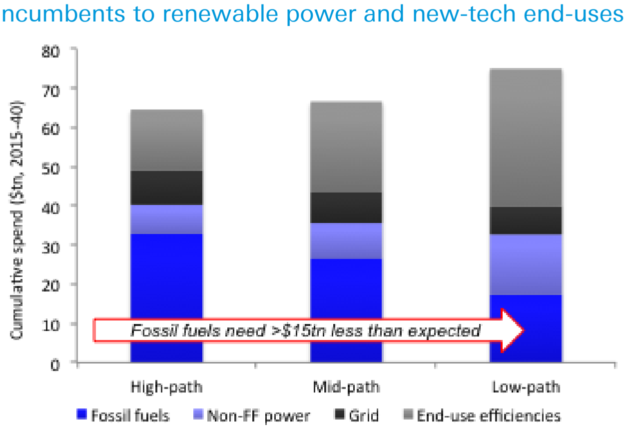
Source: Deutsche Bank estimates, IEA 2016, UN Environmental Programme

Figure 17: Alternatives also driving decarbonisation trend
Prospective capacity additions in wind, solar, EVs to 2040



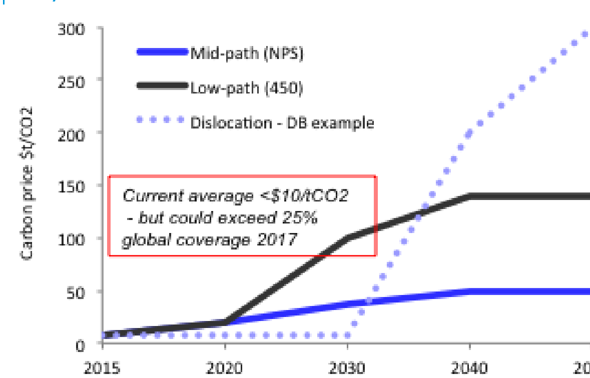
Source: IEA WEO 2016, Deutsche Bank estimates

Figure 18: Huge redeployment of capital is required from incumbents to renewable power and new-tech end-uses



Source: IEA WEO 2016, Deutsche Bank estimates

Figure 19: Are high carbon prices inevitable? Forcing early-retirements in coal, fleet turnover in autos

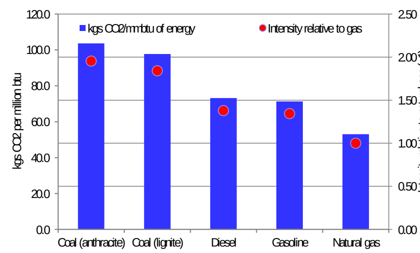


Source: IEA WEO 2016, Deutsche Bank estimates

Volume scenario summary

- **Trend established**. Political, macro and share price cycles will oscillate, but there is a secular trend towards compressed growth in energy demand, increasing alternative fuels and abated carbon. The next part of this report sets out the expectations, levers and broader context of the benchmark decarbonisation scenario.
- **IEA benchmark**. There are thousands of different scenarios for future energy demand and related emissions, each with their own biases and intentions. We do not wish to add another, focusing instead on the World Energy Outlook of the International Energy Agency. This is the benchmark against which companies will be expected to evaluate business risks and forecasts (Figure 21).
- **Change or fail**. Without reduced emissions, the impacts of warming will be detrimental to economic growth: business-as-usual forecasts will be self-defeating on a 25 year view.
- **Demand compression is happening**. Energy productivity relative to GDP growth has improved by 1.5 per cent a year since 1990. That needs to be 2-3 per cent per year to 2040 (Figure 16) to limit growth enough to constrain the total: extremely demanding, but technology and shifts in economic activity make it plausible.
- **Power transition**. Wind and solar will outperform expectations (Figures 29 and 30). The technical challenges of variability and daily load can be overcome through distributed generation and demand-side management – the risks lie in timely regulatory reform, insufficient capital and cyber-failure. The delivery of nuclear growth and the vulnerability of the coal-to-gas transition are questionable.
- **Fossil decline**. Oil demand can peak by 2025 driven by engine efficiencies (Figure 16) and constrained use in everything from cars to ships – electrification impacts later. Gas should grow to 2030; thereafter it will be fighting stubborn coal and rising renewables. Coal use (Figures 35 and 36) needs to halve by 2040 – but investment in clean-up tech may allow its domestic attractions to win out and volumes to persist.
- **Policy needed**. The unpriced nature of climate damage means policy has to force change (Figure 19). By 2030 there may have to be an aggressive carbon price regime, or widespread prohibition of certain fuels. The longer the delay, the more abrupt the intervention.
- **Capital has to shift**. The IEA low-carbon case implies that a fossil fuel sector (production to power) currently set up to invest over $30tn to 2040 has to shrink to under $20tn (Figure 18). Financial and human capital has to relocate – and right now much of the growth action is outside the listed equity markets.
- **Stranding is complicated**. In a gradual transition we see limited risks to booked oil & gas assets with invested capital. That could change if the transition is delayed and abrupt. It could get complicated if it changes the behaviour of some major hydrocarbon resource holders. There are some obvious red-flag assets (oil sands, Arctic, gas-to-liquids, export-directed and Chinese coal, OECD refining).

Figure 20: Relative carbon intensity of different hydrocarbons



Source: EIA estimates; Deutsche Bank

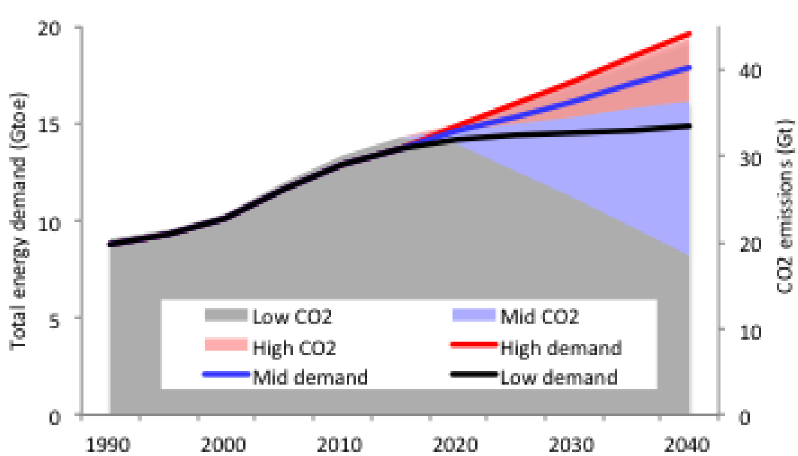
Scenario definitions

The scenarios produced by the IEA are the accepted benchmarks for future global energy demand. This status has been reinforced by the preliminary report of the G20-sponsored Taskforce on Climate-related Financial Disclosure (TCFD).

For simplicity we have labeled the IEA pathways as high, mid and low carbon as follows:

- **IEA New Policies Scenario: "mid-path".** Extends Paris conference (COP21) commitments and wider technology trends to mirror current direction of travel. Carbon dioxide emissions still increase by almost 15 per cent to 2040. This is consistent with global warming of around three degrees Celsius this century.
- **IEA 450 Scenario: "low-path".** A scenario that seeks a 50 per cent chance of limiting warming to two degrees this century (name refers to 450 parts per million – the target for the peak carbon dioxide concentration in the atmosphere consistent with less than two degrees warming). Applies policies and accelerates technology uptake to cut annual emissions by 45 per cent to 2040. Requires net-zero emissions in the second half of the century
- **IEA Current Policies Scenario: "high-path".** Only policies actually implemented by mid-2016 with gradual technology uptake from there. Emissions are 35 per cent higher by 2040 and the world is on a path to 5-6 degrees of warming.

Figure 21: IEA scenarios for global energy demand and carbon emissions, 1990-2040



Source: IEA WEO 2016, Deutsche Bank

Low carbon is here to stay

We see a secular investment trend towards decarbonisation – albeit varied in year-to-year intensity by politics (Trump), macro (growth) and value (share price) cycles. Right now the pressures look incremental with gradual shifts in expectations for demand and fuel source – and real concerns about the near-term direction of US public policy. In 2018, the United Nations will meet to review the Paris commitments and examine the options for an even more draconian emissions ambition: limiting warming to less than 1.5 degrees. Just as pressures are building on corporates to improve their climate-related risk disclosures, so policy-makers will face the prospect of ever more abrupt shifts in regulation the longer the energy transition is delayed.

One direction: diversions likely, but no u-turns

The scientific arguments behind man-made climate change are clear. Examples of impacts are already with us. Encouraged by the immediate effects of atmospheric pollution, actions to mitigate and reverse the results of fossil fuel combustion are becoming embedded in public policy and consumer preference. Innovations in the technologies that enable efficiency and provide alternative energy sources are finding the support needed to achieve the scale for accelerated cost reduction.

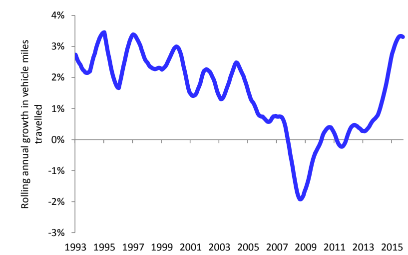
The key elements of this support are: national security concerns around energy independence and health (and by implication popular contentment with the status quo); the reinvestment of leading technology companies attuned to cash burn and disruption; and the industrial fragmentation enabled by the simplicity and limited labour-intensity of many of the technological advances.

Of course, public-policy frameworks are a vital component of early-stage adoption and overall direction, but these are now moving towards enabling rather than funding decarbonisation. Political support will rightly ebb and flow; however, scepticism will be increasingly offset by more people employed in the “clean economy”. Likewise, cycles working against decarbonisation (Figure 21) are being more than offset favourable secular trends (Figure 22).

We have seen, and will continue to see, upgrades to: the alternatives to fossil fuel power (wind, solar, electrification), energy-saving components (LEDs, electric vehicles) and control systems that manage everything from daily power loads to turning off your television. The corollary is downgrades to demand for energy and the requirements for coal, oil and gas. The providers of fossil fuel extraction and power generation are not in a growth industry.

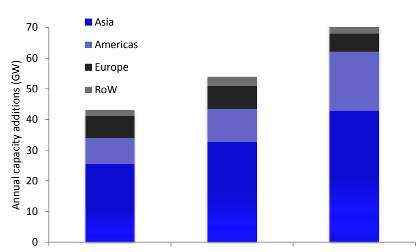
Beyond the scope of this report, the broader social implications of these changes are unpredictable. They add weight to the ongoing debate about de-globalisation. They add urgency to the need to manage the employment challenges posed by artificial intelligence, and the threats to security and privacy inherent in many control systems. At a more mundane level, they threaten the financial returns and rating of some core sectors of the developed equity markets, with the investment gap being filled by the sometimes more opaque world of direct equity and fragmented special vehicles.

Figure 22: Two sides of 2016. US miles driven rose strongly…



Source: Deutsche Bank, US department of transport

Figure 23: … but so did global solar additions



Source: Deutsche Bank estimates

The scientific pressures will grow – encouraged by the real possibility of change

Climate science is only just winning the war of global acceptance. There will still be climate sceptics (see Trump’s new team), but their actions will almost certainly be restrained by the attraction of competitive advantage and financial returns in the new technologies (see again Trump’s new team).

Instead, the scientific pressure is shifting to more ambitious goals. The first review meeting of the Paris Agreement will be in 2018. It will examine proposals for an emissions pathway designed around a 50 per cent chance of limiting end-century warming to 1.5 degrees, rather than two degrees. Instead of a near-halving of emissions by 2040, this will probably require net-zero by 2050. This is probably impossible without innovation in carbon capture and negative emission options (from additional plant growth to enhanced weathering), alongside more tax-led initiatives to encourage fuel substitution.

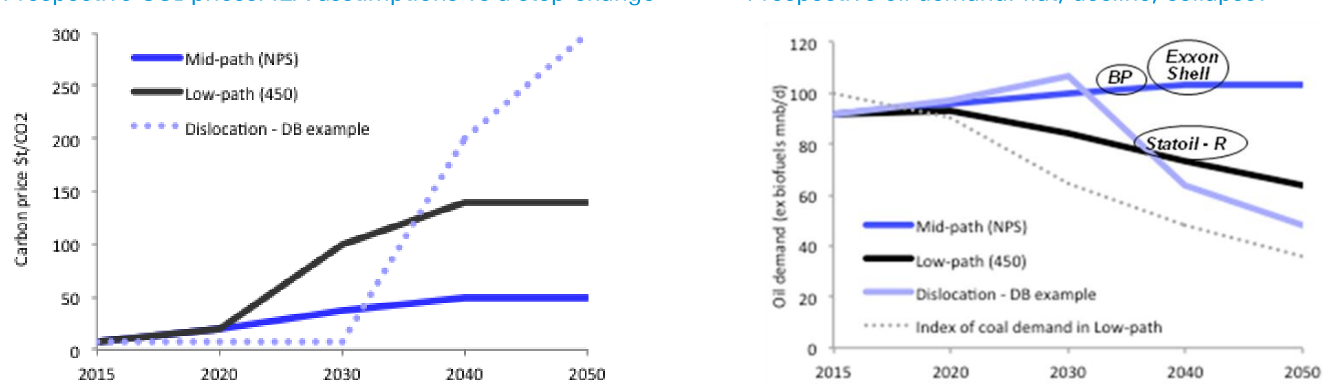
The IEA’s latest World Energy Outlook discussed this pathway for the first time (the well-below-two-degrees scenario), marking a clear direction of travel in scenario planning. Judging business resilience against the mid-path should no longer be perceived as a stress-test – it is too close to a base case. The new thinking may be that if we don’t cut emissions, the pressures on climate will impede growth and ultimately defeat forecasts through negative feedback.

Year-to-year and country-to-country moves towards a more efficient, low-carbon future will be volatile. At best, they will provide some mutual compensation to give the world a relatively smooth transition and encourage a planned redeployment of capital. At worst, we will see dislocating step-changes that leave some assets stranded and value destroyed.

For the current energy giants, we have moved beyond the credibility of no change. They need to accept the 15-20 year outlook while retaining some flexibility to take advantage of the short-term upsides in temporary diversions. Even this apparently benign statement implies a gap-down in the public views of the oil majors on future energy demand. As illustrated in Figure 23, further delay may only raise the risk of subsequent abrupt step-change bringing real risk of asset stranding and value loss.

Figure 24: Dislocated future: could it come through abrupt carbon pricing or outright fuel prohibitions?

Prospective CO_2 prices: IEA assumptions vs a step-change | Prospective oil demand: flat, decline, collapse?



Source: Deutsche Bank, IEA WEO 2016, company data. Note for chart on right: bubble indicates the end-points of the Major’s scenarios. Statoil-R refers to the Statoil Renewal scenario.

How forecasts for energy demand are constructed

How are long-term forecasts for global energy demand constructed? What are the principal assumptions and sensitivities that drive alternative scenarios? Below we give an overview of how all these forecasts come about and note the main discrepancies to be found across the various corporate and institutional outlooks.

In the wake of the Paris Agreement, increased pressure into the annual general meetings of the oil majors and miners generated a series of publications that added detail to their forecasts for long-term energy demand and supply. Companies such as BHP, Glencore, Exxon, BP, Shell and Statoil provided scenarios for acceleration in alternative energies and lower demand.

There is, of course, a gap between appreciation and implementation. There is still some distance to the adoption of a low emissions pathway as a business stress-test. Indeed few companies show signs of a public acceptance that the trend is necessary and inevitable. Moreover, there are biases. For example, oil companies have a preference for scenarios with low coal demand (cutting overall emissions and making space for gas) or for ever-improving combustion engine efficiency and biofuels rather than electric vehicles and batteries.

Below, we provide the background to the assumptions and sensitivities that drive scenarios for a low carbon future. We use the benchmark pathways produced by the IEA as a base. There are more than 1,000 alternative views analysed in the scientific literature. We won't add another, but instead wish to understand the framework against which our companies forecast and plan.

__Shell__: "we have no immediate plans to move to a net-zero emissions portfolio over our investment horizon of 10-20 years"

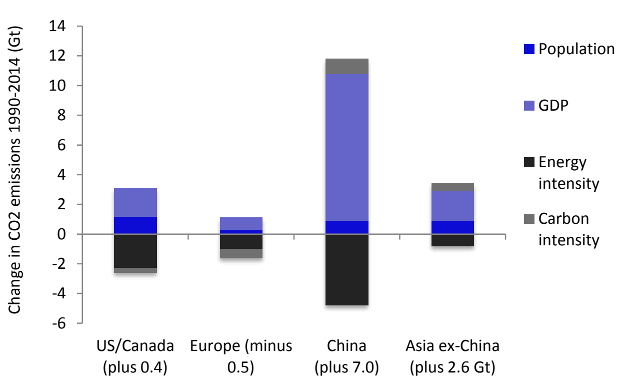
__Exxon__: "we do not believe a scenario consistent with reducing GHG emissions by 80 percent by 2050…. lies within the "reasonably likely to occur" range of planning assumptions, since we consider the scenario highly unlikely"

__Glencore__: "coal's share of the global energy mix will decline to 2030, but still increase by absolute volume""

The IEA approach

The top-down methodology used by the IEA is based on the Kaya Identity proposed by Yoichi Kaya in 1993. This runs from population through gross domestic product to assumptions about the relative intensities of energy and carbon-fuel use to indicate changes in overall carbon emissions. Figure 24 below illustrates the relative movement of these four elements since 1990.

Figure 25: The Kaya Identity in action: sources of change in carbon emissions 1990-2014

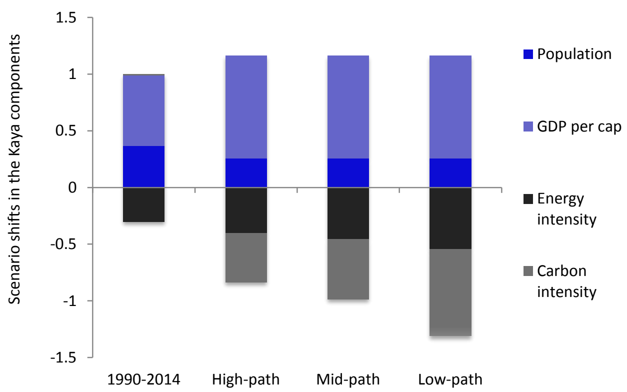


- Global carbon emissions rose by 60 per cent (12 gigatonnes) between 1990 and 2014. China was by far the largest contributor to growth, with OECD emissions effectively flat since 1990
- Energy intensity. Improvements in efficiency of use were important in all key regions – successfully offsetting all growth in economic activity in the OECD, and allowing some abatement in Asia
- Carbon intensity increased in Asia – strongly in China – due almost entirely to rising coal use

Source: IEA CO_2 Emissions from Fuel Combustion

Moving forward in the pathways to 2040 (Figure 25), the critical IEA inputs start with population growth (the UN mid case of 9.2bn people in 2040) and GDP (long-term average annual growth of 3.4 per cent in real terms). A raft of assumptions about policy, technology, costs, comparative pricing and adoption rates then underpin the headline shifts in energy and carbon intensity.

Figure 26: Moving parts in the Kaya Identity: IEA scenarios to 2040



- Relative to the prior 25 years, population growth slows but per capita GDP growth expands
- The continued shift to services reduces energy intensity, as do accelerating efficiencies in use and technology
- Non-fossil energy is the dramatic new component forcing significant reductions in carbon intensity
- The IEA low-path adds high carbon pricing and carbon capture to realise its goals

Source: IEA, Deutsche Bank

When comparing scenarios between commentators the fundamental comparative details to watch out for are:

- **GDP growth**: a more conservative outlook would generate lower demand and thus lower headline emissions
- **Coal share**: less than 15 per cent of total energy demand in 2040 (from just over 25 per cent today) is aggressive and makes space for higher gas (or renewables) against a similar emissions trajectory (Figure 26)
- **Wind and solar**: 30 per cent of power generation by 2040 is the top end of current scenarios. It requires balance through storage, load shifting and low-utilisation peaking capacity. Higher penetration implies further evolution in demand management and regulation.
- **Nuclear expansion**: any significant (50 per cent-plus) increase in global capacity in the face of forthcoming retirements looks aggressive – particularly if it assumes private sector funding. Many scenarios add overall capacity and increase current utilisation rates to boost carbon abatement
- **Carbon pricing:** long-term forecasts sit around $40 per tonne (Figure 23). Equivalent to $13 a barrel of oil, $2 per thousand cubic feet of gas and $100 per tonne of coal these levels create substitution pressures but are in balance with other policy levers. They support gas over coal in power generation, but are unlikely to be enough to support the development of carbon capture. Emission transformation cases use prices in excess of $100 per tonne of carbon by 2040.
- **Carbon capture:** supports the continued use of fossil fuel generation and covers certain industrial emissions. Still requires a cost and capacity break-through to achieve useful scale. The most recent IEA energy outlook halved expectations for 2040 capture in the low-path case to three gigatonnes of carbon (covering just over 400 gigawatts power plus some industrial emissions)

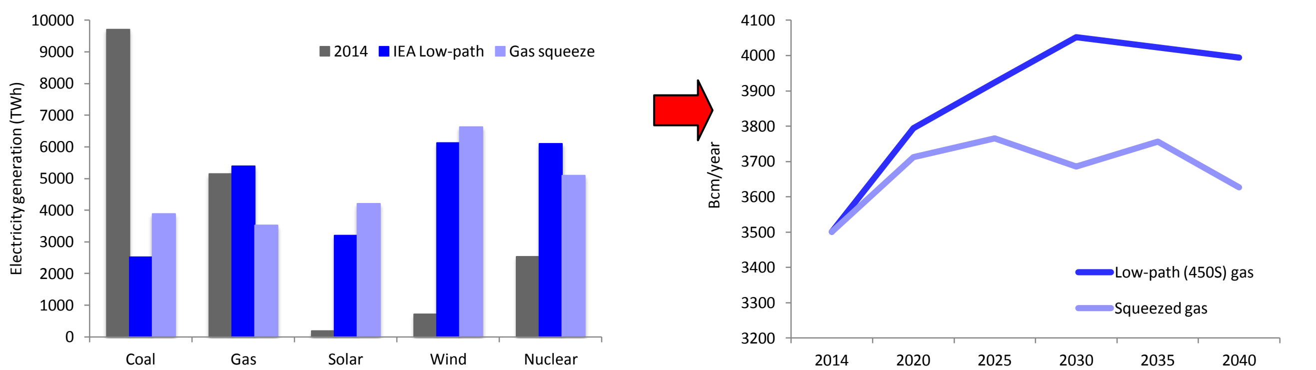
- **Biofuels:** production in excess of 4m barrels a day (more than twice current volume) assumes break-through in advanced (second generation) processing and further industrialisation of land practices
- **Vehicle fuels:** a 35 per cent improvement in fleet-wide light vehicle fuel efficiency could avoid as much oil demand today as 700m electric vehicles. It would preserve much of the current downstream oil and auto manufacturing infrastructure – but the incremental cost of these efficiency gains may now be greater than the electric vehicle switch.

Playing with levers: a gas squeeze example

On a 25 year view, adjustments to the underlying assumptions can make real differences to the end-point conclusions. A big question for the fossil fuel sector is the sustainability of natural gas as a transition fuel: under-cutting the carbon emissions of coal, providing the flexibility to support renewables. Gas provides a life-line to the structures of the current upstream and power producers. However, prospective gas growth (Figures 33 and 34) could find itself under pressure if the strong economic and political attractions of domestic coal reserves cause its demise to become extended – just as renewables penetration could be increased by new technologies that manage demand and enable storage.

Figure 26 shows the impact of a little more solar, a little more wind, a little less nuclear and a slower coal decline. Towards 2040, gas goes from a growth fuel to flat fuel. The implied revenue shift is $2tn.

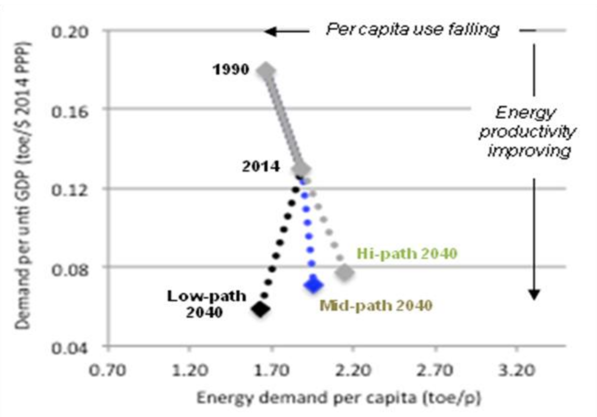
Figure 27: Squeezing the gas profile: further wind and solar upgrades could combine with stubborn coal to send gas ex-growth – even if we ratchet back some of the IEA's aggressive nuclear growth



Note: Our gas squeeze scenario results in no net change to forecast IEA 2040 power CO2 emissions – but does assume CCS applied to incremental coal use at same rate as IEA Low-path (450) case (implying an additional 700mt of CO2 capture to the 3GT IEA figure)
Source: Deutsche Bank, IEA 2016

Key supply assumptions

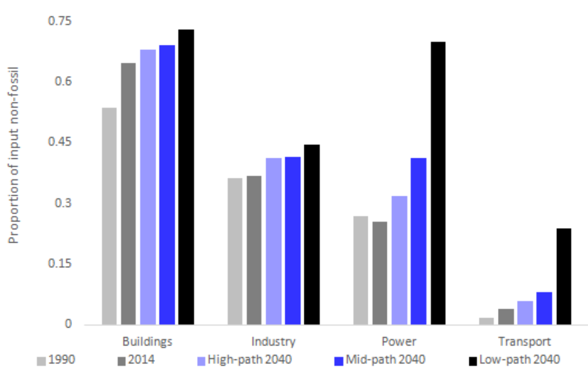
Figure 28: Energy productivity: can further gains offset more people, more economic development?



- Top-down scenarios look at energy use per capita and per unit of GDP. As per IEA WEO 2016, since 1990, the world has reduced its energy intensity per unit of GDP by around 1.5 per cent a year, but per capita use has increased – strongly in China, more recently in India
- Forecasters of low energy demand growth are often criticised for leaving much of the world undeveloped
- But with unparalleled opportunities for “technology-skip” and the reducing energy intensity of economy-wide shifts to services, that need not be the case

Source: IEA WEO 2016, Deutsche Bank Note: See Appendix in DeCAF - Decarbonisation: A guide to the language and assumptions for details by specific country

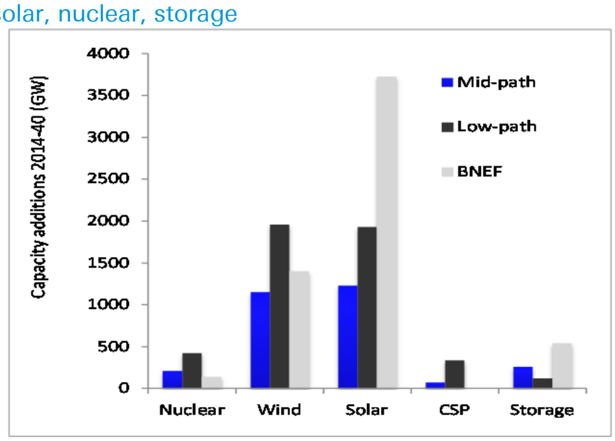
Figure 29: More electricity but less fossil fuel: can coal share in power shrink from ~50 per cent to ~10% per cent?



- The chart depicts the penetration of non-fossil sources (mainly electricity) into key sectors, and use of fossil fuels within power generation itself.
- Overall electricity share of end consumption doubled from 1970-2015 from nine per cent to 18 per cent. The next 25 years sees this grow by a further third to 24 per cent (low-path)
- The breakthroughs are renewables in power, and electricity in transport.
- By far the most important shift over this time frame is the steady elimination of coal-fired power

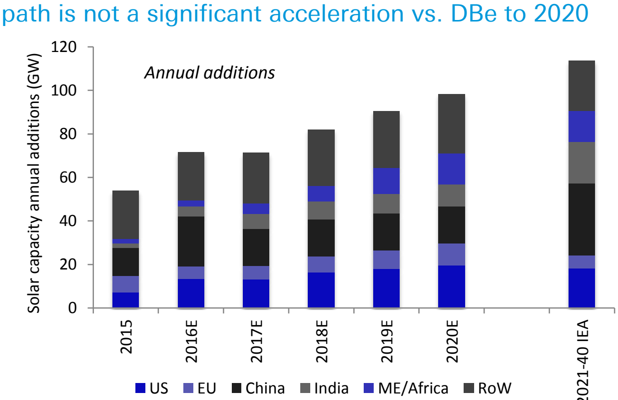
Source: IEA WEO 2016, Deutsche Bank

Figure 30: Low carbon power additions 2014-40 - wind, solar, nuclear, storage



Source: IEA WEO 2016, Deutsche Bank, Bloomberg New Energy Finance (BNEF)

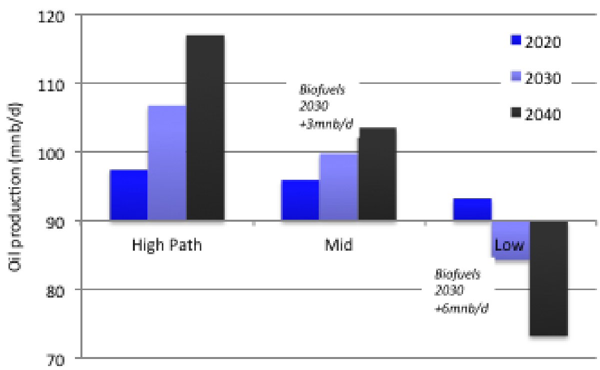
Figure 31: Solar additions are on course: the IEA Low-path is not a significant acceleration vs. DBe to 2020



Source: IEA, Deutsche Bank estimates

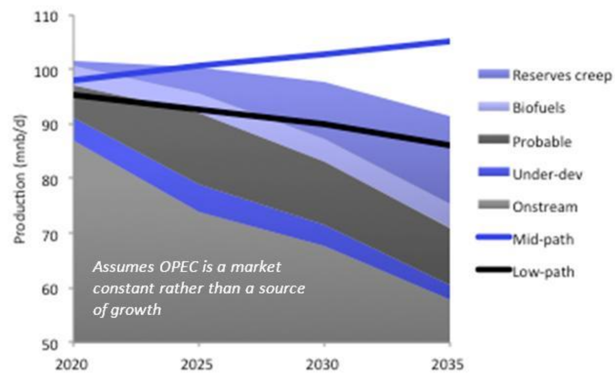
Oil steady attrition; gas potential growth; coal collapse

Figure 32: Conventional oil needs versus the current 90mnb/d base: decline increasingly plausible from 2025



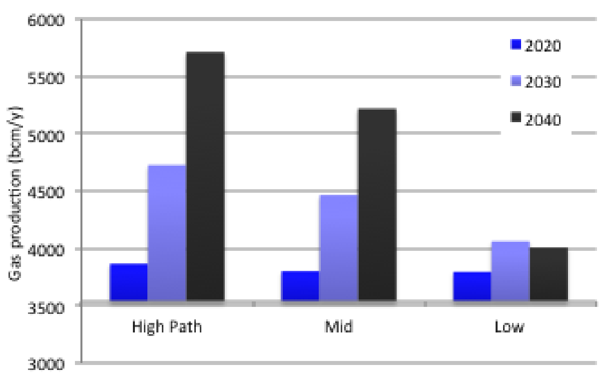
Source: IEA WEO 2016, Deutsche Bank

Figure 33: Oil supply including biofuels: need new developments – but a poor outlook for exploration



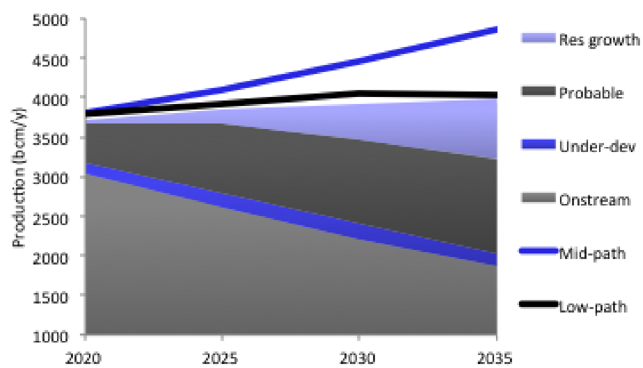
Source: IEA WEO 2016, Wood Mackenzie, Deutsche Bank

Figure 34: Demand for gas vs current base: still growing in all cases but vulnerable to a renewable/coal squeeze



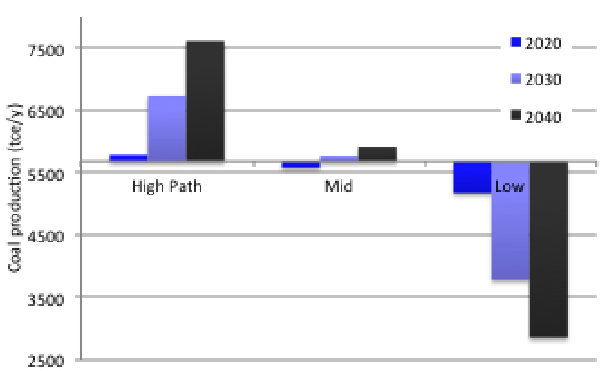
Source: IEA WEO 2016, Deutsche Bank

Figure 35: Gas supply: early 2020s gap even with reserves creep



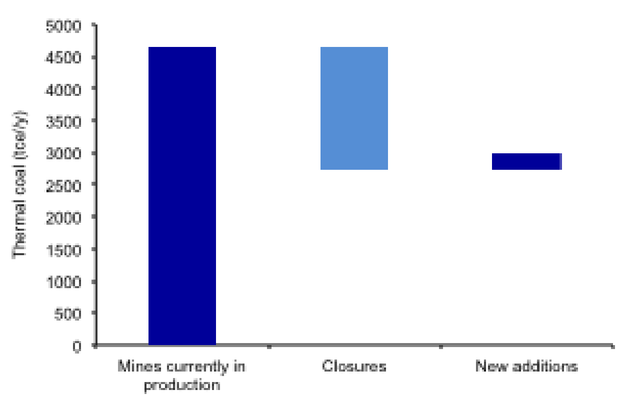
Source: IEA WEO 2016, Wood Mackenzie, Deutsche Bank

Figure 36: Demand for coal vs current base: decline demands early-closures and fights domestic advantage:



Source: IEA WEO 2016, Deutsche Bank

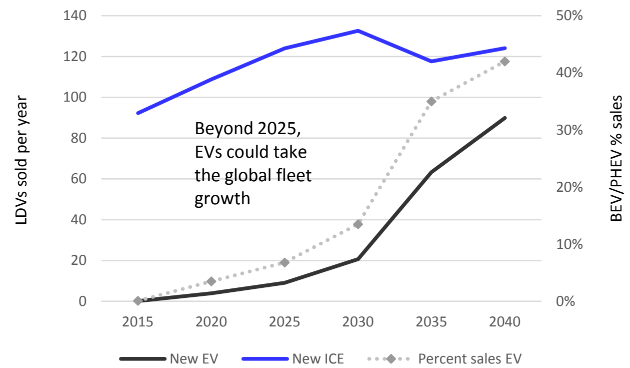
Figure 37: Coal in the Low-path case: significant closures of existing capacity would be required



Source: Deutsche Bank estimates, Wood Mackenzie

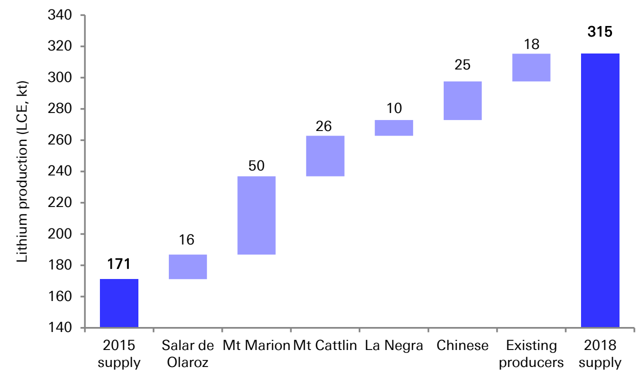
New technologies for efficiency and alternative fuels: disruptive and cheap, but unproven and policy-sensitive

Figure 38: Electric vehicles: simple, efficient – and highly disruptive to existing infrastructure



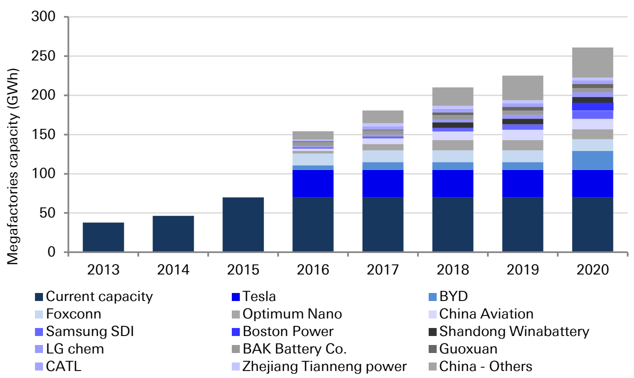
Source: Deutsche Bank estimates, IEA 2016

Figure 39: Lithium mining capacity. With a reserve life > 500yrs, expansion rests on pricing and capital allocation



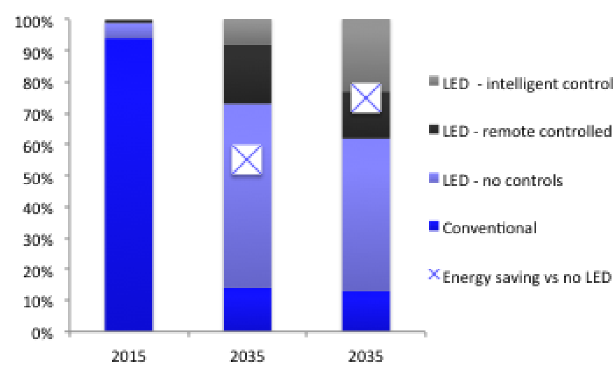
Source: Deutsche Bank estimates

Figure 40: Battery manufacturing capacity is responding worldwide via a disaggregated adoption of innovation



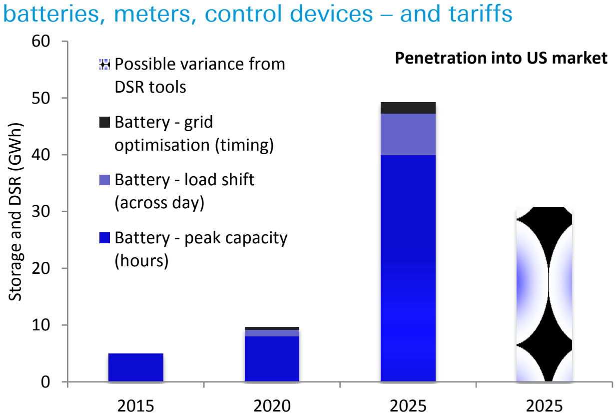
Source: BMI, Deutsche Bank

Figure 41: LEDs: simple, cheap components taking dominant share to yield massive savings



Source: US DOE, Deutsche Bank

Figure 42: Energy storage and demand side response: batteries, meters, control devices – and tariffs



Source: IEA, Cairn ERA, Deutsche Bank

Figure 43: R&D priorities – what do we need next?

- Power: demand side management – controls and incentives
- Ambient temperature – controls, heat pumps, solar thermal
- Control/cyber system security
- Next generation lithium batteries
- Alternative aviation fuels (biofuel, hydrogen)
- Carbon capture and storage (plus biofuel combination)
- Land use: reforestation, crop yields, meat alternatives

Source: Deutsche Bank

Decarbonisation pathway will be bumpy

Sitting in Europe that has long-accepted the principles of the environmental movement, it is all too easy to point to the wave of enabling technologies and believe that a sufficiently low-carbon future is achievable within an acceptable timeframe. In reality, change will be slow and potentially painful. The most difficult obstacles to navigate will be:

- *Carbon pricing*
- *Regulatory reform of power markets*
- *Enabling and encouraging capital*
- *Industry fragmentation and redundancy*
- *Asset stranding*
- *Dealing with the laggards*

Carbon tax/price

The benchmark IEA pathway to almost halve carbon emissions by 2040 and thus generate a 50 per cent chance of limiting warming to less than two degrees this century (the low-path), assumes the steady adoption of high carbon taxes on a near global basis from the late 2020s. By 2040, the assumed rate of $140 per tonne of carbon in 2015 prices is equivalent to $45 per barrel of oil, $7.50 per thousand cubic feet of gas and $300 per tonne of coal (shown relative to actual primary product prices in Figures 43-45). Such additional costs would create huge substitution pressures as well as supporting innovation in carbon capture and biofuel technologies. With no disrespect to the IEA intended, this element of its scenario is given limited prominence. Many within the environmental lobby are similarly reticent.

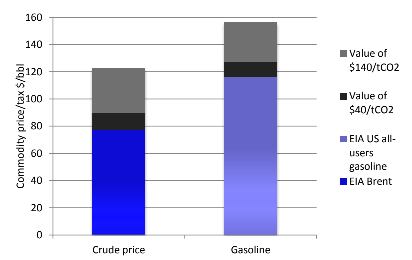
We find it hard to envisage a timely transition to a sufficiently low carbon energy mix without phased fuel prohibition (particularly coal) or an effective, wide-spread carbon pricing regime. Such is the strength of embedded infrastructure and prolific hydrocarbon reserves, that technological change and public efficiency standards alone are almost certain to be too slow to achieve the step-change in fossil fuel contribution illustrated in Figure 46. The more such a lever is delayed, the more abrupt its eventual introduction may prove.

By the book, carbon pricing could be the critical tool for bridging the time gap between the near-term cost of new technologies and the long term payback of saved energy, lower power opex and mitigated climate damage. Many in the oil and mining industries are unexpectedly supportive – preferring the "soft-push" that pricing could give from coal to gas, rather than the "hard-push" of prohibition that could jump straight from coal to renewables, missing out on their leadership in carbon capture and biofuels along the way.

Despite the uninspiring history of many of the schemes in place so far, the corporate and public acceptance of this policy lever is building. Many companies already have "shadow" prices in place, and a steady expansion of the Chinese Emission Trading Scheme through 2017 would be significant. Moreover, given the presence of the apparently pro-carbon price oil lobby in the new Trump Presidency, it will be an interesting paradox if the Republican philosophical opposition to this tool is now overcome.

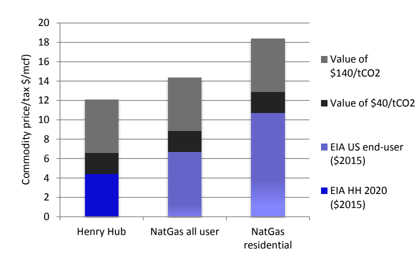
Illustrative impact of $40-$140 price per tonne of carbon on commodity and end-user prices (all 2015$). The substitution effects are huge – especially in coal

Figure 44: *US crude/gasoline at$80 per barrel WTI*



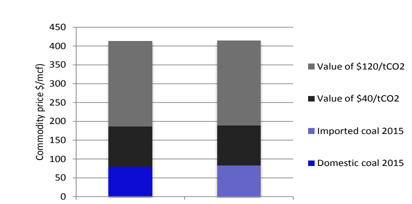
Source: Deutsche Bank

Figure 45: US natural gas at $4.40 per million British Thermal Units Henry Hub



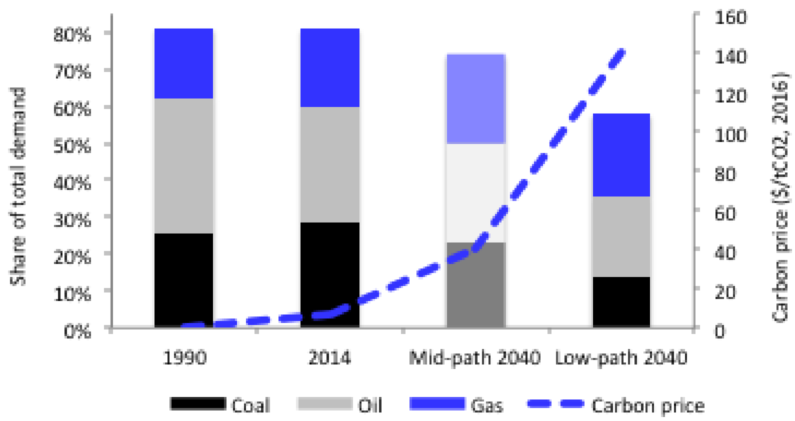
Source: Deutsche Bank

Figure 46: China coal at 2015 actuals



Source: Deutsche Bank

Figure 47: Fossil fuel share of total energy demand: can such significant shifts be achieved without pricing carbon emissions?



Source: Deutsche Bank, IEA WEO 2016

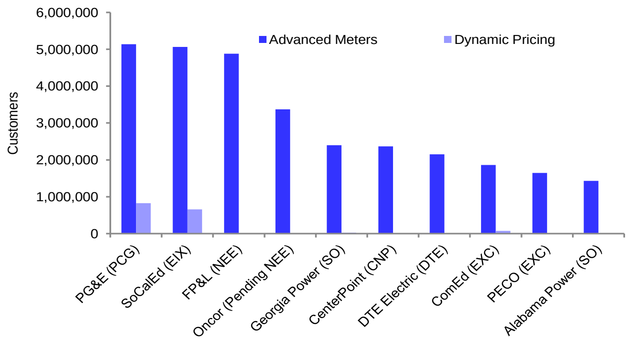
Regulatory reform in power markets

Just as an effective carbon price regime would give certainty to key low-carbon investments, so reform of power sector regulation is critical in many markets. With almost impossible foresight, regulators have to create frameworks to support the winning technologies for value, balance and reliability amongst a highly fragmented set of insurgent technologies.

Renewable power sources are by nature time-variable and need the support of peaking capacity, energy storage and demand-side management. Pricing to the end-consumer needs to recognise the value to the system as a whole, whereas modern trends have been towards temporal lowest marginal cost. We need to sustain (probably gas-fired) peaking capacity at ever-lower rates of utilisation while also encouraging the rapid development of tools that support distributed generation and the shifting of load across the day and even across season.

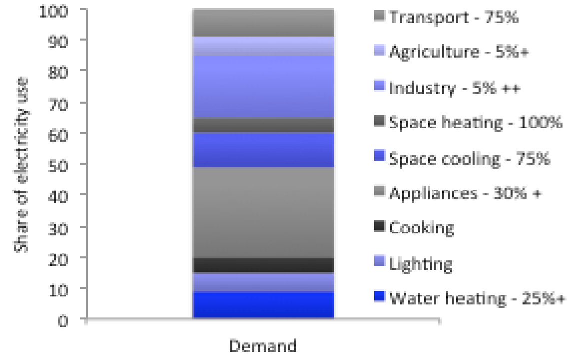
Progress in the installation of advanced metering and controls (Figure 47) now needs to be accompanied by tariffs that reflect peaks in time and location, and returns that encourage efficiency. Both storage and demand response need to be recognised as “capacity” in their own right. Only with experience will we be able to determine the true extent of demand flexibility: could the 2040 prognosis for California shown in Figure 48 be realised?

Figure 48: Advanced meters and dynamic pricing: the tools but not the means (US, December 2015)



Source: Deutsche Bank

Figure 49: Electricity demand: potential to shift by time across the end-uses (example, California 2040)



Source: Deutsche Bank

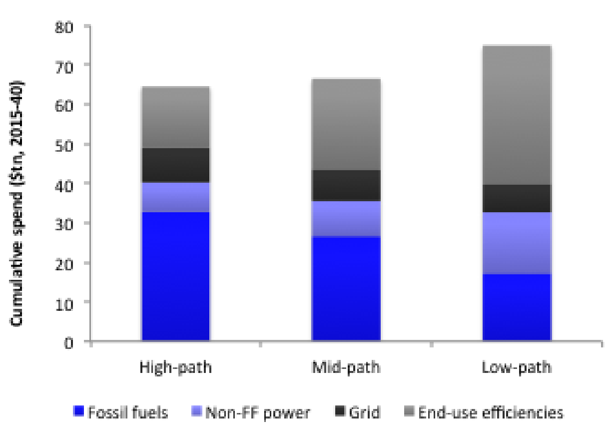
Capital redeployment

Estimates of the capital spend required to fund the energy transition suggest that significant progress can be made without a fundamental increase in total investment. As described in Figure 49, the IEA low-path has overall energy sector investment less than 15 per cent higher than the mid-path – with payback delivered through the lower associated lifetime opex.

Underneath this top line is obviously a significant redeployment in spending. The figures show almost $10tn shifting from fossil fuel supply and power predominantly into non-fossil energy sources (and more into efficiency technologies), with the non-OECD taking an ever-increasing share. On paper the most straight-forward way to achieve the shift is for the energy incumbents to use their existing systems, knowledge and employees to reinvest free cash flows in transition. In reality, there are tremendous institutional barriers to this – not least a perception that the companies have no competence to do so and run the risk of severely diluting near-term returns.

It is in this area more than any other that shareholder engagement needs to accelerate. If, as is most likely, capital continues to seep away from the incumbents, new channels for direct and specialist debt and equity, alongside the management of emerging market risk, must continue to grow.

Figure 50: Potential shifts in the pattern of energy sector investment (2014-2040 total, 2015 dollars)



- Fossil fuels include upstream, downstream and power capacity investment. End-use efficiencies also include electric vehicles
- Capital shifting from incumbents to new, more diverse entities. Investment profiles tending towards smaller, quicker payback versus multi-decade mega-projects (be it oil shales, or solar panels)
- Significant fragmentation in funding sources and investor type - away from public listed equity markets
- Current investment in variable renewables split around 40/60 non-OECD/OECD, by 2030s that could be 75/25. Can capital markets develop to match available capital to implied geographic risks?

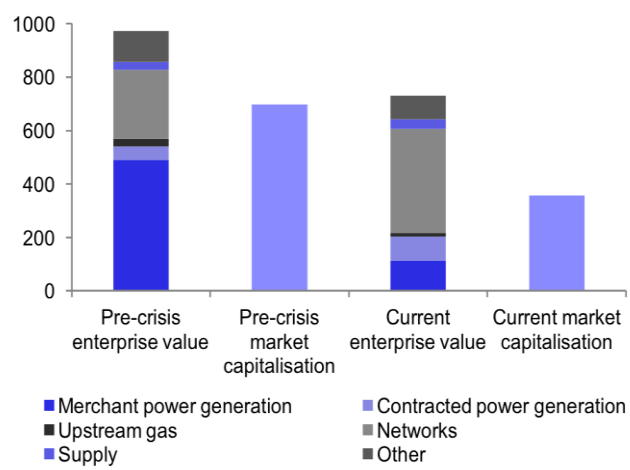
Source: IEA WEO 2016, Deutsche Bank

Industry dynamics: fragmentation and redundancy

Innovation underpins the transition. Many of the new options are shifting from niche to mainstream produced by new entrants and funded by increasingly diverse sources of capital. The ability of many of the technologies to be produced and work on a distributed, small scale basis is allowing outperformance, for example: micro-solar installations bringing access to power without full grid infrastructure; the simplicity of the electric power train enabling multiple producers of two- and four-wheelers to emerge beyond the existing auto giants; the transformative cost and accessibility of LED lighting that could see both market share and power-saving top 75 per cent by the early 2030s. Unreconstructed since at least the early 1970s, the competitive dynamics of the energy industry are changing. Agility is gaining on scale; small, short-term investments are being rewarded over mega, multi-decade ones.

For some incumbents, the results of this fragmentation will be negative. There is the value of lost growth, such as unproduced volume, stranded knowledge and infrastructure, and a rising cost of capital. A response will carry upfront costs as incumbents reconfigure current assets to be productive in the new environment and/or pay high prices to acquire the winning technologies of others. The impact on returns will be complex. Right now the oil majors' oil sand assets and US and EU utilities' fossil-fuel plants (Figure 50) represent a source of write-offs. In the volatile years of transition ahead such assets may well come to represent a source of occasional, but exceptional, future profits.

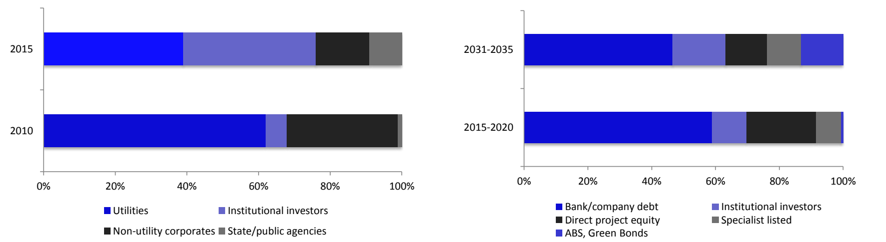
Figure 51: EU utilities: collapsing value of merchant-power generation assets



Source: Deutsche Bank

However, for some existing suppliers the fragmentation of demand represents an opportunity. We can see this in the pricing power of some major capital goods firms and among the producers of commodities such as lithium. It also exists in the financial sector where the direction of large volumes of capital outside the listed capital markets into a myriad of new entrants is creating opportunities for new products at differentiated margins (but also carrying significant risks in terms of disclosures to the capital owner, and the sheer availability of suitably experienced capital allocators). By way of example, the amalgamation of various industry sources generates the following perspective for the evolution of funding sources within EU renewables (Figure 51).

Figure 52: Transition in energy equals transition in funding sources?
Equity in EU wind projects 2010 versus 2015. Possible future funding for variable renewables



- Already strong momentum in alternative funding sources
- Pensions and SWFs with direct debt and equity
- Listed – Yieldcos, MLPs, REITs
- ABS in origination and refinancing

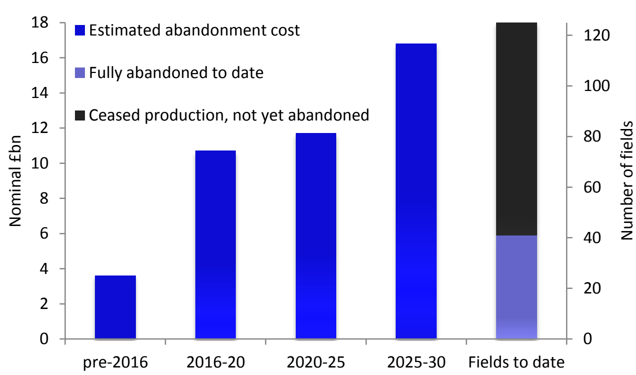
Source: Ceres, BNEF, OECD, Deutsche Bank

While the transition gains momentum from falling barriers to entry, it will make effective regulation and response more challenging in some markets. Regulatory reform and policy actions are needed to create a stable environment, but who will speak for industry? How will policy makers navigate between the draw of competitive markets and the need for security of supply?

While the resistance of the incumbents cannot be allowed to slow progress, there are valid issues around the redundancy of existing assets. We have barely scratched the surface in terms of the closure and abandonment of upstream facilities and downstream refining and processing assets. What are the appropriate remediation requirements? How will the associated costs and potential environmental liabilities be shared between the original owners, opportunistic late-life buyers and the tax payer?

Figure 52 illustrates the current state of play in a series of abandonments we know are coming: the UK North Sea offshore. Even here, experience is limited, the actual process of remediation open for negotiation and the final costs unclear.

Figure 53: North Sea offshore abandonment: with limited actual experience, costs, extent and tax rebates are unclear



- Estimated total abandonment liability currently sits at over $90bn
- Only 30 per cent of fields that have ceased production to date have actually been abandoned
- Tax rebates should cover half the costs – incentivising the government to limit the extent of abandonment – but to what?
- BP, Shell, Exxon account for around a quarter of the future bill – how strong are the others?

Source: Wood Mackenzie, Deutsche Bank

Asset stranding – physical, financial and shocking

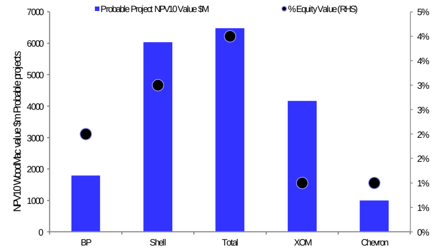
A successful energy transition is going to generate stranded assets. There will be hydrocarbon reserves that we never use and installed plant and machinery that has to close down before the end of its mechanical life. It has long been accepted that a reserve life for thermal coal of more than 120 years is more than necessary. The current reserve to production ratio for proven oil and gas reserves is around 60 years each – also probably excessive. Therefore the key questions for investors are: (1) Is there invested capital behind reserves/assets that will not be produced or used? and (2) Are there entities who may change their behavior in order to capture the remaining ex-growth market to get their reserves out of the ground?

We will return in detail to these issues in our forthcoming sector notes on oil, mining and utilities. In summary, however:

- **Oils**. Using the definition of proven and probable reserves currently assumed to be commercially viable, even the low-path needs the visible profile to be produced out, so we see very limited physical risk. In terms of financial stranding, while we see the potential for further write-downs to book value if (when) the companies cut their long-term oil price assumptions, the overall current 'market values' of the major oils look robust (see Figure 53 for an estimate of unsanctioned project value versus corporate value). A more focused area of risk lies in the potential redundancy of OECD refining assets, and the frontier assets of some smaller companies.
- **Mining**. In coal, the low-path demands significant capacity closure by 2030 – potentially 1,900m tonnes (Figure 54). There is little acceptance of an aggressive decarbonisation transition among the pure-play coal miners, so there is a clear physical and value risk. Among the large, diversified miners only Glencore retains significant exposure.
- **Utilities**. In OECD countries, we have already seen a loss of value for market-based merchant generation (Figure 50). In future, the risk is overbuilding in gas-fired peaking capacity and over-aggressive bids in renewable capacity auctions. The picture could be more dramatic in Asia, particularly China, where full application of the IEA's low-path scenario could imply the closure of a net 240 gigawatts by 2030 of the government target of 1,030 gigawatts of coal capacity for 2020.

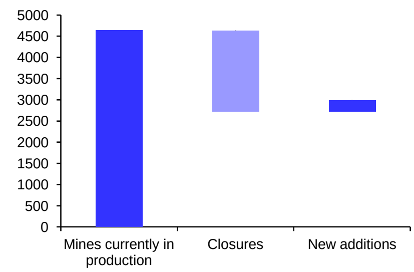
Broader is the issue of changing behavior by the big hydrocarbon nations. This is obvious for Middle Eastern OPEC producers. For example, can Saudi Arabia reduce its social costs sufficiently to drive down oil prices to retain market share? In the Trump-era, we should also consider the stance of the US. Would America protect and encourage its unconventional sector for near-term economic advantage? The same outcomes could apply in gas. Would Russia or Qatar or Iran push for gas market share? Any of these outcomes would fundamentally shift the dynamics of the fossil fuel markets – with unexpected and potentially unexpected shock implications for listed asset values.

Figure 54: WM unsanctioned project NPV10 ($m) and % of equity value



Source: Deutsche Bank, Wood Mackenzie

Figure 55: Coal capacity: potential closures in a 2030 low-path



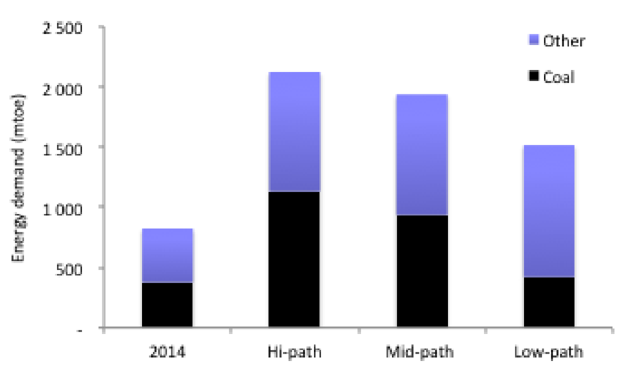
Source: Deutsche Bank, Wood Mackenzie

Laggards that cannot be ignored

There are some key parts of the energy transition process that continue to lag. Many could be resolved by progress in the areas noted above – most notably carbon capture, advanced biofuels and demand side management in power. A few others that strike us include:

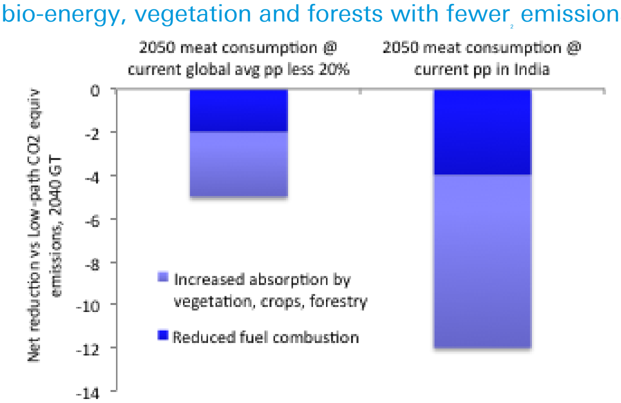
- **India**: Will economic growth accelerate, will it be fossil fuel-fired like China's 2000-10, or will it promote strong renewables growth – and possibly imported gas - over domestic coal reserves (Figure 55)?
- **Technology**: The risk lies in the management of control systems and AI. Both carry the risk of massive security threats and the invasion of personal privacy (see Yahoo, Dyn or the Ukraine national grid). A significant failure is almost inevitable at some point, and it could cause a significant diversion in the steady roll-out of autonomous and control technologies.
- **Land use and the food chain**: A critical source of future abatement and carbon absorption comes from land use, for example reforestation, crop yields and the adaption of diets via meat substitutes. Figure 56 illustrates one estimate of the potential impact of reversing the adoption of a western-style meat-focused diet through to 2050. Increasing vegetable consumption or finding a way to meat/protein substitutes (lab-burgers), could all but offset human-green house gas emissions in 2050. The sheer scale of released land and avoided cattle/sheep populations could be enormous.

Figure 56: India: Energy demand to 2040 – can it restrain energy intensity, can it drive out coal?



Source: IEA, Deutsche Bank, WEO 2016

Figure 57: Food chain: Less meat sees land released for bio-energy, vegetation and forests with fewer emissions



Source: UK Department of Energy and Climate Change, Deutsche Bank

Appendix 1

Important Disclosures

*Other information available upon request

Disclosure checklist

Company	Ticker	Recent price*	Disclosure
EDF	EDF.PA	7.63 (EUR) 23 Mar 17	7,14,15
BP	BP.L	454.49 (GBp) 23 Mar 17	1,7,8,14,15
EDP Renovaveis	EDPR.LS	6.18 (EUR) 23 Mar 17	1,7,14,15
Schneider Electric	SCHN.PA	67.19 (EUR) 23 Mar 17	6,7,8,9,14,15
PG&E Corp	PCG.N	67.54 (USD) 23 Mar 17	6,9,14,15

Prices are current as of the end of the previous trading session unless otherwise indicated and are sourced from local exchanges via Reuters, Bloomberg and other vendors . Other information is sourced from Deutsche Bank, subject companies, and other sources. For disclosures pertaining to recommendations or estimates made on securities other than the primary subject of this research, please see the most recently published company report or visit our global disclosure look-up page on our website at http://gm.db.com/ger/disclosure/DisclosureDirectory.eqsr. Aside from within this report, important conflict disclosures can also be found at https://gm.db.com/equities under the "Disclosures Lookup" and "Legal" tabs. Investors are strongly encouraged to review this information before investing.

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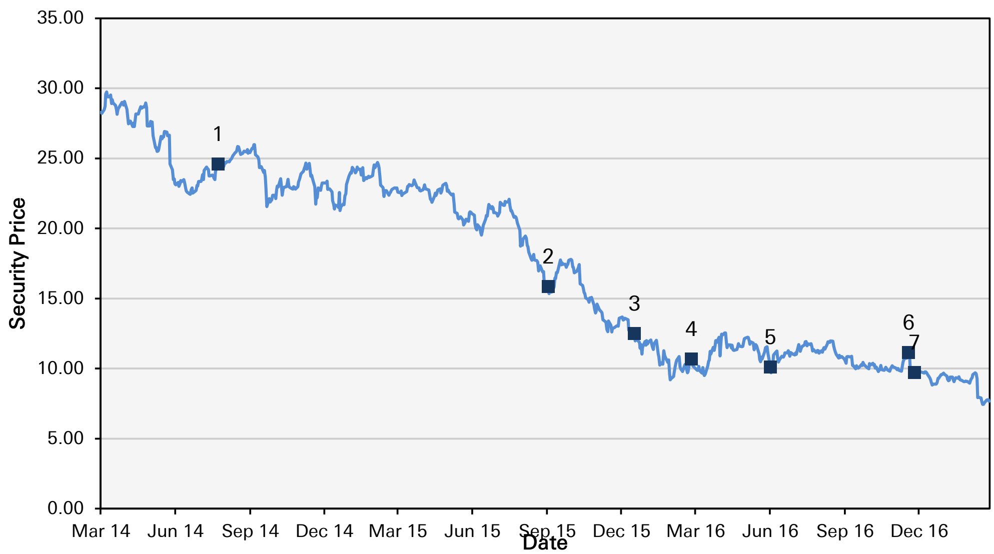
The views expressed in this report accurately reflect the personal views of the undersigned lead analyst about the subject issuers and the securities of those issuers. In addition, the undersigned lead analyst has not and will not receive any compensation for providing a specific recommendation or view in this report. Martin Brough/Lucas Herrmann

Historical recommendations and target price: EDF (EDF.PA)
(as of 3/23/2017)



Previous Recommendations

Strong Buy
Buy
Market Perform
Underperform
Not Rated
Suspended Rating

Current Recommendations

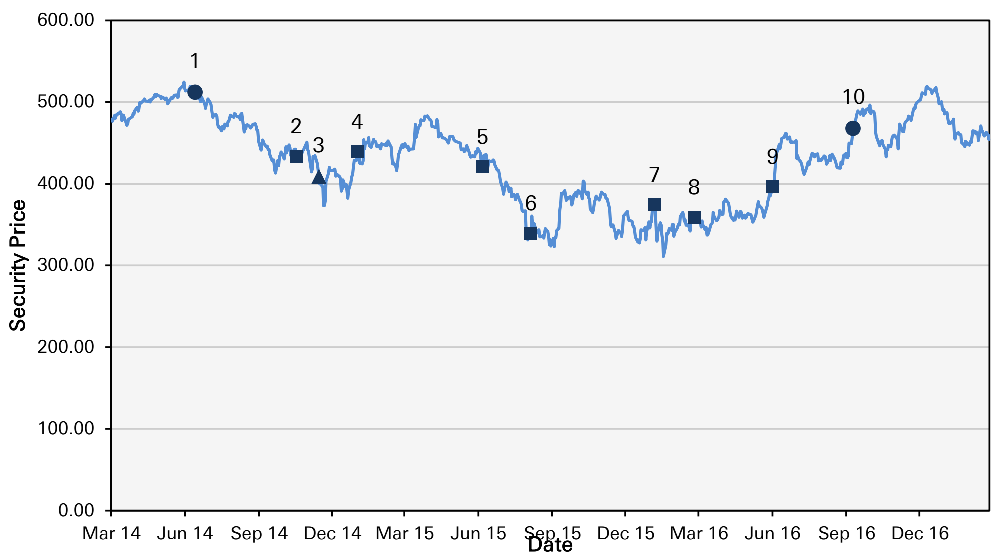
Buy
Hold
Sell
Not Rated
Suspended Rating

*New Recommendation Structure as of September 9,2002

**Analyst is no longer at Deutsche Bank

1.	18/08/2014:	Sell, Target Price Change EUR18.00 Martin Brough	5.	27/06/2016:	Sell, Target Price Change EUR8.00 Martin Brough
2.	28/09/2015:	Sell, Target Price Change EUR14.00 Martin Brough	6.	14/12/2016:	Sell, Target Price Change EUR7.00 Martin Brough
3.	12/01/2016:	Sell, Target Price Change EUR10.00 Martin Brough	7.	21/12/2016:	Sell, Target Price Change EUR6.00 Martin Brough
4.	22/03/2016:	Sell, Target Price Change EUR7.00 Martin Brough			

Historical recommendations and target price: BP (BP.L)
(as of 3/23/2017)



Previous Recommendations

Strong Buy
Buy
Market Perform
Underperform
Not Rated
Suspended Rating

Current Recommendations

Buy
Hold
Sell
Not Rated
Suspended Rating

*New Recommendation Structure as of September 9,2002

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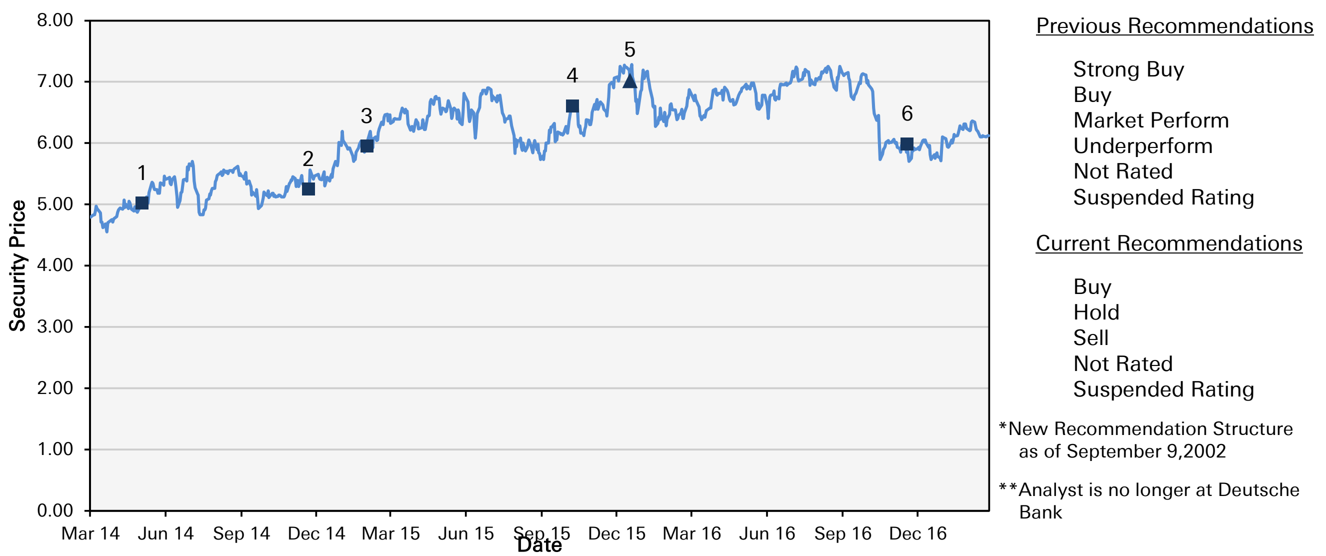
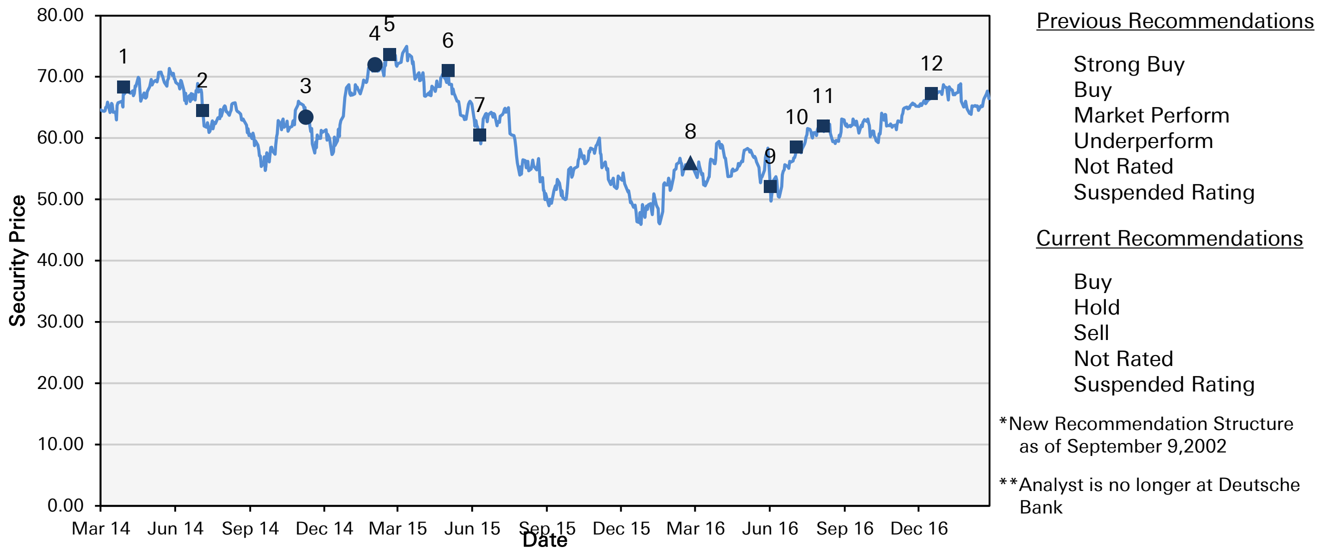
1.	09/07/2014:	Downgrade to Hold, Target Price Change GBP550.00 Lucas Herrmann	6.	31/08/2015:	Buy, Target Price Change GBP450.00 Lucas Herrmann
2.	12/11/2014:	Hold, Target Price Change GBP500.00 Lucas Herrmann	7.	01/02/2016:	Buy, Target Price Change GBP445.00 Lucas Herrmann
3.	10/12/2014:	Upgrade to Buy, Target Price Change GBP480.00 Lucas Herrmann	8.	21/03/2016:	Buy, Target Price Change GBP460.00 Lucas Herrmann
4.	27/01/2015:	Buy, Target Price Change GBP470.00 Lucas Herrmann	9.	27/06/2016:	Buy, Target Price Change GBP485.00 Lucas Herrmann
5.	02/07/2015:	Buy, Target Price Change GBP485.00 Lucas Herrmann	10.	05/10/2016:	Downgrade to Hold, Target Price Change GBP505.00 Lucas Herrmann

Historical recommendations and target price: EDP Renovaveis (EDPR.LS)
(as of 3/23/2017)



1. 29/05/2014: Hold, Target Price Change EUR5.40 Virginia Sanz de Madrid
2. 17/12/2014: Hold, Target Price Change EUR5.50 Virginia Sanz de Madrid
3. 26/02/2015: Hold, Target Price Change EUR6.40 Virginia Sanz de Madrid
4. 03/11/2015: Hold, Target Price Change EUR7.00 Virginia Sanz de Madrid
5. 12/01/2016: Upgrade to Buy, Target Price Change EUR8.00 Martin Brough
6. 14/12/2016: Buy, Target Price Change EUR7.60 Martin Brough

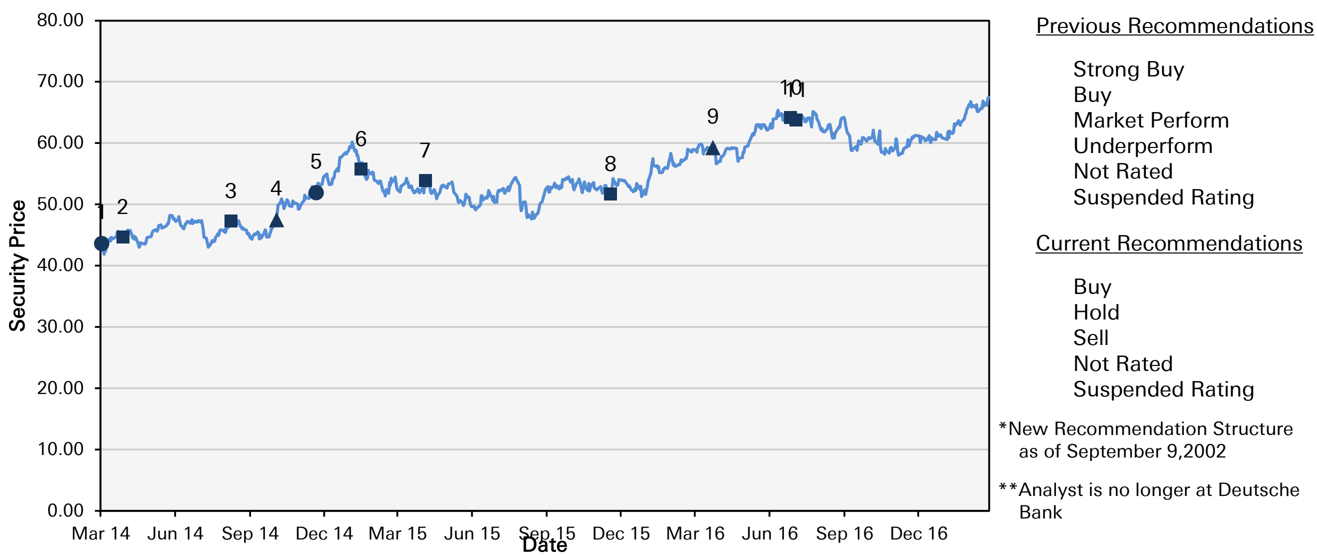
Historical recommendations and target price: Schneider Electric (SCHN.PA)
(as of 3/23/2017)



1.	24/04/2014:	Buy, Target Price Change EUR72.00 Martin Wilkie**	7.	06/07/2015:	No Recommendation, Target Price Change EUR0.00
2.	30/07/2014:	Buy, Target Price Change EUR70.00 Martin Wilkie**	8.	21/03/2016:	Upgrade to Buy, Target Price Change EUR65.00 Gael de-Bray, CFA
3.	04/12/2014:	Downgrade to Hold, Target Price Change EUR63.00 Martin Wilkie**	9.	27/06/2016:	Buy, Target Price Change EUR62.00 Gael de-Bray, CFA
4.	27/02/2015:	Downgrade to Sell, EUR63.00 Martin Wilkie**	10.	29/07/2016:	Buy, Target Price Change EUR65.00 Gael de-Bray, CFA
5.	17/03/2015:	Sell, Target Price Change EUR65.00 Martin Wilkie**	11.	31/08/2016:	Buy, Target Price Change EUR70.00 Gael de-Bray, CFA
6.	28/05/2015:	Sell, Target Price Change EUR61.00 Martin Wilkie**	12.	11/01/2017:	Buy, Target Price Change EUR73.00 Gael de-Bray, CFA

Historical recommendations and target price: PG&E Corp (PCG.N)

(as of 3/23/2017)



1.	28/03/2014:	Downgrade to Hold, USD45.00 Jonathan Arnold	7.	30/04/2015:	Hold, Target Price Change USD56.00 Jonathan Arnold
2.	23/04/2014:	Hold, Target Price Change USD48.50 Jonathan Arnold	8.	14/12/2015:	Hold, Target Price Change USD58.50 Jonathan Arnold
3.	03/09/2014:	Hold, Target Price Change USD49.50 Jonathan Arnold	9.	18/04/2016: Jonathan Arnold	Upgrade to Buy, Target Price Change USD62.00
4.	29/10/2014: Jonathan Arnold	Upgrade to Buy, Target Price Change USD52.00	10.	22/07/2016:	Buy, Target Price Change USD68.00 Jonathan Arnold
5.	17/12/2014: Jonathan Arnold	Downgrade to Hold, Target Price Change USD54.00	11.	29/07/2016:	Buy, Target Price Change USD67.00 Jonathan Arnold
6.	10/02/2015:	Hold, Target Price Change USD55.00 Jonathan Arnold			

Equity rating key

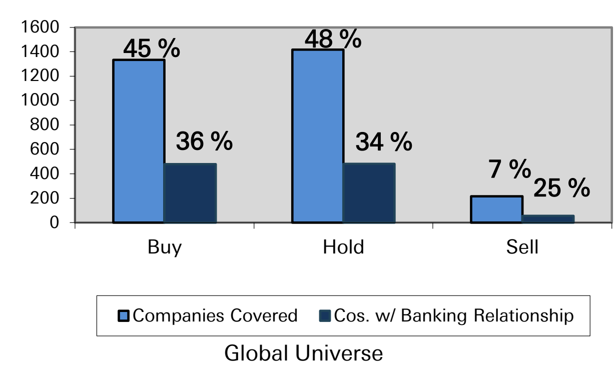
Buy: Based on a current 12- month view of total share-holder return (TSR = percentage change in share price from current price to projected target price plus pro-jected dividend yield) , we recommend that investors buy the stock.

Sell: Based on a current 12-month view of total share-holder return, we recommend that investors sell the stock

Hold: We take a neutral view on the stock 12-months out and, based on this time horizon, do not recommend either a Buy or Sell.

Newly issued research recommendations and target prices supersede previously published research.

Equity rating dispersion and banking relationships



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