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Sustainability

Decarbonisation: The Race to Net Zero

The desire to halt climate change has never been more pronounced. We look at five technologies that offer solutions to decarbonise industry, power and mobility. But it will require $50 trillion of investment and new regulation.

Sustainability

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Contents

Preface

Global greenhouse gas emissions need to be at or around net zero by 2050 in order to halt climate change and achieve the goals outlined in the Paris Agreement. This means we must move from 53.5 Gigatonnes of CO2 equivalent (GtCo2e) annual emissions today to zero by balancing the amount of emissions that are released into the atmosphere with those taken out. But the solutions needed to make this a realistic target continue to be a source of debate.

In this report we focus on five key decarbonisation technologies: Renewables, electric vehicles, hydrogen, carbon capture and storage (CCS), and biofuels. These can help to reduce energy-related carbon emissions, which account for ~62% of total global emissions.

Our 2030 base case suggests we are far from being on track to stay within a 2 degree Celsius scenario. However, there is hope. We outline in this report the level of investment needed in each technology to reach a scenario aligned with the Paris Agreement, and also which we think could be the most successful. Accelerating the adoption of these technologies could remove 25Gt of carbon emissions by 2050.

Renewables power is a key technology in its own right, but also an enabler of others. Decarbonising the production of electricity is the largest opportunity for carbon emission reductions, with a quarter of global emissions released by the power sector. The economics of solar and wind have improved significantly, which will drive growth going forward. Renewable energy is also needed for electric vehicles and hydrogen in order to offer truly green alternatives for many sectors.

The uncomfortable truth is that Carbon Capture & Storage (CCS) has to be part of the solution. Over the next ten years the current outlook suggests coal-fired power generation capacity will increase globally; only CCS can prevent its carbon emissions adding to atmospheric levels. In addition, for industries such as steel, cement and chemicals, there are no easy alternatives to using fossil fuels in certain production processes. Some decarbonisation options are available, such as reducing the amount of clinker in cement, or switching from blast furnaces to electric arc furnaces in steel. But CCS also offers a much needed solution for reducing the carbon intensity of industry.

Hydrogen has huge potential for renewables, industry, mobility and heating. The Hydrogen Council's vision is for hydrogen to account for 18% of final energy demand by 2050. This would imply a tenfold increase in hydrogen demand to 550m tons per year and create an industry with $2.5 trillion of revenues globally. We see the potential for a 'sustainable energy cycle' involving hydrogen, renewables and fuel cells.

Biofuels will fill a gap where other technologies cannot replace diesel and gasoline based mobility. In the short term, this means passenger cars. However, in the longer term, aviation, shipping and road freight should all increase their use of renewable fuels.

We estimate that $50 trillion will need to be invested in these technologies over the next 30 years. This implies an annual investment of $1.6 trillion, which is roughly the same as the amount of capital invested in the US during 2017 across all sectors of the economy.[1] With potentially $3-10 trillion of EBIT up for grabs, decarbonisation could present a material economic opportunity for companies and investors that choose to allocate capital to these key areas of growth.

The autos sector is a case study in unpopular decisions driving change. The passenger car is decarbonising, at great cost to global auto manufacturers. Decisive action taken by European governments and regulators demonstrates the impact that can be created when the desire to change the trajectory of an industry is put before short-term economic returns.

When, not if: the direction of travel for the introduction of a 'global' carbon tax seems clear. Momentum behind radical action on climate change is gathering pace, with global protests and the EU President-elect proposing carbon border adjustments. In the US, Democratic presidential candidates are incorporating environmental proposals in their key policy statements. The aspiration seems clear, and investing in low carbon technology reduces the potential cost of paying a higher – and fairer – price for carbon emissions.

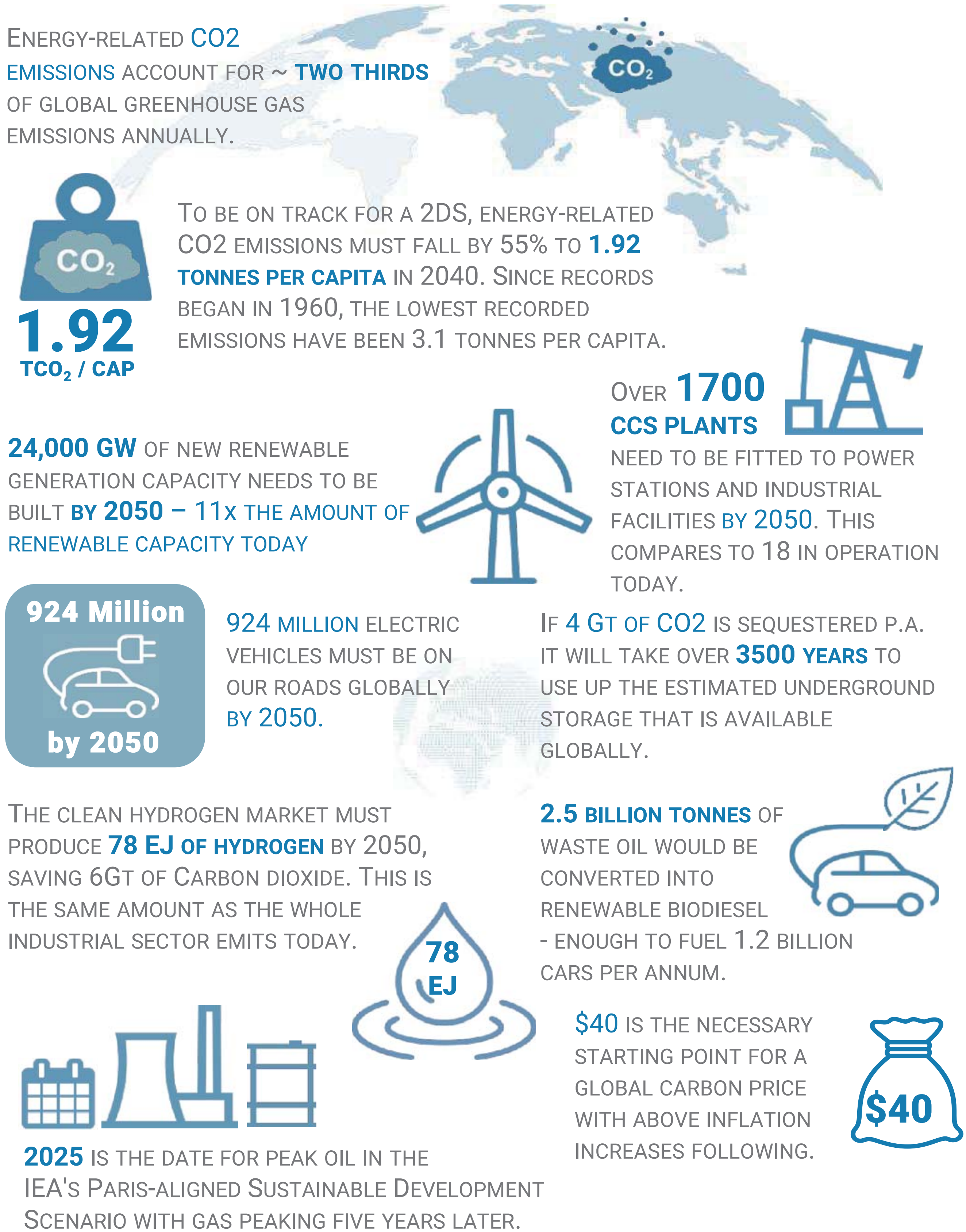
Failure to act on climate change could result in catastrophic flooding, wildfires, mass migration, and destruction of biodiversity. If the social and environmental consequences are not sufficient to drive capital towards technology solutions, then consider that going beyond a 2 degree Celsius scenario could result in a loss of up to 7% of GDP by 2100.

This report brings together the expertise and insights of more than 50 analysts and economists covering eleven sectors and over $10 trillion market cap of listed equities globally. We highlight 118 companies offering a decarbonisation solution and 33 focus stocks that are rated Overweight by Morgan Stanley analysts.

1 Source: US Census Bureau Capital Spending Report

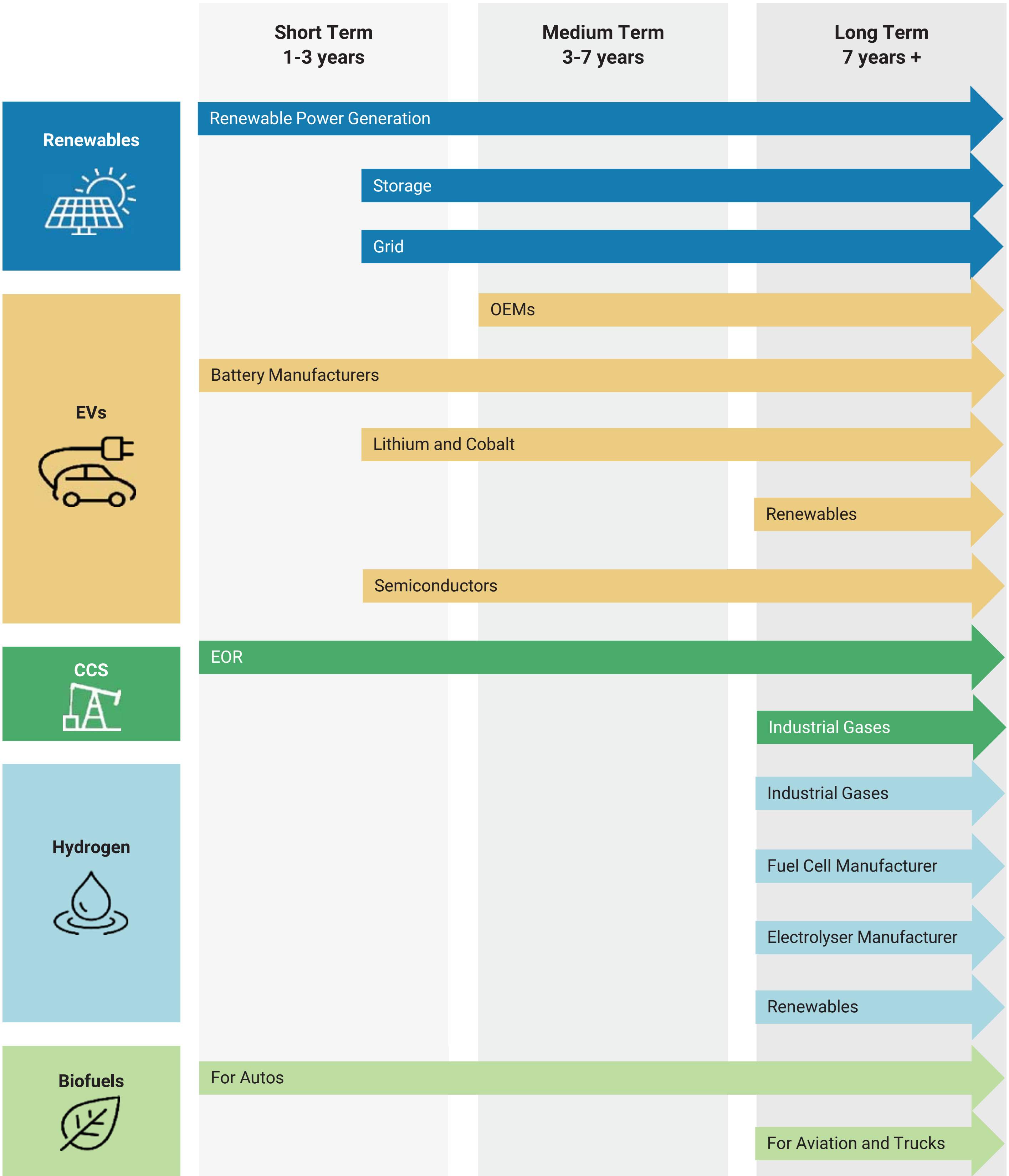
Exhibit 1:

Achieving the Paris Agreement targets: Decarbonisation in numbers



Source: Morgan Stanley Research

Exhibit 2:
Investment opportunities over the short, medium and long term



Source: Morgan Stanley Research

Focus stocks

We have identified 33 stocks that all offer ways to play the decarbonisation theme and are also rated Overweight by Morgan Stanley analysts. As such we believe they present attractive investment opportunities on a 12- to 18-month view. For a longer list of 118 companies exposed to the decarbonisation technology theme please see page 18.

Exhibit 3:

Our focus stocks offer solutions for reducing carbon emissions and are rated Overweight by MS analysts

Ticker	Company name	Analyst (Primary)	Technology
AIRP.PA	Air Liquide	Webb, Charles	Hydrogen, CCS
300073.SZ	Beijing Easpring Material Technology Co	Lu, Jack	Electric Vehicles
BE.N	Bloom Energy Corp.	Byrd, Stephen	Renewables, CCS
1811.HK	CGN New Energy Holdings	Lee, Simon	Renewables
3993.HK	China Molybdenum	Zhang, Rachel	Electric Vehicles
0836.HK	China Resources Power	Lee, Simon	Renewables
0956.HK	China Suntien Green Energy Co., Ltd.	Lee, Simon	Renewables
CPFE3.SA	CPFL ENERGIA	Rodrigues, Miguel	Renewables
DAIGn.DE	Daimler	Hendrikse, Harald	Electric Vehicles
ENEI.MI	ENEL	Scaglia, Anna Maria	Renewables
EXC.O	Exelon Corp	Byrd, Stephen	Renewables
2208.HK	Goldwind	Hou, Eva	Renewables
IBE.MC	Iberdrola SA	Sitbon, Arthur	Renewables
020150.KS	Iljin Materials	Kim, Ryan	Electric Vehicles
JMAT.L	Johnson Matthey	Webb, Charles	Electric Vehicles, Hydrogen
051910.KS	LG Chem Ltd	Shin, Young Suk	Electric Vehicles, Energy Storage
MIN.AX	Mineral Resources Limited	Anand, Rahul	Electric Vehicles
NESTE.HE	Neste Corporation	Chilukuru, Sasikanth	Biofuels
NEE.N	NextEra Energy Inc	Byrd, Stephen	Renewables
NXPI.O	NXP Semiconductor NV	Hettenbach, Craig	Electric Vehicles
6752.T	Panasonic	Ono, Masahiro	Energy Storage
003670.KS	Posco Chemical Co Ltd.	Kim, Ryan	Electric Vehicles
PRY.MI	Prysmian S.p.A.	Carrier, Lucie	Renewables
PEG.N	Public Service Enterprise Group Inc	Byrd, Stephen	Renewables
6963.T	Rohm	Yoshikawa, Kazuo	Electric Vehicles
006400.KS	Samsung SDI	Kim, Shawn	Energy Storage
SMTO3.SA	Sao Martinho SA	Martinez de Olcoz Cerdan, Javier	Biofuels
603659.SS	Shanghai Putailai New Energy Tech Co Ltd	Lu, Jack	Electric Vehicles
SIEGn.DE	Siemens	Uglow, Ben	Renewables
SSE.L	SSE	Ho, Timothy	Renewables
STM.PA	STMicroelectronics NV	Olszewski, Dominik	Electric Vehicles
TPIC.O	TPI Composites Inc.	Ellison, Ethan	Renewables, Electric Vehicles
002812.SZ	Yunnan Energy New Material Co Ltd	Lu, Jack	Electric Vehicles

Source: Morgan Stanley Research

Executive Summary

"Human beings are the greatest problem-solvers our planet has ever known. We are just yet to apply ourselves to this problem with the scale and urgency it requires." —*Sir David Attenborough, Davos 2019.*

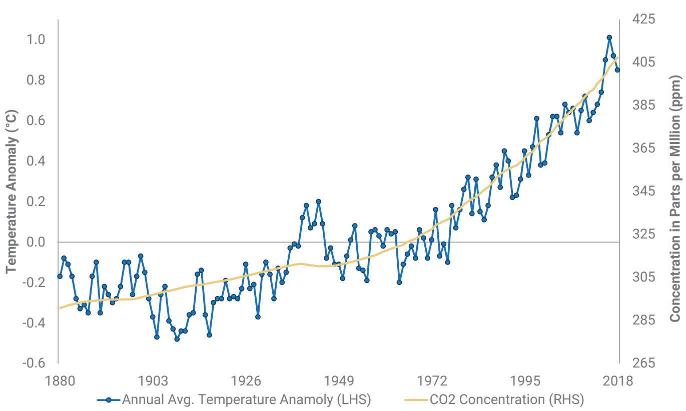
The Challenge of Climate Change

Climate change has arrived. CO2 emissions stand at the highest levels in human history, reaching 53.5 GtCo2e p.a. in 2017.[2] Driven by a number of human-made factors, chiefly broader industrialisation and the burning of fossil fuels, rising emissions have brought a steady increase in global temperatures. Relative to the average from 1951 through 1980, 18 of the 19 warmest years on record have occurred since 2001, with 2018 0.8° C (1.44° F) above the average.

The number of extreme weather events is climbing, wildlife habitats are shifting, glaciers are retreating and sea levels are rising. The effects of climate change are here today, disrupting livelihoods and causing billions of dollars of economic damage.

Exhibit 4:

These material increases in atmospheric CO2 concentrations have coincided with higher temperature anomalies



Source: NASA, NOAA, Morgan Stanley Research

2 Source: UN Environment Emissions Gap Report, 2018

Conditions will worsen under the current trajectory of carbon emissions. An additional 1.5 billion people will inhabit the planet by 2040 – some 20% more than in 2018.[3] With carbon emissions per capita expected to continue edging upwards, energy sources will account for total annual emissions of 42Gt by 2040, nearly a third higher than today.[4] And this will bring unparalleled disruption. The effects of climate change are a key focus of debate: studies suggest it could spawn the mass migration of up to 200 million people globally over the first half of this century[5], an additional 1 billion people could be at risk of infectious diseases[6], while 20-30% of species may face extinction.[7]

Climate change could subtract $10-20 trillion from global GDP by 2100. Academic studies have tried to quantify the economic impact of climate change using multiple approaches. A survey of the recent literature suggests that the economic losses due to climate change could affect anywhere between 3-7% of global GDP over the long term. (For more detail, see **The Economic Consequences of Climate Change**.)

A realistic chance of keeping the rise in temperature below 2° C requires net zero emissions by midway through the 21st century. This ambitious goal was enshrined in the 2015 Paris Agreement adopted by nations around the world. Numerous paths lead to net zero, although none are straightforward. The agreement commits countries to reduce carbon emissions significantly in order to limit global temperature increases to 1.5°-2° C above pre-industrial levels.

3 Source: UN Population Division

4 Source: IEA's current policy scenario

5 Source: National Geographic, January 24, 2019

6 Climate Change Raises Risk of Infectious Disease; Sizing the Impact on Biopharma (23 Jul 2019)

7 Source: WWF: The Effects of Climate Change

"In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to ***achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century****, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty."* (Article Four of the Paris Agreement)

What is net zero?

To reach net zero, any greenhouse gas emissions produced must be offset by taking emissions out of the atmosphere. It is more realistic than a gross zero target but still extremely ambitious.

Clear opportunities to reduce emissions exist, such as through more renewable power generation, a transition to electric vehicles, and development of biofuels. However, for some sectors, emissions reduction is simply not viable, whether due to cost, technical complexities or a lack of alternatives.

Examples of negative emissions include planting trees to absorb CO2 or incorporating carbon capture and storage into carbon intensive industrial processes.

Five Technologies to Decarbonise Energy

The good news is that multiple technologies offer solutions to reduce energy-related carbon emissions. In 2017, energy accounted for ~33GT of CO2e or c.60% of total emissions. (Agriculture, land use change & forestry, industrial processes and waste are responsible for the remaining emissions.) In this report, we focus on five technologies that offer viable means to cut energy-related emissions significantly: (1) renewable power, (2) electric vehicles, (3) carbon capture and storage (CCS), (4) hydrogen and (5) biofuels. In the chapters that follow we explore the decarbonisation opportunity offered by each technology. We also consider the level of investment required to be on track for sufficient adoption, whether government policy is supportive, and finally we outline focus stocks that offer a way to play this theme. In subsequent chapters, we look at how decarbonisation is impacting the fossil fuel sector, economic consequences of climate change, implications for green financing, and consider the issue of a 'just transition'.

Our analysis considers what level of adoption of each technology is needed by 2050 to be on track to meet the Paris Agreement and stay within a '2DS scenario', and what the capital investment thus needed may be.

Decarbonisation: Two scenarios

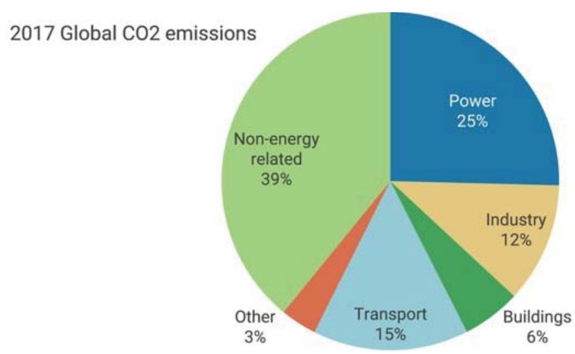
In this report we consider two different scenarios for the adoption of five decarbonisation technologies: Renewables, EVs, CCS, Hydrogen and Biofuels.

Base case: Our bottom up analysis calculates the level of adoption of each technology that is likely by 2030 and the impact this will have on global emissions. For renewable power and electric vehicles, we leverage estimates from our global Utilities and Autos teams. The MS Sustainability team has created new estimates for hydrogen, biofuels and CCS penetration.

2DS aligned: We analyse the amount of investment needed in the 5 technologies for the world to be on track to meet the Paris Agreement and goal of reaching net zero emissions by mid-way through the current century. For power generation, EV penetration, the volume of biofuels and installation of CCS capacity we have used the IEA's Sustainable Development Scenario as a starting point (see the Appendix for more details). For hydrogen, we follow the assumptions outlined in the Hydrogen Council's 2017 publication 'Hydrogen: Scaling Up'.

Exhibit 5:

Energy-related emissions account for ~60% of global carbon emissions



Source: IEA, IPCC

Renewables

Renewable power is the cornerstone of decarbonisation. Power generation produces a quarter of all global carbon emissions, as coal, oil and gas still make up ~65% of electricity generation. In our calculations to be on track for a 2 degree Celsius scenario, renewables need to deliver ~80% of global power generation in 2050, which will require over 11,000 GW of additional renewable capacity (ex hydropower) over the next 30 years. Incremental renewable power is also needed for electric vehicles and hydrogen to truly offer a low carbon solution for mobility and industry; we estimate these two technologies will need another 12,000 GW of incremental power by 2050.

Since the turn of the century, ~2,600 GW of renewable generation capacity has been installed globally. Renewables together account for 37% of global power generation capacity (2019e) compared to 25% in 2000. Over the next decade we expect strong growth in renewables, driven by improving economics. To date, **solar** has been the smallest source of renewable power after hydro and wind, but rapidly improving economics position it to be the fastest growing technology over the coming decade, with capacity increasing at a 13% CAGR (MSe). We see a strong growth outlook for **wind**, driven primarily by compelling wind energy economics across emerging and incumbent markets. Rapid improvements in technology have made wind the lowest cost form of energy in many markets. **Hydropower** has dominated renewable and/or energy generation due to its relatively low cost in some regions, including China and Brazil, and will continue to play an important role in achieving climate change goals.

The penetration of renewable power generation needed to stay within a 2 degree Celsius scenario will require $14 trillion of investment by 2050, on our estimates. We assume incremental renewable capacity (ex Hydro) of ~3,500 GW by 2030 (vs 2017) and ~11,000GW by 2050, with capital expenditure ranging from $0.9m to $3.3m per MW.

Electric Vehicles

In reality, electric vehicle (EV) technology is relatively new, with just over 5m [8] battery EVs sold globally in 2018. However, concerns around air pollution as well as climate change have helped to accelerate investment, with the internal combustion engine unlikely to meet strict combined CO2 and nitrogen oxide (NOx) targets. Cars currently account for c 7% of global greenhouse gas emissions. We have no doubt that the transition to EVs is underway, with regulation making it nearly impossible to meet tighter carbon emission standards without significant battery EV penetration, especially in Europe and China. As VW CEO Herbert Diess said in his VW Annual Roundup 2017, "Economically meaningful measures to lower CO2 have been exhausted… The EU is planning new, challenging targets for fleet emissions. That means: we need electric vehicles to meet fleet targets". Our autos analysts think meeting the FY2030 European CO2 target requires battery EV penetration of at least 30-35% of European sales.

MS forecasts 113 million EVs globally by 2030 and 924 million by 2050. To reach this level requires significant growth in sales from ~1.3mn units in 2018 (1.5% penetration) to 23.2mn in 2030 (23.7%). The growth in EVs that we forecast over the next decade will have only a marginal impact on power consumption, but our 2050 projection could result in incremental electricity capacity close to the current level in the US – and this would need to be renewable power. In addition, network management must improve significantly. **To fully build out the required global infrastructure to support electric vehicles, we forecast $11 trillion of total expenditure through 2050,** or $350bn p.a.

Carbon Capture and Storage

CCS is needed to fully decarbonise the industrial and power generation sectors. While renewables will reduce the carbon intensity of the power industry, fossil fuel power generation will not disappear completely. Over 200,000 MW of new coal-fired generation capacity is currently under construction globally [9] and CCS is the only option for decarbonising these plants. It will also enable gas power stations (probably needed for grid stability) to be carbon neutral. Regarding the industrial sector, certain processes in the steel and cement industry need fossil fuels, and CCS is one of the few options available for removing the emissions from these activities.

CCS projects require protracted project timelines and high upfront capital expenditure. We believe this will hinder private investment without strong government incentives or public-private partnerships. To make CCS attractive to investors long term, national-level policies need to incentivise emission reductions and put a price or credit on emissions avoided and stored. The IEA estimates that an incentive of $40 per ton of CO2 would enable the commercialisation of 450 MT of carbon for permanent geological storage. [10]

8 Source: IEA: Global EV Outlook 2019

9 Source: The Global Status of CCS 2018, Global CCS Institute

10 Source: The Global Status of CCS 2018, Global CCS Institute

Fulfilling the potential of CCS under a 2 degree scenario would require upfront capital investment of ~$2.5 trillion by 2050. We estimate the current cost of CCS to be ~$711mn per million tonnes per annum (Mtpa) of captured carbon. We would expect the cost of building CCS plants to reduce over time, and assume a 15% decline by 2040 and 30% by 2050.

Hydrogen

Clean hydrogen (produced using either CCS or renewable power) offers a material opportunity to reduce carbon emissions in industry, which so far has struggled to find clean alternatives to many of the processes needed in steel and cement, for example. Green hydrogen can also help manage electricity grid stability as more renewable energy comes on line, and can be used for heating and cooling as well. There is also an opportunity for hydrogen in mobility, although we question whether infrastructure for both EVs and fuel cell vehicles will be built for the passenger car sector.

From grey to blue to green: Today, most hydrogen is produced from fossil fuels (mainly methane from natural gas). This can be either merchant hydrogen (produced in a central industrial plant and distributed to customers) or captive hydrogen (produced by the consumer on site). However, there is growing interest in the ability to produce hydrogen using low carbon techniques. Blue hydrogen is produced by separating hydrogen from methane, with carbon dioxide as a by-product, which is then captured and stored. Green hydrogen requires the use of renewable energy to power the process of water electrolysis.

The Hydrogen Council aims for hydrogen to account for 18% of final energy demand by 2050. This would imply a tenfold increase in hydrogen demand (to 550mn tons a year), and create an industry with $2.5 trillion of revenues globally (from hydrogen and equipment). To achieve this will require more active government support to incentivise investment in infrastructure and reduce the cost of clean energy needed for the production process.

To reach the 2050 target, ~$5.4 trillion would need to be invested in electrolysers. In addition, significant investment in renewable power generation capacity would be required to ensure the hydrogen produced is green. We estimate this would require $13 trillion of investment in new capacity by 2050 (or $400bn a year).

Other investment would be needed for infrastructure, such as storage, transportation and distribution, including an estimated $1 trillion for storage.

Biofuels

Biofuels will be an effective transition fuel for light road vehicles over the coming decades to reduce the carbon intensity of the remaining combustion engines. Aviation could potentially take over as a key use for this clean fuel once electric vehicles become the main form of passenger car transport.

There are three generations of biofuels. The first generation is produced using food crops. Naturally occurring vegetable oils such as starch, sugarcane, soy beans, maize, corn, canola and others make this feedstock neither sustainable nor green due to its impact not only on land and water usage but also on the food supply if it were produced at scale. Second generation biofuels are produced using non-food feedstocks such as waste, wood, animal fats, grasses and inedible parts of plants. The third generation is derived from algae.

We estimate that ~4% of global transportation fuels will come from biofuels in 2030. Our estimates suggest that by 2030, the hydrotreated vegetable oil biodiesel market will reach 20 M/t, while the rest of the biodiesel market will grow volumes at a 4% CAGR and the ethanol market will grow at a 3% CAGR, in line with 5-year historical growth rates. The choice of feedstock will greatly affect the decarbonisation potential of both ethanol and biodiesels. First generation feedstocks have higher emissions, particularly when we take into account their indirect emissions, which are calculated looking at the indirect land use change (ILUC).

Building sufficient biofuels capacity to be aligned with a 2DS will require an investment of ~$2.7 trillion by 2050. This assumes that aviation and road freight rapidly increase the adoption of biofuels in addition to further penetration of passenger road vehicles.

Exhibit 6:

The 5 decarbonisation technologies offer solutions for a number of sectors

	% global emissions	Renewables	EVs	CCS	Hydrogen	Biofuels
Power	26%	●		●	●	
Transport	15%	●	●		●	●
Industry	12%	●		●	●	
Buildings	6%				●	

Source: IEA, Hydrogen Council, Morgan Stanley Research

Counting the cost… and returns

Together, these five technologies could cut global carbon emissions by ~9Gt by 2030 and over 25Gt by 2050 to help ensure we are on track to achieve the Paris Agreement goals. There is no one route to a 2 degree Celsius scenario, and our analysis aims to show the potential that these technologies offer and the amount of investment that is needed over the next 30 years. For power generation, EV penetration, the volume of biofuels and installation of CCS capacity we have used the IEA's Sustainable Development Scenario, which is aligned with the Paris Agreement, as a starting point. For hydrogen we follow the Hydrogen Council's 2017 publication 'Hydrogen: Scaling Up'.

We estimate this effort will require $50 trillion of capital investment by 2050. This equates to an investment of roughly $1.6 trillion annually for the next 20 years. To contextualise this, Bloomberg's New Energy Finance estimates that global clean energy investment totalled only $332 billion in 2018. Our projections of the capital each technology will require are outlined in **Exhibit 7** . We note that the OECD estimates $6.9 trillion of annual investment in infrastructure is needed to 2030[11] , while the IPCC forecasts that it would cost ~ $2.4 trillion p.a. between now and 2035 to keep the rise in temperature to 1.5 degrees. [12] These estimates are not comparable to our forecasts as we have limited the scope of our analysis to five technologies.

11 Source: OECD: Green Finance and Investment

12 Source: The Economist: Conquering carbon dioxide, November 29, 2018

Exhibit 7:

Key assumptions and resulting emissions from the adoption of 5 key decarbonisation technologies in alignment with a 2 degree Celsius scenario

	2018	2020	2030	2040	2050
Renewables					
CO2 emissions Gt	13.6	12.9	7.8	3.3	2.2
Renewables % power generation	25%	29%	49%	66%	79%
Emissions reduction vs 2017 (Gt)			5.7	10.3	11.4
Electric Vehicles					
% of passenger car stock	0.6%	0.8%	14.5%	30%	67%
Emissions reduction vs 2017 (Gt)			0.5	0.9	2.2
CCS					
Power MtCO2	2.4	2.4	350	1488	1763
Industry MtCO2	0.8	0.8	500	1600	2200
Emissions reduction vs 2018 (Gt)			0.8	3.1	4.0
Hydrogen					
Hydrogen supply EJ	8	10	14	28	78
Emissions reduction vs 2018 (Gt)			1.2	2.3	6.0
Biofuels					
Mtoe	88	97	280	351	995
Emissions reduction vs 2018 (Gt)			0.5	0.5	1.7

Source: IEA, Hydrogen Council, Global CCS Institute, Morgan Stanley Research

Exhibit 8:

Cumulative costs for adopting the decarbonisation technologies in alignment with a 2 degree Celsius scenario (2DS)

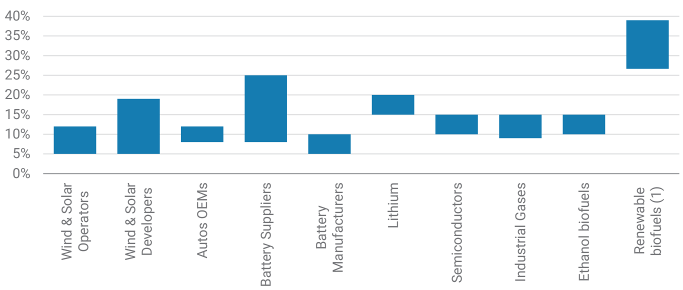
$bn	2030	2040	2050
Renewables	4,272	8,845	14,033
EVs	1,852	4,639	10,990
CCS	583	2,056	2,538
Hydrogen	3,394	6,940	19,843
Biofuels	750	936	2,653
Total	10,850	23,416	50,058

Source: IEA, Hydrogen Council, Global CCS Institute, Morgan Stanley Research

Exhibit 9:

There is an opportunity to generate attractive returns on the required $50 trillion of investment

Unlevered ROCE

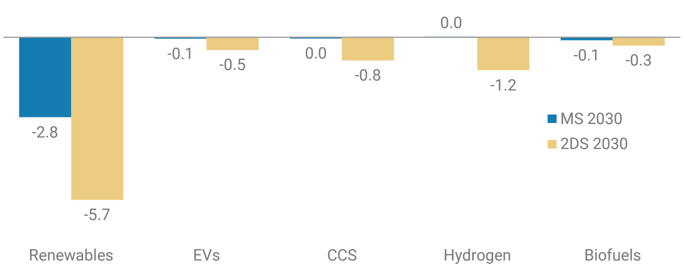


Note: Current ROCE achieved by the companies within each sector. (1) This estimate is based upon analysis on Neste's biofuel only. Source: Morgan Stanley Research estimates

Exhibit 10:

Our base case forecasts suggest that in 2030 we will not be sufficiently on track with key decarbonisation technologies

Increase/ (decrease in CO2 emissions by 2030 (Gt)



Source: IEA, Hydrogen Council, Global CCS Institute, Morgan Stanley Research

While the headline capex numbers are significant, there is an opportunity to generate attractive returns. We see potential for $3-10 trillion of incremental EBIT assuming a 5-15% post-tax ROCE (Exhibit 9) on the $50 trillion of invested capital.

In Exhibit 9 we outline the range of post-tax returns on capital that could be generated in the various sectors providing decarbonisation solutions. For some, there is already a good opportunity to generate attractive returns. For example, in electricity, NextEra in the US has been generating levered returns on onshore wind in the mid-teens to 20%, while Orsted highlights a 7.5-8.5% unlevered IRR (whole of life) on its next vintage of offshore wind projects. In biofuels, Neste is already generating returns of over 50% (returns on net assets pre-tax) for its renewable products. In other industries, such as autos, the transition to electric vehicles will be a headwind for the OEMs that need to invest for future growth. Hydrogen is a much longer term opportunity, as outlined by the investment time horizon diagram in Exhibit 2 . For CCS, this is currently just a cost for the majority of companies that could adopt the technology, but the economics would change overnight should a much higher carbon price be implemented.

Current trajectory dampens hope

However, our base case assumptions for these five technologies suggest we are not on track for this to be achieved. To reach net zero in 2050 and beyond, we need to see meaningful change in the next decade. Yet, in the four years since the Paris Agreement, little has changed in terms of explicit regulation to drive decarbonisation towards the net zero target. By 2030, we expect energy-related emissions to have only fallen by 3Gt compared to the 7Gt needed to be on track for a 2DS.

We are confident in the long-term EV trajectory, but the carbon savings won't be seen by 2030. We expect that the passenger road vehicle will be electrified, with regulation making it impossible to reach CO2 and NOx targets with the existing combustion engine. However, over the next decade we believe growth in EVs will be insufficient to offset the increase in miles driven per ICE (as the growing global fleet of cars and shared mobility will take share from public transport). In addition, the electricity required to power the EVs will need to come from renewable sources, and this transition will take time.

Decarbonisation of power generation needs to accelerate. We expect similar growth in demand to the IEA's Sustainable Development Scenario or SDS (~1.5% CAGR). However, we anticipate a slower rate of power decarbonisation, with the average emissions per TWh falling from 0.53Mt/ TWh to 0.35Mt/TWh in our 2030 scenario compared to 0.25Mt/TWh in the SDS. We expect fewer coal capacity closures and less new solar and wind capacity based on existing policy.

CCS must form part of any decarbonisation strategy, but we are conservative given the policy outlook. Based on current policy, costs and planned projects it looks nearly impossible to achieve the 2DS-aligned target of 850Mt of CO2 by 2030. We assume just 9% of this carbon reduction is achieved by 2030.

Exhibit 11:

Key assumptions for MS' base case and 2DS aligned scenarios in 2030

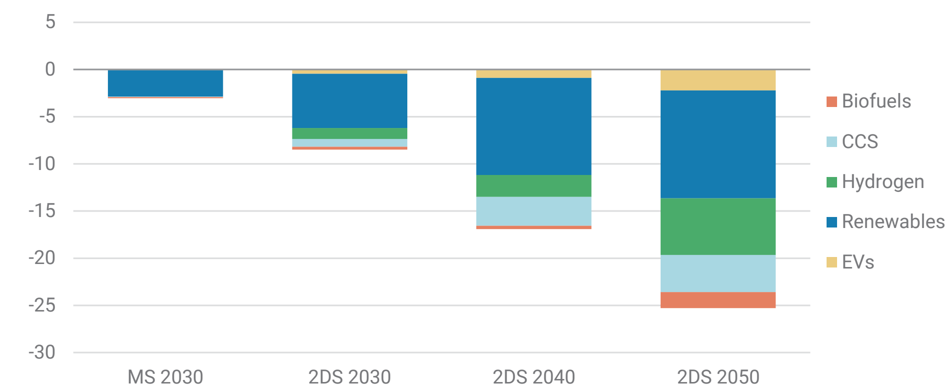
	MS 2030	2DS 2030
Renewables	Carbon intensity falls to 0.35 CO2 per Twh (-34% vs 2017)	Carbon intensity falls to 0.25 CO2 per Twh (-52% vs 2017)
EVs	8.5% of total passenger road vehicles	14.5% of total passenger road vehicles
CCS	78 Mt of CO2 captured	850 Mt of CO2 captured
Hydrogen	2 million tonnes of clean hydrogen	98 million tonnes of clean hydrogen
Biofuels	136 Mtoe of biofuels	280 Mtoe of biofuels

Source: IEA, Hydrogen Council, CCS Institute, Morgan Stanley Research

Exhibit 12:

Our analysis of the 5 technologies suggests minimal impact on carbon emissions by 2030

Increase/ (decrease) in CO2 emissions vs 2017 (Gt)



Source: IEA, Hydrogen Council, CCS Institute, Morgan Stanley Research

Policy Must Find a Higher Gear

To get decarbonisation on track to reach net zero, we need to see an acceleration on the policy front. In broad terms, more regulation is needed either to incentivise the development and adoption of low carbon options or to disincentivise the high carbon incumbents. Governments haven't broadly embraced the specific target of net zero emissions, but we are seeing some commitments at the national and state levels. In June, the UK adopted a net zero emission target for 2050 [13] following in the footsteps of Finland (2035) and Norway (2030). In California (the world's fifth-largest economy), former Governor Jerry Brown signed an executive order committing the state to carbon neutrality by 2045, while 12 US cities have made a similar pledge.

Over the last year the likelihood of more ambitious climate policy has improved significantly. Awareness and concern about climate change amongst the general population is growing, driven by more frequent extreme weather, media coverage and action by protest groups. According to a December 2018 poll in the US [14] , 69% of respondents were somewhat or very concerned by climate change.

In Europe, 43% of respondents cited "combating climate change and protecting the environment" as a concern compared to 35% a year ago. [15] Elsewhere, the CEO of SAS commented earlier this year that he thought "flight shaming" was behind the decline in Swedish air traffic during the first quarter of 2019. [16]

In Europe, the EC's President-elect, Ursula von der Leyen, has announced intentions to create a climate plan. This includes legislation to achieve carbon neutrality by 2050, the introduction of a green border tax, and the creation of a fund to advance a 'just transition'.

In the US, the 2020 candidates offer different perspectives on the climate agenda. While the current administration withdrew the country from the Paris Agreement, the majority of Democratic candidates have made climate change a key element of their policy agendas, whether through commitments to rejoin the Paris Agreement, phase out fossil fuels or reach net zero greenhouse gas emissions.

13 Source: The Guardian, June 11, 2019

14 Source: Climate Change in the American Mind, December 2018

15 Source: Bloomberg, June 26, 2019: How Climate Change is Viewed Around the World

16 Source: The Telegraph, May 31, 2019

Possible options for climate policy

Subsidise new technologies until they become cost competitive. Renewable energy provides a good example. In the US, federal subsidies for renewable energy (including biofuels for transportation use) were ~$15 billion p.a. in FY 2010 and FY 2013. They have helped drive the transition, with the amount of renewable energy increasing from 9% in 2000 to 17% in 2017. Subsidies are now falling ($6.7 billion in fiscal year 2016), but the cost of renewable energy generation and storage technology has declined to a point where our US Utilities analyst expects that in many regions, solar and wind are likely to remain the most economic choice for new generation, even after federal tax credits sunset later this decade (see Renewable Energy: What Cheap, Clean Energy Means for Global Utilities).

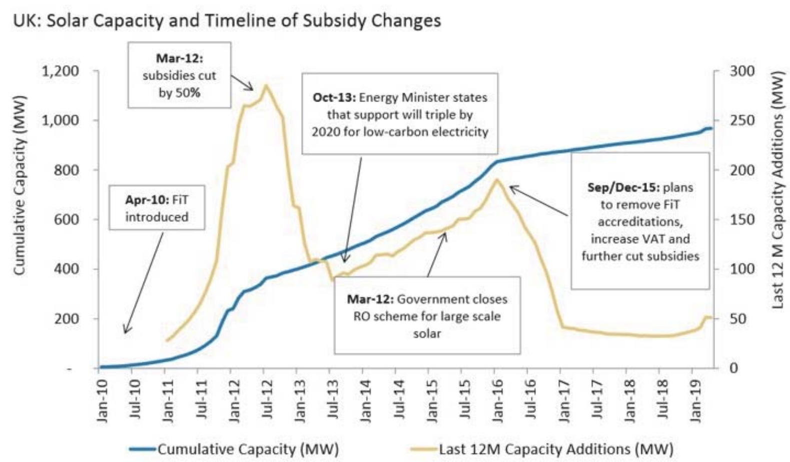
Elsewhere, as **Exhibit 13** shows, the introduction and subsequent withdrawal of subsidies for solar power in the UK had a clear impact on capacity additions.

In China, sharp cuts in national NEV subsidies and the elimination of local NEV subsidies caused the first YoY sales decline for EVs since January 2017 (**Exhibit 14**).

However, while there are examples of subsidies working, the challenge with using this approach for all decarbonisation technologies is the impact on fiscal budgets. Global public debt levels are currently at 73% of GDP, almost close to the peak of 75% of GDP. Elevated levels of public debt will likely be a constraint for governments to lift public investment to deal with climate change, over and above the cyclical challenge of managing the cycle.

Exhibit 13:

Subsidies have been a key driver of solar capacity additions in the UK

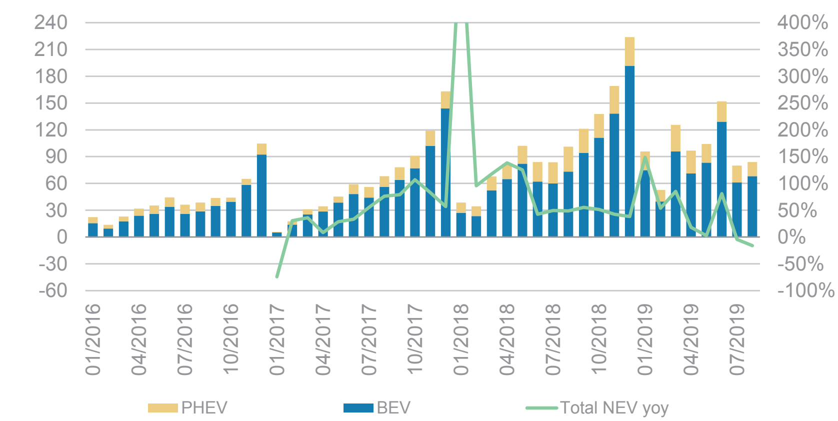


Source: BEIS, Morgan Stanley Research

Exhibit 14:

NEV monthly sales in China

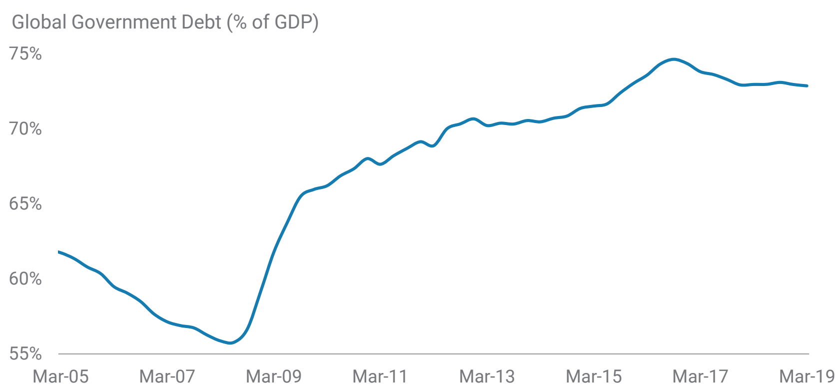
(k units)



Source: CAAM, Morgan Stanley Research

Exhibit 15:

Elevated global government debt may limit the ability of governments to subsidise decarbonisation technologies



Source: BIS, CEIC, Haver Analytics, IMF, national sources, Morgan Stanley Research

Limit use of the high carbon options. Restricting the use of carbon-intensive technologies is another route to decarbonisation, as seen in the auto industry. The last three years has witnessed a steady shift towards making it difficult and unappealing to drive ICE vehicles. CO2 emissions standards continue to tighten, with Europe leading the way (95g/km by 2020, 60g/km by 2030) and China following suit with a few years' time lag. Annual road taxes are heavily skewed against higher CO2 vehicles, and CO2 pricing will further raise fuel prices for ICE, making BEVs relatively more affordable. Low emission zones are now legislated in many European cities such as Hamburg, London, Paris and Amsterdam. While in theory cars with combustion engines can still be driven in such areas, in reality the OEMs have indicated that engineering is reaching its limit, and in fact electric cars offer the best solution for cutting carbon emissions in road passenger vehicles.

Internalise the real cost of carbon. According to the World Bank, there are currently 51 different carbon pricing schemes globally, all focused on domestic emissions. Former World Bank chief economist Nicholas Stern thinks a carbon tax of $40-$80/t by 2020 would be required to reach the goals of the Paris agreement [17] , which suggests that the majority of carbon pricing projects globally are currently too low. In line with Mr Stern, the IEA estimates that a carbon tax of $40/t of CO2 would, for example, enable the commercialisation of around 450 MT of CCS. Former US Federal Reserve Chair Janet Yellen similarly advocates a $40/t carbon tax. [18] Mr Stern suggests that this tax should rise to $50-$100 by 2030. More recently, the IMF has estimated that a global carbon tax of $75 per ton by 2030 would be necessary to limit the planet's warming to 2C. [19]

Green borders – a global solution? Even if the price of carbon rose enough to be effective, the other issue is the domestic focus of carbon regulation. To succeed, carbon regulation must be global. The current domestic focus ignores the contribution of individual nations to a global emissions problem, partly driven by the relocation of industrial production to regions with a more coal-based energy mix. It also either increases the risk of carbon-intensive industries relocating to countries with less punitive climate policies, or reduces the effectiveness of any carbon tax by providing free carbon allowances to industries with a high risk of carbon leakage. We argue that a material domestic carbon price plus a green border adjustment is needed. Indeed, in the US, the Climate Leadership Council has proposed a four-pillar plan for carbon pricing. This includes a border carbon adjustment in addition to an economy-wide carbon fee starting at $40 a ton (in 2017 dollars) and increasing every year at 5% above inflation. For more details see Green Borders: Tax and Dividends for a Low Carbon Economy. Earlier this month, the nominee for the EU's economic and tax commissioner, Paolo Gentiloni, indicated there may be an acceleration of plans to introduce carbon border adjustments. Reuters quoted Mr Gentiloni saying: "We will try to be very quick and effective on a carbon border tax," and added that work will begin to make sure such a tax would align with rules from the World Trade Organisation. For more information please refer to Sustainability: EU Signals Move Towards Green Borders (October 3, 2019).

Decarbonisation Beneficiaries

Our analysts have identified 118 companies that have exposure to our five technologies. Some of these companies are already generating attractive returns and cash flow from decarbonisation technologies, while others are at the early stage of development but could benefit from future adoption.

17 Source: LSE press release, December 12, 2017

18 Source: The FT, February 17, 2019

19 Source: The Independent, October 10, 2019

Executive Summary

118 companies exposed to the five key decarbonisation technologies

Ticker	Company name	Analyst (Primary)	Stock rating	Share price		Technology
RENEWABLES						
UTILITIES						
AES.N	AES Corp.	Byrd, Stephen	Equal-Weight	16.13	USD	Targeting 70% reduction in emissions intensity by 2030 vs 2016
TIET11.SA	AES Tiete Energia SA	Rodrigues, Miguel	Equal-Weight	11.55	BRL	Focused on renewables growth; no fossil fuels exposure
AY.O	Atlantica Yield Plc	Byrd, Stephen	Equal-Weight	23.95	USD	Owns and manages a diversified portfolio of contracted assets in power generation and transmission
AEE.N	Ameren Corp	Byrd, Stephen	Equal-Weight	75.72	USD	Midwest Utility where wind economics are favourable
AEP.N	American Electric Power Co	Byrd, Stephen	Equal-Weight	92.60	USD	Midwest Utility where wind economics are favourable
1811.HK	CGN New Energy Holdings	Lee, Simon	Overweight	1.02	HKD	China renewable utility
0916.HK	China Longyuan Power Group	Lee, Simon	Equal-Weight	4.01	HKD	China renewable utility
0836.HK	China Resources Power	Lee, Simon	Overweight	9.51	HKD	Coal power company increasing investment in renewables
0956.HK	China Suntien Green Energy Co., Ltd.	Lee, Simon	Overweight	2.26	HKD	China renewable utility
CWEN.N	Clearway Energy Inc	Byrd, Stephen	Equal-Weight	19.40	USD	Wind, solar and gas plant owner and operator
CMS.N	CMS Energy Corp	Byrd, Stephen	Equal-Weight	63.54	USD	Midwest utility with favourable wind economics
ED.N	Consolidated Edison Inc	Byrd, Stephen	Underweight	90.84	USD	Wires-only utility with need to increase capex to modify the grid
CPFE3.SA	CPFL ENERGIA	Rodrigues, Miguel	Overweight	31.85	BRL	Exposed to renewables through its subsidiary (23% of EBITDA 2018)
0991.HK	Datang Int'l Power	Lee, Simon	Equal-Weight	1.58	HKD	Coal power company increasing investment in renewables
D.N	Dominion Energy Inc	Byrd, Stephen	Equal-Weight	81.80	USD	Southeast Utility investing in solar and gas infrastructure
DUK.N	Duke Energy Corp	Byrd, Stephen	Equal-Weight	95.13	USD	Southeast Utility investing in solar and gas infrastructure
EDF.PA	EDF	Sitbon, Arthur	Equal-Weight	9.31	EUR	6.8GW in Renewables capacity (24 GW including hydro); majority of company is nuclear
EIX.N	Edison International	Byrd, Stephen	Equal-Weight	69.84	USD	Predominately wires-only utility with need to increase capex to modify the grid
EDP.LS	EDP Energias de Portugal SA	Ho, Timothy	NAV	3.59	EUR	82.6% stake in EDPR; plans to invest into renewables
EDPR.LS	EDP Renovaveis	Ho, Timothy	NAV	9.69	EUR	Renewable pure play
ENEI.MI	ENEL	Scaglia, Anna Maria	Overweight	6.81	EUR	39GW of renewables; plans for close to 4GW new installations p.a
ENIC.N	Enel Chile	NC	NC	NA	NA	Growth in renewable capacity; targeting a coal-free mix
ENGIE.PA	ENGIE	Sitbon, Arthur	Equal-Weight	15.01	EUR	3.3 GW of renewables capacity (16 GW including hydro); plans for 9 GW of gross additions by 2021
EGIE3.SA	Engie Brasil	Rodrigues, Miguel	++	43.31	BRL	Reducing exposure to fossil fuel by selling coal fired plants
ETR.N	Entergy Corp	Byrd, Stephen	Equal-Weight	116.04	USD	Southeast Utility investing in solar and gas infrastructure
ES.N	Eversource Energy	Byrd, Stephen	Equal-Weight	84.58	USD	Wires only utility with need to increase capex to modify the grid, and unregulated clean energy business
EXC.O	Exelon Corp	Byrd, Stephen	Overweight	44.91	USD	Competitive merchant generation businesses with low carbon intensities
600027.SS	Huadian Power Int'l	Lee, Simon	Underweight	3.68	CNY	Coal power company increasing investment in renewables
600011.SS	Huaneng Power	Lee, Simon	Equal-Weight	5.82	CNY	Coal power company increasing investment in renewables
0958.HK	Huaneng Renewables	Lee, Simon	Equal-Weight	2.95	HKD	China renewable utility
IBE.MC	Iberdrola SA	Sitbon, Arthur	Overweight	9.16	EUR	16.6GW (29 GW including hydro) of installed capacity with 20GW pipeline to 2030
NEE.N	NextEra Energy Inc	Byrd, Stephen	Overweight	229.91	USD	Targeting 67% reduction in CO2e intensity levels by 2025 vs 2005
NEP.N	NextEra Energy Partners LP	Byrd, Stephen	Equal-Weight	51.17	USD	Wind, solar and gas plant owner and operator
ORSTED.CO	Oersted A/S	Ho, Timothy	Equal-Weight	629.60	DKK	Growth targets of 30GW+ onshore and offshore wind by 2030
PEGI.O	Pattern Energy Group Inc	Byrd, Stephen	Equal-Weight	26.13	USD	Wind and solar asset owner and operator
PEG.N	Public Service Enterprise Group Inc	Byrd, Stephen	Overweight	61.78	USD	Competitive merchant generation businesses with low carbon intensities
RWEG.DE	RWE AG	Ho, Timothy	Equal-Weight	27.44	EUR	9.1GW capacity, with growth plans; transitioning out of fossil fuels
SRE.N	Sempra Energy	Byrd, Stephen	Equal-Weight	144.85	USD	Wires-only utility with need to increase capex to modify the grid
SO.N	Southern Company	Byrd, Stephen	Underweight	61.09	USD	Southeast utility investing in solar and gas infrastructure
SSE.L	SSE	Ho, Timothy	Overweight	1,305.50	GBp	4GW of renewables assets; pipeline of new growth projects
XEL.O	Xcel Energy Inc	Byrd, Stephen	Equal-Weight	63.49	USD	Targeting 80% reduction in CO2e emission levels by 2030 vs 2005

Ticker	Company name	Analyst (Primary)	Stock rating	Share price		Technology
RENEWABLES						
EQUIPMENT MANUFACTURERS						
FSLR.O	First Solar Inc	Byrd, Stephen	Equal-Weight	55.01	USD	Designs and manufactures solar modules
GE.N	General Electric Co.	Pokrzywinski, Joshua	Equal-Weight	8.90	USD	Wind turbines for onshore and offshore platforms and support services
2208.HK	Goldwind	Hou, Eva	Overweight	9.36	HKD	Global provider of comprehensive wind power solutions
NEXS.PA	Nexans S.A.	Carrier, Lucie	Equal-Weight	34.06	EUR	Manufactures and sells an extensive range of cables and cabling systems
PRY.MI	Prysmian S.p.A.	Carrier, Lucie	Overweight	20.41	EUR	Operates in the cables and systems industry
SENG.DE	Senvion	NC	NC	0.09	EUR	Wind turbine manufacturer for onshore and offshore installations
SIEGn.DE	Siemens	Uglow, Ben	Overweight	100.72	EUR	Exposed to renewables via its ownership of Siemens Gamesa
SPWR.O	SunPower Corp	Byrd, Stephen	Underweight	9.28	USD	Vertically integrated solar products and services company
002531.SZ	Titan Wind Energy Suzhou Co Ltd	Hou, Eva	Equal-Weight	6.71	CNY	Production distribution of wind towers and wind power components
TPIC.O	TPI Composites Inc.	Ellison, Ethan	Overweight	18.99	USD	Manufactures composite wind blades
VWS.CO	Vestas Wind Systems A/S	Uglow, Ben	Equal-Weight	524.00	DKK	Leading provider of onshore wind turbines services globally
RENEWABLE STORAGE						
300750.SZ	Contemporary Amperex Technology Co. Ltd.	Lu, Jack	Equal-Weight	69.69	CNY	Batteries for energy storage systems and EVs
051910.KS	LG Chem Ltd	Shin, Young Suk	Overweight	304,000	KRW	Lithium-ion batteries for energy storage systems and EVs
006400.KS	Samsung SDI	Kim, Shawn	Overweight	220,000	KRW	Rechargeable batteries for industries including energy storage systems
096770.KS	SK Innovation Co Ltd	Shin, Young Suk	Equal-Weight	162,500	KRW	Battery division manufactures lithium-ion batteries for the EV industry
TSLA.O	Tesla Inc	Jonas, Adam	Equal-Weight	259.75	USD	Powerwall product is a battery for storing excess renewable energy generated
OTHER						
BE.N	Bloom Energy Corp.	Byrd, Stephen	Overweight	2.95	USD	Designs, manufactures and sells solid-oxide fuel cell systems
HASI.N	Hannon Armstrong	Byrd, Stephen	Equal-Weight	28.30	USD	Debt and equity financing to energy efficiency, wind, and solar projects
LANDI.S	LANDIS GYR GROUP AG	Uglow, Ben	Underweight	90.20	CHF	Market leader in smart electric metering worldwide
NEW.AX	New Energy Solar Ltd	Koh, Rob	Equal-Weight	1.24	AUD	Externally-managed pure-play renewables investment fund
RUN.O	Sunrun Inc	Byrd, Stephen	Equal-Weight	16.94	USD	Dedicated residential solar company

Ticker	Company name	Analyst (Primary)	Stock rating	Share price		Technology
ELECTRIC VEHICLES						
OEMS						
DAIGn.DE	Daimler	Hendrikse, Harald	Overweight	48.80	EUR	Targeting 15-25% of sales from EVs by 2025
TSLA.O	Tesla Inc	Jonas, Adam	Equal-Weight	259.75	USD	Pure play EV manufacturer; plus battery storage
7203.T	Toyota Motor	Mineshima, Kota	Underweight	7,383	JPY	Targeting 5.5m annual BEV/PHEV by 2030
VOWG_p.DE	Volkswagen	Hendrikse, Harald	Equal-Weight	169.78	EUR	2-3m EV sales by 2025 (>25% sales)
BATTERY MATERIAL SUPPLIERS						
300073.SZ	Beijing Easpring Material Technology Co	Lu, Jack	Overweight	22.77	CNY	Cathode material for lithium-ion batteries
086520.KQ	Ecopro Co Ltd	Kim, Ryan	Equal-Weight	18,650	KRW	Core cathode materials and lithium cells for EVs
4217.T	Hitachi Chemical	Watabe, Takato	Equal-Weight	3,540	JPY	Functional materials for the electronics industry
020150.KS	Iljin Materials	Kim, Ryan	Overweight	36,550	KRW	Elecfoils which are a key component of EV batteries
JMAT.L	Johnson Matthey	Webb, Charles	Overweight	2,995	GBp	Developing a battery technology platform
066970.KQ	L&F Co Ltd	Kim, Ryan	Underweight	21,950	KRW	NCM cathode materials (80% of revenues)
600884.SS	Ningbo Shanshan Co. Ltd.	Lu, Jack	Underweight	10.56	CNY	Lithium battery cathode materials, anode materials, electrolytic solutions
003670.KS	Posco Chemical Co Ltd.	Kim, Ryan	Overweight	43,000	KRW	Integrated EV battery supplier
603659.SS	Shanghai Putailai New Energy Tech Co Ltd	Lu, Jack	Overweight	49.35	CNY	Lithium battery anode materials, battery coating machines
UMI.BR	Umicore SA	Webb, Charles	Underweight	36.31	EUR	Active materials for cathodes in EV batteries
002812.SZ	Yunnan Energy New Material Co Ltd	Lu, Jack	Overweight	33.01	CNY	Separators for EVs batteries
BATTERY MANUFACTURERS						
1211.HK	BYD Company Limited	Hsiao, Tim	Underweight	38.30	HKD	Researches, develops and manufactures rechargeable batteries
300750.SZ	Contemporary Amperex Technology Co. Ltd.	Lu, Jack	Equal-Weight	69.69	CNY	Batteries for energy storage systems and EVs
002074.SZ	Guoxuan High-Tech	Lu, Jack	Equal-Weight	12.28	CNY	Manufactures lithium-ion batteries
051910.KS	LG Chem Ltd	Shin, Young Suk	Overweight	304,000	KRW	Lithium-ion batteries for energy storage systems and EVs
6752.T	Panasonic	Ono, Masahiro	Overweight	907	JPY	Businesses include automotive lithium-ion batteries
006400.KS	Samsung SDI	Kim, Shawn	Overweight	220,000	KRW	Rechargeable batteries for industries including energy storage systems
096770.KS	SK Innovation Co Ltd	Shin, Young Suk	Equal-Weight	162,500	KRW	Battery division manufactures lithium-ion batteries for EVs
SEMICONDUCTORS						
ADI.O	Analog Devices Inc.	Hettenbach, Craig	Equal-Weight	110.59	USD	Sells battery management systems (BMS) into EVs
CREE.O	Cree	NC	NC	46.42	USD	Products include silicon carbide for EVs
IFXGn.DE	Infineon	NC	NC	16.29	EUR	Electric powertrain components
MXIM.O	Maxim Integrated Products Inc.	Hettenbach, Craig	Equal-Weight	57.75	USD	Sells battery management systems (BMS) into EVs
NXPI.O	NXP Semiconductor NV	Hettenbach, Craig	Overweight	108.61	USD	Sell battery management systems (BMS) into EVs
6963.T	Rohm	Yoshikawa, Kazuo	Overweight	8,910	JPY	SiC technology
STM.PA	STMicroelectronics NV	Olszewski, Dominik	Overweight	19.42	EUR	SiC technology
LITHIUM						
ALB.N	Albemarle Corporation	Andrews, Vincent	Underweight	67.58	USD	Vertically integrated company within lithium and lithium derivatives
MIN.AX	Mineral Resources Limited	Anand, Rahul	Overweight	12.73	AUD	Two long-life hard rock lithium mines
ORE.AX	Orocobre Ltd.	Anand, Rahul	Equal-Weight	2.35	AUD	Global lithium company
GXY.AX	Galaxy Resources Ltd	Anand, Rahul	Equal-Weight	0.93	AUD	Global lithium company
002460.SZ	Ganfeng Lithium Co. Ltd.	Zhang, Rachel	Underweight	22.01	CNY	Operates across the lithium value chain
SQM.N	Sociedad Quimica y Minera de Chile S.A.	Martinez de Olcoz Cerdan, Javier	Equal-Weight	27.92	USD	Lithium Carbonate (cathode material in lithium-ion batteries)
MINING						
3993.HK	China Molybdenum	Zhang, Rachel	Overweight	2.53	HKD	Operates one of the largest copper and cobalt mines
OTHER						
NEXS.PA	Nexans S.A.	Carrier, Lucie	Equal-Weight	34.06	EUR	Provides cabling for the electrification of electric vehicles and also supplies charging station units
TPIC.O	TPI Composites Inc.	Ellison, Ethan	Overweight	18.99	USD	Manufactures composite wind blades

Ticker	Company name	Analyst (Primary)	Stock rating	Share price		Technology
CCS						
AIRP.PA	Air Liquide	Webb, Charles	Overweight	118.50	EUR	Oxycombustion
APD.N	Air Products and Chemicals Inc.	Andrews, Vincent	Equal-Weight	214.21	USD	Oxycombustion
ADM.N	Archer Daniels Midland	Andrews, Vincent	Equal-Weight	39.70	USD	Spearheaded the Illinois Industrial CCS project
BE.N	Bloom Energy Corp.	Byrd, Stephen	Overweight	2.95	USD	Developing carbon capture technology for its products to eliminate carbon emissions
DNR.N	Denbury	NC	NC	1.01	USD	Uses CO2 EOR to develop depleted reservoirs
LIN.N	Linde PLC	Andrews, Vincent	NAV	196.85	USD	Oxycombustion
OXY.N	Occidental Petroleum Corp	McDermott, Devin	Equal-Weight	40.34	USD	Planning a Direct Air Capture facility in the Permian by 2021

Ticker	Company name	Analyst (Primary)	Stock rating	Share price		Technology
HYDROGEN						
CNHI.N	CNH Industrial NV	Yakavonis, Courtney	++	10.80	USD	Investment in Nikola, a fuel cell truck manufacturer
CMI.N	Cummins Inc.	Yakavonis, Courtney	Equal-Weight	166.18	USD	Acquired Hydrogenics - a hydrogen fuel cell developer and manufacturer
ALSO.PA	Alstom	Self, Katie	Equal-Weight	38.53	EUR	Manufactures hydrogen trains
ITM.L	ITM	NC	NC	47.45	GBp	Pure play hydrogen technology company manufacturing electrolysers
JMAT.L	Johnson Matthey	Webb, Charles	Overweight	2,995	GBp	Established a fuel cell component manufacturing facility
LIN.N	Linde PLC	Andrews, Vincent	NAV	196.85	USD	Hydrogen mobility
MCPHY.PA	McPhy Energy	NC	NC	3.36	EUR	Designs, manufactures and integrates hydrogen solutions
NEL.OL	Nel ASA	NC	NC	7.95	NOK	Pure play hydrogen technology company
PLUG.O	Plug Power Inc.	Byrd, Stephen	Equal-Weight	2.94	USD	Make hydrogen fuel cells
SIEGn.DE	Siemens	Uglow, Ben	Overweight	100.72	EUR	Manufactures PEM electrolysers
YAR.OL	Yara International ASA	De Neve, Lisa	Equal-Weight	383.30	NOK	N-Tech Platform to decarbonise ammonia production
AIRP.PA	Air Liquide	Webb, Charles	Overweight	118.50	EUR	25% of its sales from hydrogen; invested in fuel cells and biomethane
APD.N	Air Products and Chemicals Inc.	Andrews, Vincent	Equal-Weight	214.21	USD	Hydrogen refuelling infrastructure, energy services and equipment

Ticker	Company name	Analyst (Primary)	Stock rating	Share price		Technology
BIOFUELS						
AGRO.N	ADECOAGRO S.A.	Martinez de Olcoz Cerdan, Javier	Equal-Weight	5.80	USD	Sugarcane ethanol manufacturer
ANDR.VI	Andritz AG	Davies, Robert	Equal-Weight	37.98	EUR	Designs and builds feed and biomass plants
ATIS.O	Attis Industries	NC	NC	1.33	USD	Uses waste fats and oils to produce renewable diesel/ gasoline / jet fuel
CSAN3.SA	Cosan SA	Martinez de Olcoz Cerdan, Javier	Equal-Weight	57.55	BRL	Biofuels
DAR.N	Darling Ingredients	NC	NC	19.13	USD	Produces sustainable natural ingredients from bio-nutrients
NESTE.HE	Neste Corporation	Chilukuru, Sasikanth	Overweight	28.36	EUR	World's largest producer of renewable fuels from waste and residues
PTBBU.PK	POET biorefinning LLC	NC	NC	1.05	USD	Ethanol producer
REGI.O	Renewable Energy Group	NC	NC	15.15	USD	Production of renewable diesel fuel
SMTO3.SA	Sao Martinho SA	Martinez de Olcoz Cerdan, Javier	Overweight	17.90	BRL	Sugarcane ethanol manufacturer
VALMT.HE	Valmet Oyj	Davies, Robert	Equal-Weight	17.87	EUR	Services and technologies for industries including 2nd generation ethanol
VLSV.L	Velocys	NC	NC	2.02	GBp	Advanced biofuels from household waste, forest residues etc

Prices as of October 16, 2019. NC = Not covered by Morgan Stanley, NA = Not available. ++ Stock Rating, Price Target, or Estimates for this company have been removed from consideration in this report because, under applicable law and/or Morgan Stanley policy, Morgan Stanley may be precluded from issuing such information with respect to this company at this time. Source: Company data, Morgan Stanley Research

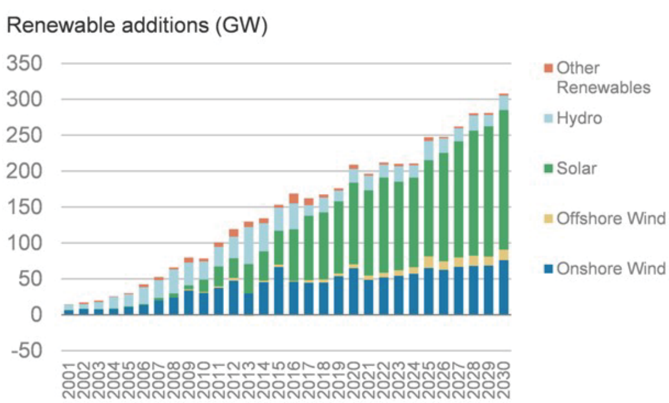
Renewables

Improving economics for wind and solar should drive strong growth in renewable power generation globally. Alignment with a 2 degree celsius scenario requires almost 12,000 GW of new renewable capacity by 2050 plus upgrades to the grid and new storage capabilities. We estimate a 30-year investment requirement of $14 trillion to reduce emissions by ~11Gt.

Contributing equity analysts: David Arcaro, Stephen Byrd, Lucie Carrier, Ethan Ellison, Timothy Ho, Eva Hou, Shawn Kim, Rob Koh, Simon Lee, Jack Lu, Janaki Narayanan, Joshua Pokrzywinski, Rob Pulleyn, Miguel Rodrigues, Anna Maria Scaglia, Arthur Sitbon, Young Suk Shin, Ben Uglow.

Exhibit 16:

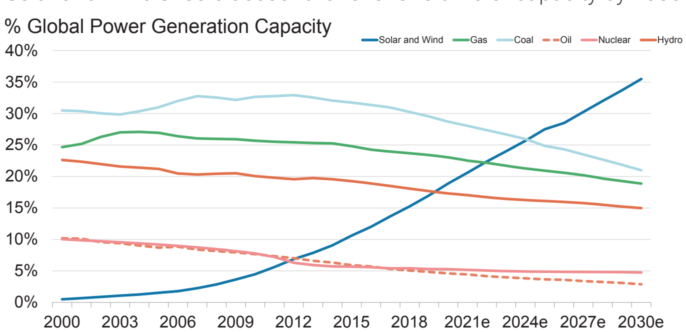
We forecast a significant step-up in renewable capacity additions



Source: Morgan Stanley Research estimates

Exhibit 17:

Solar and Wind should account for over one-third of capacity by 2030



Source: Morgan Stanley Research estimates

Contribution towards decarbonisation

Global electricity generation is likely to continue to rise by ~1.5% p.a. over the next 20 years, we estimate (without taking into account additional potential drivers such as EVs or hydrogen). Faced with this structurally growing demand for electricity, there needs to be a significant rebalancing of fossil fuel versus renewable capacity in order to meet the Paris Agreement. Indeed, a continuation of the current carbon intensity of power generation would see an incremental ~3Gt of annual CO2 emissions released by 2030, which would be a 5% increase on the world's total carbon emissions of 53.5Gt in 2017. [16]

But significant renewables growth should reduce carbon emissions from electricity generation by 2030 in our base case. Between 2017-30 Morgan Stanley's Utilities team forecasts ~ 3,900 incremental GW of power generation capacity globally; almost all of this increase is expected from Renewables. The carbon intensity of power generation should fall from 0.53MT per TWh in 2017 to 0.35MT per TWh in 2030, on our estimates. We expect total global carbon emissions from power generation to fall by nearly 3Gt over the next decade, with the mix shift sufficient to offset the growth in overall demand for electricity.

16 Source: UNEP Emissions Gap Report, 2018

To be on track for alignment with a 2DS there will need to be more rapid closure of coal power generation capacity... The IEA's Sustainable Development Scenario outlines that coal will need to account for just 5% of power generation by 2040 [17] versus 38% in 2017.

...and a substantial build of renewable capacity. We estimate almost 12,000 GW of new renewable capacity between 2017 and 2050 is required to be on track for a 2 degree scenario. This would result in renewables representing ~79% of electricity generation (with wind and solar accounting for ~55%).

17 Source: IEA, Coal-fired power: Tracking Clean Energy Progress, May 24, 2019

There will also need to be significant investment in the grid... The current distribution and transmission grids that operate globally were not built with renewables in mind. Once solar and wind reach ~35-50% of total power generation, there will need to be more significant investments in the grid to ensure sufficient stability.

...and storage. In the US and Europe, we expect storage facilities to grow rapidly in order to 'balance out' the intraday supply imbalances caused by the growth in solar, and anticipated growth in wind power. For example, many new renewable projects (especially solar) being developed by NextEra include a storage component.

Over time, as renewables becomes an increasingly large component of power generation, utility management teams expect to use a combination of energy storage (predominantly to address intraday supply/demand imbalances) and flexible natural gas-fired generation and/or hydrogen-based solutions (to handle intraday supply/demand imbalances).

In China, our analysts do not expect growth in renewable assets to be accompanied by large investments in storage, but instead expect power grid operators to invest in peaking facilities such as pumped storage power plants.

Incremental renewable power generation is also critical for the successful adoption of electric vehicles and hydrogen as part of the transition to a low carbon economy. By 2050, we estimate there will be 924 million electric vehicles (EVs) on the roads globally, resulting in the need for incremental electricity capacity almost equivalent to that already installed in Europe. As such, for EVs to maximise their carbon reduction potential, this incremental power will need to be from renewable sources. Additionally, producing hydrogen through electrolysis is highly energy intensive; only if the electricity used in the process is renewable can it then be referred to as 'green hydrogen'.

A significant change in policy is required in many regions for a 2 degree aligned scenario to be achieved.

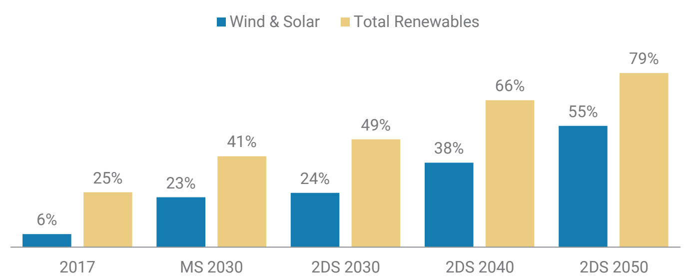
At the moment, **China** plans to shut down around 200GW of old coal power plants and replace them with new ones from 2020-30. We expect China to maintain around 1200GW thermal (coal and gas) power plants from now to 2030. China accounts for 53% of global coal capacity and this will increase slightly over the coming decade, according to MS forecasts. To move towards the 2050 net zero target we would need to see further tightening of air quality control and coal consumption reduction targets. China has not announced any specific carbon emission target, but has said that it should reach peak carbon emission in absolute terms at around 2030.

In **India**, coal accounts for ~55% of India's primary commercial energy and ~72% of the entire power generated in the country is coal-based. While the government is actively looking to expand its renewable energy capacity, with a particular focus on solar, it is simultaneously expanding its coal industry. Of note, India plans to increase its production from ~608mnt in F2019 to 1000mnt by F2025-26. The government is also reported to be planning to open up the sector to

Exhibit 19:

Investment in grid and storage is needed for the decarbonisation of electricity generation to be aligned with a 2DS

Renewables as % of Global Power Generation



Source: IEA, Morgan Stanley Research estimates

Exhibit 18:

NextEra Energy Resources' development program

	2019 – 2020 Signed Contracts	2019 – 2020 Current Expectations	2021 – 2022 Signed Contracts	2021 – 2022 Current Expectations	2019 – 2022 Current Expectations
Wind	3,938	3,000 – 4,000+	392	2,000 – 3,800	5,000 – 7,800
Solar[1]	1,485	1,000 – 2,500	2,358	2,800 – 4,800	3,800 – 7,300
Energy Storage[1]	50	50 – 150	460	650 – 1,250	700 – 1,400
Wind Repowering	2,130	>2,000	0	0	>2,000
Total	**7,603**	**6,050 – 8,650**	**3,210**	**5,450 – 9,850**	**11,500 – 18,500**
Build-Own-Transfer	774		110		

Note: signed contracts as of July 24, 2019. MW capacity expected to be owned and/or operated by Energy Resources. (1) Excludes 680 MW of solar and 208 MW of storage (total of 888 MW) signed for post 2022 delivery. Source: NextEra Energy Company Presentation.

commercial mining [18], which is currently restricted to government owned enterprises. Lastly, in August of this year, the government also approved 100% foreign direct investment under the automatic route (rather than the route requiring approval) in the mining, processing and sale of coal.

In the **US**, we forecast zero new build for coal generation in 2020 and beyond. We project a continued reduction in coal plant capacity and plant utilisation rates, given that coal plants are more costly to operate relative to renewables and natural gas-fired capacity. The reduction in coal fuel usage that we forecast by the US power sector is striking, moving from ~1,200 TWh of coal-fired power output in 2017 to ~370 TWh of coal-fired power output by 2030 (a ~70% decrease over 13 years). A move away from coal could theoretically be accelerated by (i) a change in policy by states where coal is still an economic generation resource to encourage the adoption of renewables (e.g. an enforced cap and trade/ carbon tax program); (ii) a Democratic administration in 2020, with a number of Democratic candidates expressing support for aggressive climate change regulation, such as 100% clean energy targets; (iii) sustained low natural gas prices putting pressure on coal plants; and (iv) an increasing level of energy procurement from solar and wind (both offshore and onshore), putting pressure on power prices in deregulated markets and rendering additional coal plants uneconomic.

In **Europe**, we do not expect new coal plants to be built. The economics are unattractive, and even if attractive in a particular country, the increased carbon intensity would mean them moving away from their own internal carbon targets, rather than getting closer. In Germany, for example, the government has confirmed it will implement the cross-party Coal Commission's recommendation to shut down all coal power generation by 2038 (with the option to fully accelerate these and fully exit coal by 2035). Coal and lignite still represent around 21% of the region's power generation installed capacity (2018). With 12.5GW of coal and lignite capacity to close by 2022 according to the Coal Commission's final report, coal and lignite would represent only 16% by then and less than 10% by 2030. The drop in terms of percentage of total German power production could be even more dramatic if economics remain unfavourable and significant new renewables capacity is built.

18 Source: Reuters, September 18, 2019

Investment

Achieving the required penetration of renewable power generation to stay within a 2DS will require $14 trillion of investment by 2050e. We assume that incremental renewable capacity of almost 12,000 GW will be required by 2050, with capital expenditure ranging from $0.87m to $3.3m per MW depending on the type of renewable technology.

Incremental investment in storage will also be needed. We estimate that currently only around 1% of renewable capacity is supported by storage infrastructure. By 2030, this figure is likely to have reached 50% and then it will probably get to 100% by 2050, incentivised by the fall in cost of battery storage from c.$400m/kWh in 2017 to a cost of $160m/kWh by 2030, on our estimates.

There will also be incremental costs that we have not been able to estimate in this report. These could include upgrades to the network and system security. In the grey box below, we highlight lessons learnt from South Australia's transition to renewable power generation.

Exhibit 20:

Renewables: Key assumptions

	MS 2030	2DS 2030	2DS 2040	2DS 2050
Power generation - new capacity needed (GW)				
Wind	761	1,197	2,304	2,783
Solar	1,789	1,948	3,842	7,450
Other Renewables	183	377	759	789
Total	2,732	3,522	6,905	11,022
Capex				
Solar PV ($mm per MW)		0.872		
Offshore wind ($mm per MW)		3.27		
Onshore wind ($mm per MW)		1.09		
Average renewable power ($mm per MW)		1.53		
Storage ($ mm per MwH)		0.16		
Capex $bn				
Wind *	1,161	1,827	3,516	4,247
Solar	1,560	1,699	3,350	6,497
Other Renewables	219	452	910	946
Storage	295	295	1,069	2,344
Total $bn	3,235	4,272	8,845	14,033

* Wind capex estimates include both onshore and offshore projects. Source: IEA, Morgan Stanley Research estimates

Getting to >75% of energy sourced from renewables? Lessons from South Australia

Increasing the proportion of renewables generation involves a number of technical and market inflection points, which could add significantly to the cost of transition vs. our central scenario estimate. We provide some insights from the South Australian transition from <1% of renewables in 2010 to ~50% today.

For background, South Australia (SA) consumes ~12.5TWh of electricity each year (~7.5MWh/capita), supplied by 7.3GW of generation (~20% capacity factor) comprising: 3.7GW of thermal (gas and diesel), 2.0GW of onshore wind, 0.4GW of large-scale solar PV, 1.1GW of rooftop solar (~31% of households), and the 0.1GW/0.13GWh Hornsdale Power Reserve (currently the largest chemical battery installation in the world).

1. The 'duck curve' – with significant household and large-scale solar generation, SA has seen considerable hollowing out of daylight hour price and demand. This daily cycle contributed to the early retirement of baseload coal-fired generation in the state, which had limited ability to ramp up and down each day. The loss of low-cost generation earlier than anticipated raised the price of power for consumers, and reduced the reliability of the power system overall. Conventional reserve capacity analysis in power markets focuses on annual peak demand and average energy consumption, but going forward the framework will need to consider daily solar cycles, in our view.

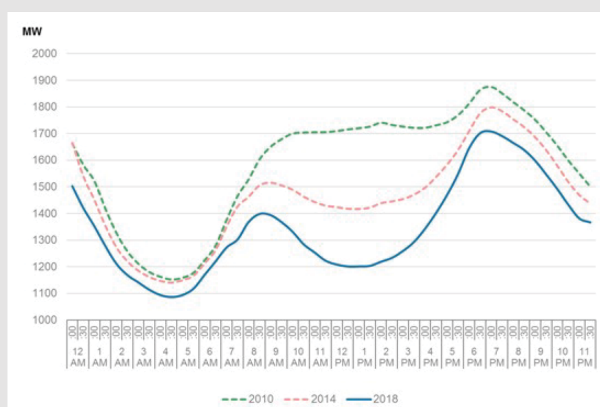
2. Variable vs. dispatchable generation – with half of all SA generation coming from variable renewable energy (solar and wind), the role of firming (power or demand response that can be dispatched when required) becomes more critical to balance demand, and at a cost (e.g., lower overall capacity utilisation, lower thermal plant efficiency). Traditional power economics based on levelised costs of energy (LCOE) need to be reassessed, in our view, with the theoretical new entrant cost being a combination of variable renewable energy and firming capacity, rather than (say) the simple LCOE of a gas-fired plant. Australia is contemplating a 2025 energy market redesign (currently an energy-only market, with no payments for capacity).

3. System security – new entrant renewable energy is asynchronous (the frequency comes from the inverter software, rather than the spinning turbine of a conventional thermal plant), so SA's power system saw a significant drop in inertia (the rate of change of frequency) and system strength (the rate of change in voltage), leading to persistent system trips (outages). The SA government solved the problem by subsidising the Hornsdale Power Reserve which, among other things, provides frequency and other system security services. The SA transmission provider has also invested in additional synchronous condensers to stabilise frequency variation, and synthetic inertia trials using new generation inverters are underway. The SA government is also supporting trials for virtual power plants (orchestrated fleets of household solar and battery installations, to balance energy and provide system security services).

4. Network over-volting – the high penetration of rooftop solar has seen numerous areas within SA's distribution network with a 'reverse' flow of energy. Network solutions have included limiting the capacity of rooftop installations and raising the voltage in the network, so as to limit household export (causing higher power consumption, energy losses, and appliance degradation at the household level). The building block regulatory framework for networks also provides no incentives to facilitate two-way energy flow within the grid (a potential blockchain-for-energy application).

5. Transmission resource planning – the wholesale replacement of the existing generation fleet requires a new approach to transmission network planning. The existing SA network was planned and built during the post-war period, to link coal and gas resources to demand centres. The new resources (solar and wind) are in different locations, and with lower energy density, so different spines and more connections are required, leading to a higher and more complex network planning task. Many renewables plants have suffered from congestion losses, grid harmonics issues, and curtailment in the rush to connect to the grid. The Australian Energy Market Operator has prepared an integrated system plan identifying Renewable Energy Zones, whereas the Australian Energy Market Commission is proposing to create dynamic nodal pricing and a financial transmission hedging market.

The South Australia duck curve



Source: Australian Energy Market Operator, Morgan Stanley Research

To learn more about a duck curve, please see Video: Australia Regulated Utilities: What is a Duck Curve anyway?

Technology

Since the turn of the century, almost 1,800 GW of renewable generation capacity has been installed globally. Renewables together account for 25% of global power generation. Over the next decade we expect strong growth in renewables driven by improving economics. For example, as **Exhibit 23** shows in the US, even when adding in the cost of storage we expect onshore wind and solar to remain competitive after subsidies are removed in 2023.

Specific economics do vary by region; as **Exhibit 22** shows, there is significant variance in prices of renewable auction results, even within Europe itself. Generally speaking, however, one trend witnessed at a global level is the falling cost of renewable energy, as demonstrated by **Exhibit 23**.

Solar

To date, solar has been the smallest source of renewable power after hydro and wind power. However, we expect it to be the fastest growing technology over the coming decade at a 13% CAGR for capacity driven by rapidly improving economics.

Oversupply of solar panels has put significant pressure on module prices since the middle of 2016. Panels are an important component of a solar project's total cost, and typically represent 20-40% of the total installed cost of a utility-scale system. In addition, panel pricing tends to be relatively homogeneous on a global basis. As such, the declines we have seen in panel prices translate into widespread global improvements in solar economics.

That said, there is limited competitive differentiation in solar project development. We expect this to keep pressure on developers' returns, which will dampen capacity additions in the short term.

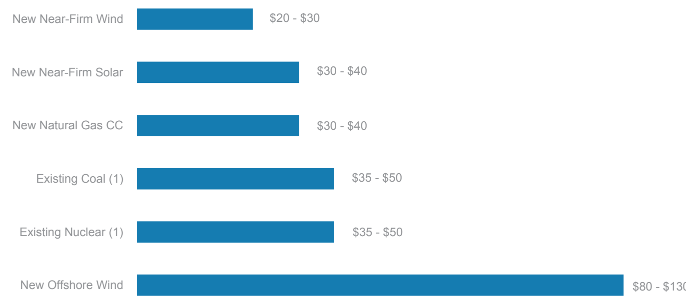
However, from 2025 we forecast an acceleration in new solar installations, with particularly strong growth in China and India.

In **India,** solar power has become the cheapest form of power generation driven by rapidly declining component and installation costs, increasing debt tenors and declining interest rates, and significant interest from developers to participate in this high-growth market. We expect India to be the fastest growing solar market globally.

For **China,** the combination of falling costs and China's drive to increase renewables as a percentage of primary energy is driving growth in solar power.

Exhibit 21:

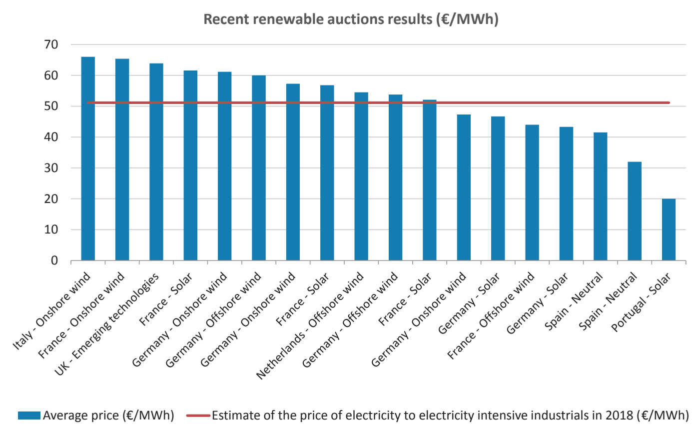
Estimated costs of generation resources post 2023 in the US ($/MWh)



Note: Figures are based on NextEra Energy Resources' estimate. For New-Firm Wind and New Near-Firm Solar, the costs include storage adders. (1) Represents all-in cash operating cost per MWh including fuel and ongoing capital expenditures. Source: NextEra Energy Company Presentation.

Exhibit 22:

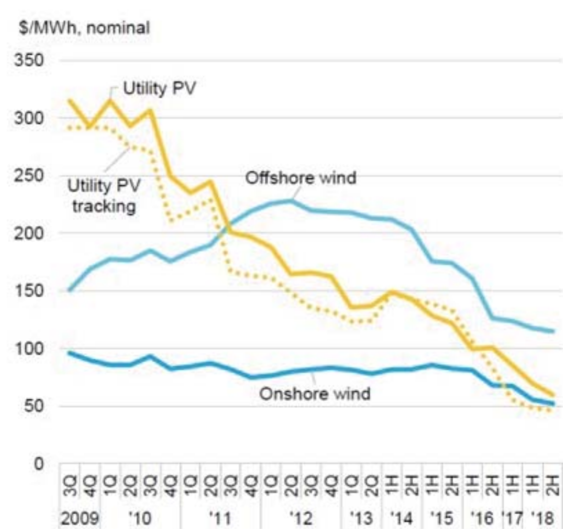
The prices of renewables paid by industrials vary significantly depending on geographies, renewable types even within Europe, and when the results were announced



Source: Morgan Stanley Research

Exhibit 23:

The levelised cost of energy (LCOE) global benchmarks show a downward trend



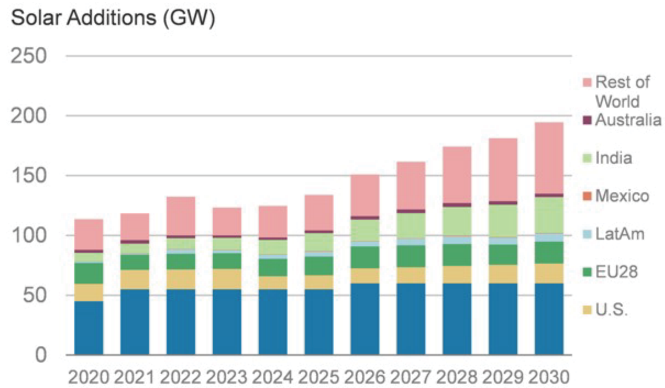
Source: Bloomberg NEF

In the **US,** our Utilities team expects significant solar installation volume through 2023 while tax credits make solar projects highly economic, and continued steady growth after a reset in 2024 with tax credit declines. In southern US states, utility-scale solar projects are much less expensive than new natural gas plants, and in many areas are more economic than wind. Utilities are increasingly pairing solar with storage to meet peak demand and considering shutting down existing old resources to replace with cheaper, non-emitting solar. The rooftop market is also a very appealing opportunity, with net metering policies continuing to enable customers in many states to save money vs. the utility grid with rooftop systems, and rising utility rates will lead to a broadening economic value proposition that is effective across more customers and states over time (particularly since we expect solar costs to continue their decline). We see a more favourable market opportunity for US rooftop solar installation, an area that offers better competitive differentiation, share gains for top players, and an emerging storage opportunity. Solar development is becoming increasingly competitive with returns shrinking as differentiation is more difficult to achieve, and solar manufacturing we think is a commodity business that will face price declines and shrinking margins.

In **Europe,** solar power remains small for now: it only accounts for 4% of total electricity production in EU-28 countries. However, it has been identified as an important potential driver of renewables growth by numerous EU countries in their draft 2030 national energy plans. Our Utilities team believes that solar power capacity could grow by 2-3x by 2030, based on EU members' draft national energy plans. Most of this growth should come from Spain, Italy, France and Germany.

For **Brazil,** solar has been a tiny part of the energy mix representing just 0.5% in 2018. Despite its early stage of development in Brazil, solar is already cheaper than certain thermal sources, and the Energy Research Company (EPE) estimates solar will likely represent 10% of power generation in 2030 with capacity of 25GW, of which 17GW will be large-scale projects and 8GW distributed generation.

Exhibit 24:
Growth in Solar Power capacity, 2020-30



Source: Morgan Stanley Research estimates

Wind

We see a strong growth outlook for wind, driven primarily by compelling wind energy economics across emerging and incumbent markets. Driven by design, manufacturing and transportation solution breakthroughs, wind blades have been getting significantly longer more quickly than many observers expected. This improves wind economics at an exponential rate, as the swept area of a wind blade is a function of the square of the radius. To illustrate this dynamic: global average blade length is expected by MS analysts to move from ~51 meters at year-end 2016 to ~57 meters by 2021. This is driven by replacements of <50m blades and the introduction of >70m blades. While this move in blade length may seem insignificant, it will increase wind turbine productivity by ~25%. This leads to higher load factors (the turbines generate electricity more consistently) and a lower all-in cost of wind power, making wind — the technology that is already most cost-effective in many parts of the world — even more economic. The newest iteration of ~72m blades will allow for wind capacity factors in excess of 65% in some locations, a number that would have been inconceivable a few years ago.

In addition to the benefits of longer wind blades, higher towers can have a significant impact on power output due to superior wind conditions. The US Department of Energy (DoE) has estimated that "gains of 20-45% are possible by increasing the height of the towers from 80m to 140m in moderate-to-high shear sites" — the power varies as the cube of the wind speed, and even modest increases in wind speed (as a function of height) contribute to the power captured.

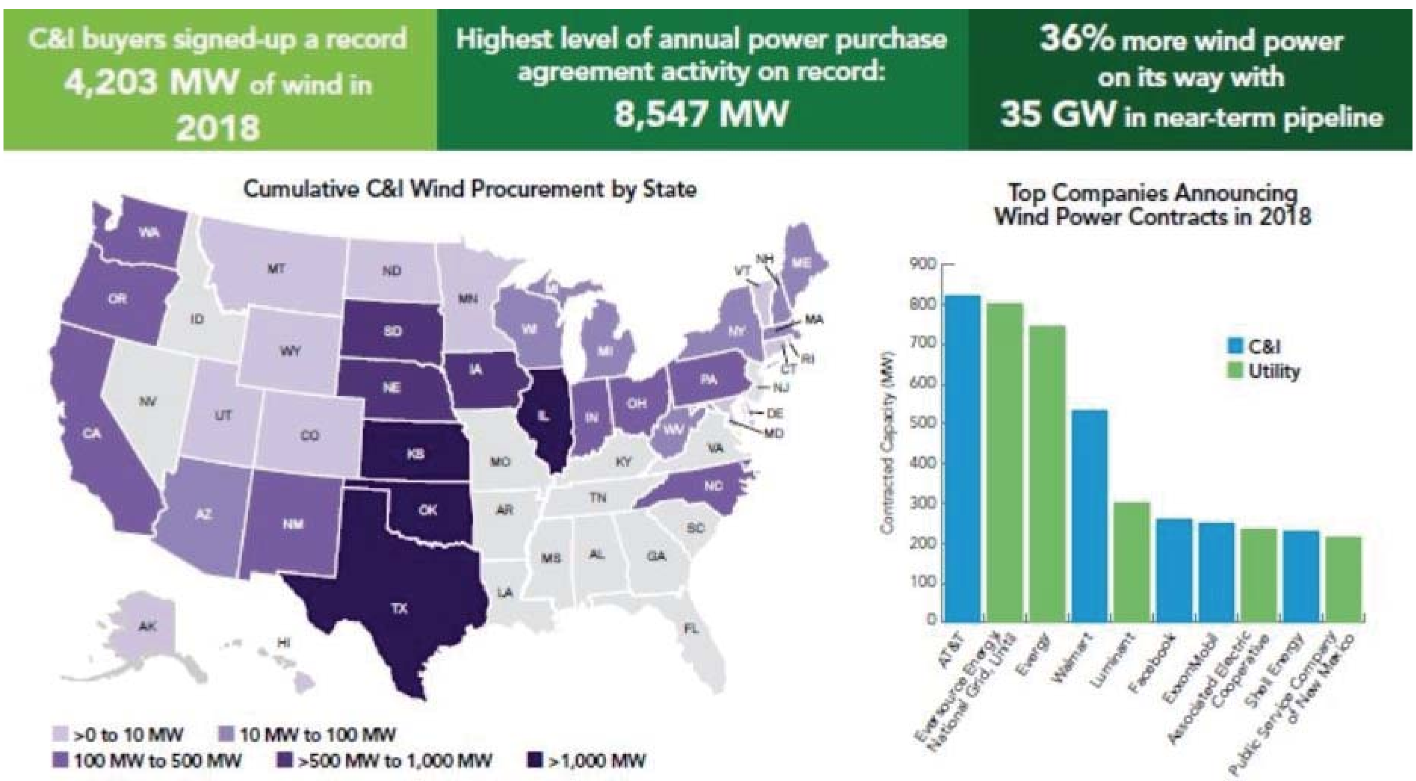
As a result of these rapid improvements in technology, wind has become the lowest cost form of energy in many markets. In the midwest US, for example, we estimate a levelized cost of energy (LCOE) for wind of <$20/MWh, compared to an LCOE for new gas-fired generation in the $40-60/MWh range. This should enable continued growth even when subsidy programmes come to an end.

In the **US,** our Utilities team sees improving economics for wind technology (as evidenced by continually falling bids in competitive auctions), which is leading to wider scale adoption by utilities and corporates, particularly in the midwest US. They expect very strong demand for wind capacity through 2019 and 2020 in advance of a proposed step down in the wind production tax credit (from 100% to 80%) in 2021.

While some investors are concerned about the sustainability of renewables growth in the US given a sunsetting of tax credits in the early 2020s, we would note that renewable technologies continue to drop in cost at a rapid rate. Wind power in particular benefits from a simple geometric equation: the surface area of a circle is a function of the square of the radius. Why does this matter? As wind blades increase in length, the power output of wind turbines increases exponentially. Currently, in the middle portion of the US, we are seeing wind output contracts signed at prices as low as in the mid-teens per MWh. As a frame of reference, a new natural gas-fired turbine would need revenue of $45-55/MWh, and the fuel cost alone for a coal-fired power plant is typically in the $20-35/MWh level, with all-in cash costs much higher than that amount. It can be challenging to forecast total onshore US wind growth, given that contracts currently signed give us visibility for just ~2 years of likely future growth. We would note that corporate customers are becoming a very important incremental source of wind demand. For example, in 2018, nearly half of new wind contracts were signed with corporate customers, as per data from the American Wind Energy Association (AWEA).

Exhibit 25:

Commercial and Industrial customers are becoming a very important source of incremental wind demand



Source: AWEA

Wind economics keep improving, and will remain competitive post subsidies, in our view. Even with no tax credits we expect wind with a storage system to be more economic than gas new builds, and significantly cheaper than variable costs of existing coal and nuclear plants. We also see attractive returns for wind project developers, given the higher barriers to entry for this business relative to large-scale solar installations, which are relatively straightforward to develop.

Across **Europe,** our Utilities and Capital Goods teams have a positive view on potential wind development as the region tries to achieve 2030 targets on CO2 reduction. Development of new capacity is expected to be linked to the development of the PPA market. However, incremental capacity is likely to put pressure on prices in the mid term, which could affect stocks with merchant and cap goods exposure. We note pricing has stabilised in the last 2-3 quarters.

In **China,** our Utilities team expects moderate levels of installation at around 25GW p.a. for 2019 and 2020, given the Chinese government has issued policy documents in regards to wind grid parity from 2021. In the grid parity market from 2021 and onwards, the team expects China to add 20GW new wind capacity on average each year: 1) major IPPs to shift their thermal power spending to renewables, and accept the relatively lower return without a tariff subsidy; 2) onshore wind to return to Three North Regions due to curtailment relief and UHVs; 3) offshore wind to pick up to 3-5GW p.a.; and 4) distributed wind to mature in lower wind speed regions. Similar to wind, China has also announced the grid parity policy document on solar. Thanks to technology advances and substantial cost reductions, solar projects in most of China have already achieved grid parity conditions. We expect China to add 40GW in 2019 and 45GW in 2020, and accelerate to 55-60GW p.a. from 2021 and onwards, due to ongoing cost reduction and technology advantages.

In **Brazil,** wind is now the lowest-cost source of power in Brazil, but represents only 7.6% of the installed capacity. We expect it to gain share due to challenges in developing new hydro plants in the Amazon and Tocantins-Araguaia basins, where there are environmental protections in place for rain forest areas.

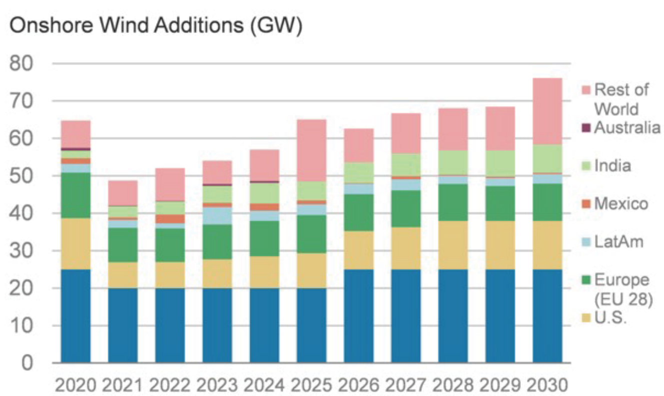
Onshore wind: This has dominated, representing 95% of global wind power generation in 2018. [19] We expect global demand for onshore wind to grow at a 7-8% CAGR through 2025 and beyond.

19 Source: IEA

Offshore wind: This is a growing global opportunity and the Global Wind Energy Council expects a >8x increase in offshore wind from 23GW today to 190GW by 2030 (in its 'Business As Usual' scenario), which is above the capacity implied by the IEA's Sustainable Development Scenario. Europe is the leader in offshore wind today, but Asia could be the biggest market in the world by 2030 if growth aspirations are delivered in India, Japan, South Korea and China. Permitting for offshore wind in the US has its challenges, but we expect to see new capacity approved on the East Coast. Our US Utilities team estimates an additional 12.76GW of cumulative offshore wind development will materialise by 2030 (vs current levels of 30MW offshore wind currently in operation).

Exhibit 26:

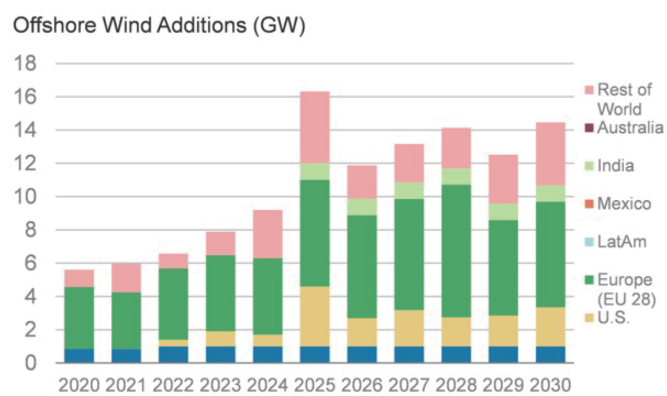
Growth in Onshore Wind power, 2020-30



Source: Morgan Stanley Research estimates

Exhibit 27:

Growth in Offshore Wind power, 2020-30



Source: Morgan Stanley Research estimates

Renewables

Hydro

Hydropower has dominated renewable and/ or energy generation. This is due to its relatively low cost in some regions, including China and Brazil, and it will continue to play an important role in achieving climate change goals.

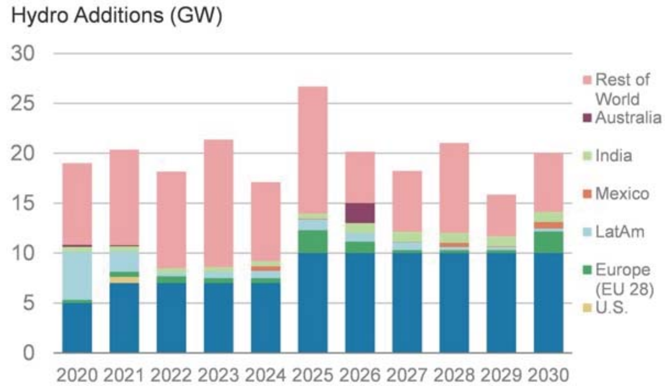
Our **China** Utilities analyst expects hydropower to account for 50% of China's renewable energy contribution outlined in the renewable portfolio standards for 2020 and 2030. It will benefit from China's effort to reduce curtailment through construction of new power lines and relocating energy intensive industries from eastern to western China. In addition, as China's wind and solar power generation trends towards grid parity by 2021, hydropower will be relatively competitive given lower unit power generation costs.

In **Brazil**, hydroelectricity (including small hydro) represents ~65% of total generation installed capacity, implying a relatively clean generation matrix compared to other regions. Hydro plants will still be added to the system, but will likely lose share as a percentage of total capacity as reservoirs have not been allowed for most recent hydro plants due to environmental regulation. This norm will likely continue for new large hydroelectric plants, which should remain run-of-the-river. This reduces not only the average generation potential of a particular plant, but also its contribution to the reliability of the system, as reservoirs play a storage role.

In Brazil, the Chamber of Electric Energy Commercialization's (CCEE) recent downward revision in Brazil's hydrology outlook for 2019 contributed to higher expectations for the hydro-deficit and spot prices for the year, leading to the potential continuation of a challenging environment for the hydro generators. This affects mainly the companies that are not hedged (as they may have to purchase power in the spot market at high prices), or other Generation Scaling Factor (GSF) mitigation products (i.e. insurance products from the Brazilian Electricity Regulatory Agency (ANEEL)).

Exhibit 28:

Growth in Hydro power, 2020-30



Source: Morgan Stanley Research estimates

Grid and storage

A large increase in wind and solar power penetration should also lead to additional investments in electricity grids...

Current electricity systems are not adapted to high renewables penetration rates. Up until recently, electricity was only generated from so-called traditional sources (i.e. mainly nuclear, coal, gas, oil and hydro). The key differences between traditional generation and new renewables (wind and solar) is that the former has a more predictable generation pattern and tends to follow the same frequency ('synchronous generation'). The output and the frequency of renewables depend on factors such as wind speed and tidal strength, and it is more volatile ('asynchronous generation'). In terms of electricity supply requirements, the intermittent nature of renewables creates more demand for back-up plants (a niche generally met by faster-starting thermal and hydro plants, and perhaps also large-scale battery banks). The asynchronous nature of new entrant renewables at high penetration percentages may also bring about system issues, for example the requirement for greater frequency and voltage control. As an electricity system needs to maintain the frequency (the electromagnets spinning at the same speed) to keep operating without blackout, the increase in renewables creates the need for stronger grids and mechanisms that will ensure system stability (supplying electricity upon demand with required frequency and voltage, and balancing active and reactive power). This could come from either large traditional generators that provide system inertia, or other systems, such as flywheels and batteries, that can give the system synthetic inertia. On top of these differences between traditional and renewable sources, the optimal location of renewable assets (i.e. where the wind blows or where the sun shines) does not always coincide with the location of traditional power plants, which sometimes leads to the need to build new grid connections.

There is a debate on the degree to which the benefits from the low (and falling) cost of renewables will be offset by higher costs (in grid capex and energy storage) to ensure grid stability. While dynamics vary from one grid to another, typically renewables penetration can reach levels of up to 35-50% without the need for massive grid upgrades above the levels already being planned by utilities. We are getting close to these levels in some large European electricity markets. Germany, Spain and Portugal are the large markets with the highest wind and solar power (24-25% of these countries' power output in 2018).

Ultimately, the amount of potential additional investments needed to adapt grids to higher renewables penetration rates is difficult to quantify, as we lack visibility on 1) the size of prior investments undertaken to modernise the grids, 2) where those prior investments were physically going, and 3) where new renewable assets will be installed. In any case, the situation differs from one country to another. For example, Germany appears to need investments in better interconnections between north and south (as a lot of the country's wind farms are located in the north while several large power consumption hubs are located in the south of the country). The same types of issues are faced in Italy (although with consumption in the north and generation in the south). On the other hand, according to our channel checks, the Spanish transmission grid could support close to twice as much renewables capacity without much incremental investment. For storage, costs remain high for current technologies and a lot will depend on the evolution of the cost curve.

...and storage systems – $2 trillion of investment in storage is needed by 2050e. Currently, we estimate that only around 1% of renewable capacity is supported through storage infrastructure, but given the rise in renewables and the improving economics of storage (as outlined below), we forecast incremental renewable capacity supported through storage to grow to 50% by 2030 and 100% by 2050. Given these assumptions, we forecast a total investment of $295 billion by 2030, however we suggest that in order to be on track for a 2DS, an investment of over $2 trillion would be needed by 2050.

Electricity is difficult to store and it has not been economical to do so until recently as we expect storage costs to more than halve by 2030. This has arguably put a cap on the penetration of renewable energy across a single energy network. However, the economics are improving and starting to reach an inflection point now. Previously, economies of scale were the driving factor behind the falling prices of storage, with increasing manufacturing capacity pushing the cost of production down. Now, the falling cost of materials, particularly lithium, is what has been pushing the cost of storage down. Additionally, as technology improves, less materials are needed within a storage unit to be just as effective – this too has had a positive impact on the cost of storage. As such, our North America Utilities team point out that storage is reaching an inflection point currently, with the levelized cost of energy (LCOE) appearing more attractive for renewables than fossil fuels in many locations. We estimate the cost of storage to fall from $400m/gWh in 2017 to a longer-term $160m/gWh by 2030. Leading suppliers were originally Korea-based manufacturers (such as Samsung SDI, LG Chem and SK Innovation), but Chinese and US players (such as CATL and Tesla) are becoming increasingly important. NextEra Energy, the leading developer of renewables in the US, has shown the incremental revenue requirements of energy storage when combined with wind and/or solar projects, and the incremental cost is surprisingly low, at $4-9/MWh in the long term (the average utility bill is over $100/MWh, and a natural gas-fired plant typically requires revenue of >$40/MWh).

There are numerous benefits to the grid from energy storage. It can (1) store excess solar and wind power (often produced during periods of low power demand) and release the power during peak demand periods, thereby lowering power pricing and more effectively using existing grid resources; and (2) counteract the unpredictability of solar and wind power output, effectively acting as a 'shock absorber'.

Exhibit 29:

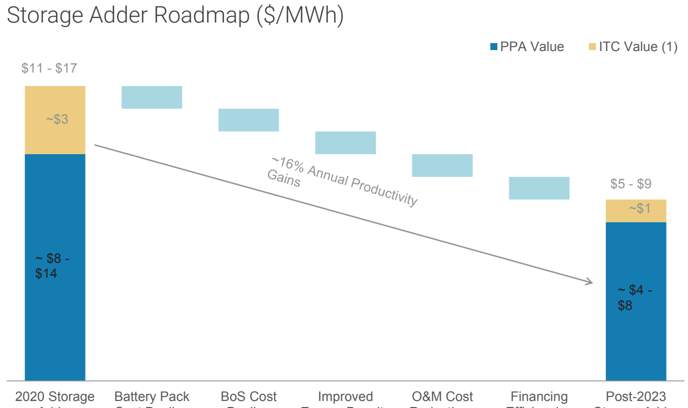
Storage – Key assumptions

	2DS 2030	2DS 2040	2DS 2050
Power generation - new capacity needed (GW)			
New Renewable Capacity	3,522	6,905	11,022
Percentage of renewables with storage	50%	90%	100%
Capex storage ($Mil per Gwh)	159	159	194
Total incremental storage investment ($bil)	295	1069	2344

Source: IEA, Morgan Stanley Research estimates

Exhibit 30:

Storage Adder Roadmap ($/MWh)



Note: Figures are based on NextEra Energy Resources' estimate; assumes 25% of facility's generating capacity for a 4-hour duration. (1) Pre-tax value of investment tax credit levelized over the life of the project. Source: NextEra Energy Company Presentation.

Renewables

It could also reduce costs for customers and defer expensive infrastructure upgrades in the distribution and transmission networks.

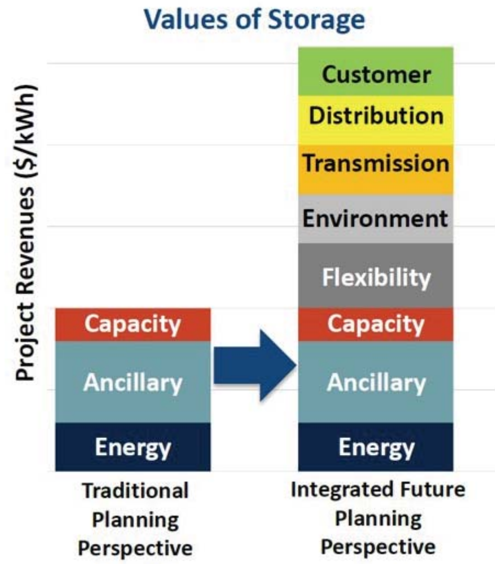
In the US, the rapid growth of solar supply has resulted in substantially lower midday power demand (net of solar power being produced), causing record excess power supply in some markets. The anticipated near- to medium-term growth of wind power supply is expected to result in a similar disruption to overnight power demand, given that wind production is typically strongest at night (see page 25 for an example of a California power demand 'duck graph'). We expect storage to grow rapidly in the near term to 'balance' intraday supply imbalances.

Our US Utilities team projects that demand for energy storage in the US will grow from <$300mm/year in 2017 to $2-4bn/year by 2020, with a total addressable market of ~85GWh, or $30bn. They believe this is partly a result of tying in storage along with wind and solar projects, but also see the benefits of storage standing on its own driving this growth in storage investment. We think the collective benefits of energy storage are greater than currently appreciated. As renewable energy penetration increases along with the rapid reduction in the cost of both storage and renewables, we think regulated utilities will realise the grid benefits from deploying storage, including greater reliability and lower required grid expenditures. For example, for NextEra Energy (NEE), the all-in cost of near-firm wind and solar projects (including storage) are comparable or cheaper than a low-cost gas plant and cheaper than existing coal and nuclear operating costs.

In the US, a key regulatory issue will affect the size of the storage market. The issue relates to whether utilities can deploy storage in deregulated (competitive) power markets, which comprise ~40% of the potential US storage market. This tension between state subsidies and ensuring a fully functional competitive market is currently under review by the federal regulator (FERC), and could have an impact on the regulatory treatment of energy storage in deregulated power markets. Our base case assumes that utilities will not be permitted to deploy significant amounts of storage in deregulated markets. Under this scenario we forecast the US addressable energy storage market to be ~85 GWh, or $30bn. If we are incorrect and energy storage is allowed in deregulated markets, the storage market would be ~60 GWh, or ~70%, larger than our base case. Under this outcome, the margin potential for competitive power generators could be threatened (because storage will reduce on-peak power prices, reducing margins for incumbent power generators), representing a significant risk for NRG, Vistra, Exelon and PSEG. For more detail please see Energy Storage: Disruptor or Enabler?.

Exhibit 31:

The emerging role of energy storage

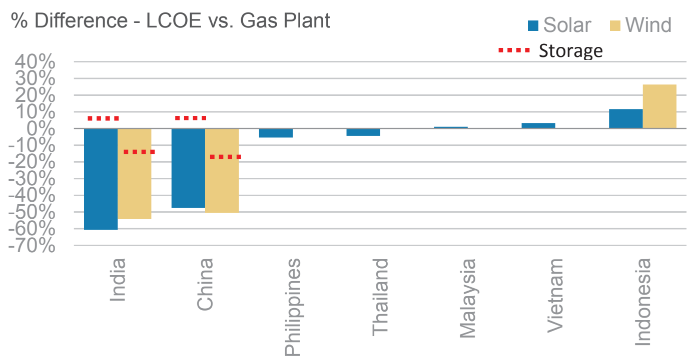


Source: The Brattle Group

We think storage costs will decline even more rapidly than solar and wind over the next 5 years, making the combination of renewables and storage possibly the dominant source of new power generation in India and China.

Exhibit 32:

Renewables economics in many Asian countries are already much cheaper than, or similar in cost to, new gas combined cycle emissions



Source: Bloomberg New Energy Finance

Hydrogen is also needed though. While battery storage can store excess renewable energy and shift it to periods when customer demand is highest, it is not likely to be a cost-effective method to protect against extended periods of low renewable output (e.g. from extended cloudy periods). The most likely approach to ensuring grid reliability will also involve the usage of hydrogen within the existing gas utility system. Excess solar power can be used to generate hydrogen, which can be injected into the gas utility system where it can be stored for significant periods of time, and used for power generation during periods of low renewable power output. For more details please see the **Hydrogen** section.

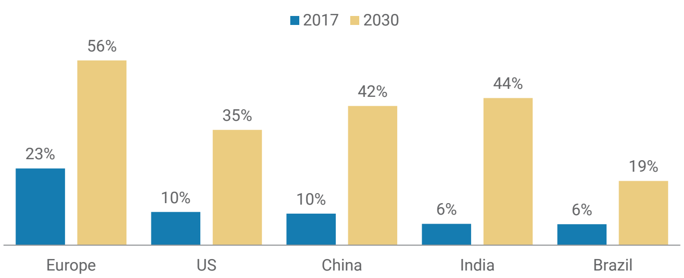
Policy

Adoption of renewable power generation has been driven by a combination of policy and economics. All five regions that we consider below should experience a material increase in the amount of power capacity that comes from solar and wind over the next 13 years.

Exhibit 33:

MS forecasts material increases in solar and wind power generation capacity across all regions

Solar and Wind as % of total power capacity



Source: Morgan Stanley Research Estimates

Europe: Europe has been a pioneer in renewables deployment, with renewables electricity generation accounting for 31% of total gross electricity generation in 2015 according to Eurostat. However, given the much higher cost of renewables when Europe was deploying large amounts of clean energy, this boom led to political intervention due to growing concerns over the affordability of incentive schemes. End consumers' bills grew more than expected as a result of high renewables penetration and higher costs (due to deploying renewables when they were much more costly than they are today). A deceleration in new renewable installations followed regulatory changes. In addition, very high renewables penetration has created an active debate centered on grid stability impacts from renewables, though this in turn has fueled investment opportunities for regulated utilities. Recent renewables auctions show that operators are willing to build new capacity at zero incentives, assuming further improvement in technology costs.

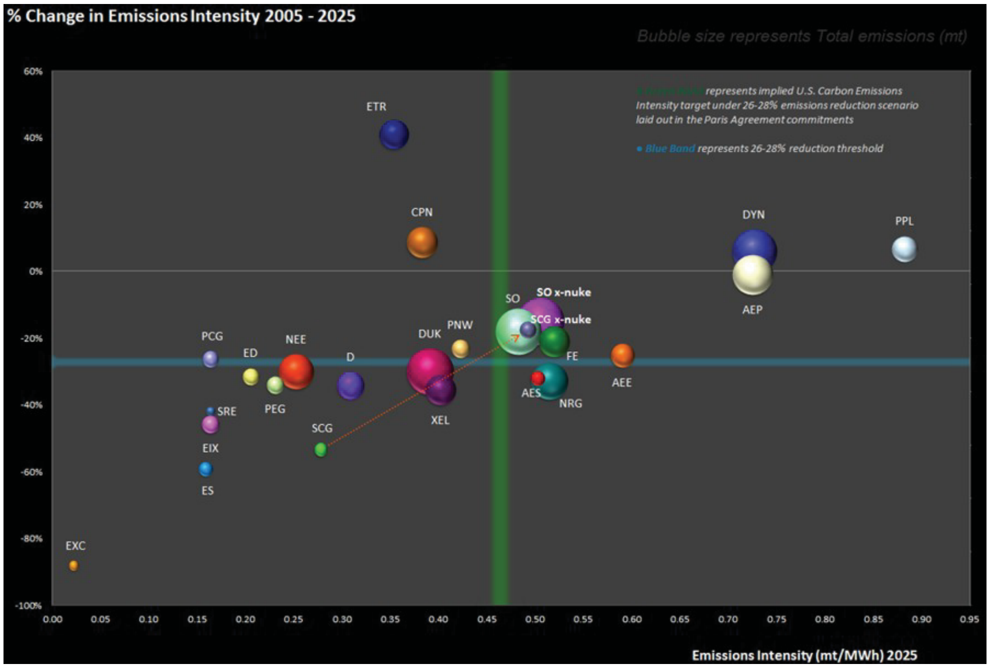
In 2018, the EU's revised Renewables Energy Directive came into force, committing the region to a binding renewable energy target of at least 32% by 2030, with a possible upward revision by 2023. Renewable energy is defined as final consumption of electricity from renewable sources; final consumption of energy from renewable sources in the heating and cooling sector; and final consumption of energy from renewable sources in the transport sector.

In addition to explicit renewable targets, the EU has used a carbon emissions trading scheme to incentivise growth in renewable energy. Phase IV of the EU Emissions Trading Scheme begins in 2021 and will run until 2030. To encourage an acceleration in the speed of emission cuts, the number of emission allowances in the scheme will fall by 2.2% p.a. compared to 1.74% at present.

US: In 2017, President Trump announced that the US would withdraw from the Paris climate accord, although in practice it will take four years to officially retreat from the commitment. Despite this policy change, there is still a clear path to energy decarbonisation in the US, driven by improving economics of the key technologies. Our analysis shows that coal retirements, economics-driven fuel switching, and renewables development will drive a natural ~34% reduction in US utility carbon emissions by 2030, exceeding both the Paris climate accord and the (now defunct) EPA Clean Power Plan (see our in-depth report here). Since that report, a number of utility companies in our coverage have made significant efforts to accelerate their generating fleet's rate of decarbonisation. For instance, both AEE and AEP were previously not expected to meet carbonisation levels comparable to Paris Agreement goals (companies on/above the blue line in **Exhibit 34** were not expected to meet the 26-28% reduction threshold). The chart shows our projected 2025 carbon intensity for US utilities, as well as the percentage change in carbon intensity from 2005-25. As a frame of reference, the exhibit also shows the former US commitment in terms of carbon intensity by 2025 under the Paris Agreement. Ameren (AEE) has since announced it is targeting a ~35% CO_2 reduction by 2030, off a 2005 baseline. After the retirement of two coal units in 2019 and 2020, American Electric Power (AEP) is targeting 38-40% of its fleet's capacity from coal, a 30% reduction from 2005 levels.

Exhibit 34:

US Utility carbon intensity in 2025, and % carbon intensity reduction 2005-25e



Source: SNL, Morgan Stanley Research. Note: the size of the dot indicates the absolute volume of carbon emissions; the vertical line indicates the overall resulting carbon intensity target under the Paris climate accord, while the horizontal line shows the US commitment to a reduction in carbon emissions under the Paris climate accord.

China: In contrast to the US, China's renewable energy effort is driven mainly by government policy. China's decarbonisation strategy began with previous President Hu Jintao's committing China to achieve 15% renewable energy among total energy consumption by 2020. Since then, China has set ambitious renewable energy installation targets, and provided investors with attractive returns through a feed-in-tariff structure.

In our view, China's commitment to renewables is not solely driven by air pollution or environmental concerns. Instead, China aims to encourage domestic renewable consumption in order to provide a boost to its renewable equipment sector. This explains why China's early wind/solar installations all have domestic component requirements. We believe China's manufacturing segment development strategy was fully achieved by 2016, with China accounting for ~30% and ~75% of the global supply of wind and solar equipment, respectively, and dominating the top 10 largest wind and solar module makers.

Individual companies are required to have different fleet profiles (the listed companies have specific generation type focus – some are primarily coal, some are wind, nuclear, solar, etc.). Fuel mix change considerations are therefore not made at the listed company level, but as dictated by the parent (state-owned) enterprises. Overall, we still believe the utility sector as a whole will meet the non-carbon targets (non-fossil share of generation to reach 20% by 2030) laid out by the Chinese government when they ratified the Paris Agreement.

India: The Indian government has set a target of achieving 175 GW of renewable capacity by 2022, which is set to increase to 500 GW by 2030, by which point renewable energy capacity would likely reach 59% (CleanTechnica, May 17, 2019)). In addition, it has introduced stricter emissions limits for existing and in-construction coal-fired power plants with a plan to replace/ retire plants that are >25 years old with supercritical (more efficient) coal-fired plants. The government has thus far identified ~37 GW of inefficient coal to be retired/replaced, which we expect to occur over the next 7-10 years. Finally, there is also a clean energy tax at a rate of INR 400 levied on every ton of coal used in producing electricity, and a concerted effort to broadly implement energy efficiency.

Brazil: The dominance of hydro in Brazil's power sector means it has a much cleaner energy mix than other countries globally. Looking ahead, although the current administration has supported the development of new large hydro generation projects, the improving economics for wind and solar should result in a declining share for hydro. Wind power is now the lowest cost source of power in Brazil, while solar power is well on its way to being one of the cheapest sources.

Risks

Cheap gas

The globalisation of natural gas could potentially be a headwind for renewable growth penetration. Our global energy team believes that a new wave of investment in LNG will create a global gas market. They expect to see near-record sanctioning of new LNG investments over the next 2-3 years, with ~155 mtpa (million tonnes per annum) of 'very likely' and 'likely' projects — supporting nearly 50% growth in the global market size by 2025.

Natural gas prices in North America, Europe and Asia (historically independent regional markets) look set to converge, delinking global natural gas and oil prices in the process. With a large availability of cheap gas, we expect the US to act as a swing producer — unleashing low-cost shale gas into global gas markets. Long-term LNG prices are likely to hover between marginal costs to produce and ship US LNG during periods of oversupply ($5.00-5.50/mmbtu in Asia), and the break-even price of new projects during periods of supply tightness ($6.50-7.50/mmbtu in Asia).

Long-term gas prices will be cyclical but MS expects them to average 40% below history. On the positive side for the energy transition, this will bring continued headwinds for the global coal industry, with an acceleration of coal to gas switching trends. However, should gas prices trend low enough to make gas power generation materially below that of renewable power generation, this could disincentivise investment in new wind and solar capacity. For more details, please refer to Natural Gas: Fueling Global Disruption.

Stock Implications

North America Utilities

NextEra Energy is targeting a 67% reduction in CO2e intensity levels by 2025 (from 2005 levels). Based on its current emissions intensity, this implies an annual rate of improvement of 5.7% through 2025. The company plans to do this by phasing out a coal facility and installing more solar capacity. By 2020, NEE projects that its energy mix will have more solar than coal and oil. Currently its renewable energy mix is 37% and 33% of EBITA is related to utility fuel switching.

AES is targeting a 70% reduction in emissions intensity by 2030 (from 2016 levels), implying a ~5.4% annual reduction. The company has been proactive in adopting the recommendations of the Task Force on Climate-Related Financial Disclosures (TCFD), which includes addressing stranded asset risk due to its historically heavy reliance on fossil fuel generation. The company has made noticeable strides in its decarbonisation efforts, including the sale or retirement of 4.3 GW of fossil-fired generation and the acquisition of 2.3 GW of renewables across power and wind assets in Brazil and Mexico. In 2018, its renewable mix was 27% and 18% of EBITA was related to utility fuel switching.

Atlantica Yield Plc owns and manages a diversified portfolio of contracted assets in power generation and transmission and 79% of its revenue is exposed to renewable energy.

Xcel Energy is targeting an 80% reduction in CO2e emission levels by 2030 (from 2005 levels), implying an annual reduction of 5.3%. This is largely being facilitated by i) a further shift into renewables, with plans to add thousands of megawatts of wind and solar capacity, and ii) the retirement of coal units.

American Electric Power and **Ameren Corp** (along with Xcel Energy) are midwest utilities where wind economics have become so favourable that the utilities can build wind farms and shut down coal plants while still producing a net economic benefit for customers. American Electric Power currently has a 14% renewable energy mix. Ameren Corp is targeting a ~35% CO2 reduction by 2030, off a 2005 baseline.

Clearway Energy Inc is a wind, solar, and gas plant owner and operator. Currently, 71% of its revenues are exposed to renewables.

CMS Energy Corp is a Midwest utility with favourable wind economics. The company is investing ~10% of its 5-year capex budget in new utility renewables.

Edison International is predominately a wires-only utility company; currently its renewable energy mix is 37%.

Entergy Corp, Southern Company, Dominion Energy, Duke Energy (and NextEra) are southeast utilities that are accelerating decarbonisation efforts through a combination of solar investments and investments in gas infrastructure to replace coal-fired power plants. Currently, Entergy's renewable energy mix is 0.3% and MS analysts estimate that 14% of EBITA relates to utility fuel switching. Southern Company's renewable energy mix is 11% and MS analysts estimate that 4% of its EBITA is related to utility fuel switching. Approximately 8% of Dominion Energy's EBITA is related to utility fuel switching.

Eversource Energy is a 'wires only' utility company that will need to increase capex to modify the grid, and has an unregulated clean energy business. The company is investing in US offshore wind projects, which Morgan Stanley's US Utilities team estimates will represent ~4% of the company's value in mid 2020.

Exelon Corp and **Public Service Enterprise Group** are competitive merchant generation businesses with low carbon intensities that would benefit from state or federal efforts to reduce carbon emissions. Exelon Corp owns a merchant nuclear generation fleet, which represents ~$11/share or 18% of the total value that the US Utilities team estimates for the company. Public Service Enterprise Group owns a merchant nuclear generation fleet, which represents ~$6/share or 9% of the total value that the US Utilities team estimates for PEG, and the team expects the company to invest ~10% of its capex budget in energy efficiency and renewables.

NextEra Energy Partners LP is a wind, solar and gas plant owner and operator. MS analysts estimate that currently 86% of revenues are exposed to renewable energy.

Pattern Energy Group Inc is a wind and solar asset owner and operator with 100% of revenues exposed to renewable energy.

Sempra Energy and **Consolidated Edison** are 'wires-only' utilities (i.e., no ownership of power plants) that will need to increase capex to modify the grid to permit greater renewables penetration. MS analysts estimate that Sempra Energy currently has 1% of EBITA exposed to utility fuel switching, and Consolidated Edison 7%.

European Utilities

EDF has a portfolio of 6.8GW in Renewables capacity (24 GW including hydro). However, this exposure is dwarfed by its Nuclear business, which represents the majority of the company. Currently, its renewable energy mix is 12% and MS analysts estimate that 14% of EBITDA is related to utility fuel switching (incl hydro).

EDP Energias de Portugal SA has exposure to 11.3 GW of wind and solar capacity through its 82.6% owned subsidiary **EDPR** (mainly in wind), along with plans to reinvest the proceeds of its hydro disposal into new renewable opportunities. 2018 renewable energy mix was 67%. MS analysts estimate that 67% of 2018 EBITDA came from renewables.

EDP Renovaveis is one of the few large and listed renewable pure plays in Europe, and it also has strong exposure to the US wind market. 100% of EBITDA is related to utility fuel switching.

Enel has today 39GW of renewables sources installed (of which c28GW is hydro). The company's business plan sees the path of installations annually getting closer to 4GW, and the company remains confident it is able to reach and maintain such a path. The new plan to be announced on November 16 should shed clarity on the future growth of the business. Noticeably, Enel has no exposure to offshore wind and does not plan to change this. The management continues to see better growth opportunities elsewhere for the group. Currently, its renewable energy mix is 40% and MS analysts estimate that ~30% of EBITDA is related to renewables.

Engie has 3.3 GW of renewables capacity (16 GW including hydro). However, Renewables is a core part of the strategy, with 6 GW secured and under construction to meet the target for 9 GW of gross additions by 2021. Currently, its renewable energy mix is 26% and MS analysts estimate that 17% of EBITDA is related to utility fuel switching (incl hydro).

Iberdrola is one of the leading renewable companies globally, with 16.6GW of installed capacity (29 GW including hydro). The company's 2018-22 plan envisages adding 10 GW (averaging 2.5 GW additions per year). Growth areas are primary Europe, Latam and the US, with the latter through its subsidiary Avangrid. The company also sees a further 10GW pipeline out to 2030. Currently, its renewable energy mix is 42%, and MS analysts estimate that 26% of EBITDA is related to utility fuel switching (incl hydro).

Orsted is set to continue to lead development in the global offshore wind market for the next decade and beyond. We believe that it can achieve its ambitious growth targets (15GW offshore by 2025 / 30GW+ onshore and offshore wind by 2030), and go above and beyond these, creating significant shareholder value. We are confident in Orsted's growth given: 1) the sheer amount of offshore wind growth planned globally and clear industry levers to reduce costs; and 2) Orsted's strong track record of winning competitive auctions (~1 in 3GW so far) and ability to deliver below budget. Currently, its renewable energy mix is 84%. MS analysts estimate that 92% of 2018 EBITDA is related to utility fuel switching.

RWE post the proposed asset swap deal will be the 4th largest renewable generator in Europe with 9.1GW capacity, with plans to add 2-3GW per year going forward. Based on the new RWE structure (post the planned E.ON asset swap) applied to pro-forma 2018 numbers, the renewables energy mix is 15%, and MS analysts estimate that 60% of pro-forma 2018 EBITDA comes from renewables.

SSE plans to simplify its business over the next year as it exits E&P and B2C retail energy supply, creating a focused Networks (~45%) / Renewables (~40%, of 2022e EBITDA) business. Its 4GW of renewables assets are a mix of hydro, on- and offshore wind assets, and it has a significant pipeline of new growth projects in the UK and Ireland. MS analysts estimate that 36% of EBITDA is related to utility fuel switching.

Asian Utilities

Huadian Power, Huaneng Power, Datang International Power and **China Resources Power** are all Chinese coal power companies that are increasing the amount they invest in renewable power generation. MS analysts estimate that revenue exposures to the utility fuel switching theme for Huadian Power, Huaneng Power, Datang International Power and China Resources Power are 7%, 5%, 26% and 31%, respectively.

Huaneng Renewables, China Longyuan Power Group, China Suntien Green Energy and **CGN New Energy Holdings** are Chinese renewable utilities companies. MS analysts estimate that revenue exposures to the utility fuel switching theme for Huaneng Renewables, China Longyuan Power Group, China Suntien Green Energy and CGN New Energy Holdings are 100%, 93%, 82% and 59%, respectively.

LatAm Utilities

AES Tiete Energia is a pure generation company which is highly focused on renewables growth. It does not have exposure to fossil fuels. 100% of EBITA is related to utility fuel switching.

Engie Brasil is also a pure generation company. It is reducing its exposure to fossil fuel by selling coal fired plants. MS analysts estimate that 87% of EBITA is related to utility fuel switching.

Enel Chile generates and distributes energy in Chile, and has a strategy of growth in renewable capacity, targeting a coal-free mix.

CPFL Energia is an integrated electricity company involved in both generation and distribution operations. It is exposed to renewables through its subsidiary CPFL Energias Renovaveis, which MS analysts estimate accounts for 23% of the group's EBITDA as of 2018.

Equipment Manufacturers

First Solar designs and manufactures solar modules using a proprietary thin film cadmium telluride semiconductor technology. FirstSolar's customers typically develop, own and operate solar power plants or sell turnkey solar power plants to end-users. 100% of EBITA is related to utility fuel switching.

General Electric supplies wind turbines for onshore and offshore platforms in addition to support services representing around 8% of revenues (MS analysts estimate).

Goldwind is a global provider of comprehensive wind power solutions, and its business includes R&D for wind turbine generators, manufacturing and sales, wind power services, and wind farm investment, development, and sales. 100% of EBITA is related to utility fuel switching.

Nexans manufactures and sells an extensive range of cables and cabling systems to industries including offshore wind farms. MS analysts estimate that 12% of EBITA is related to utility fuel switching.

Prysmian operates in the cables and systems industry. It supplies numerous industries including wind and solar. MS analysts estimate that 13% of EBITA is related to utility fuel switching.

Senvion (not covered) is a wind turbine manufacturer for both onshore and offshore wind installations.

Siemens is exposed to renewables via its ownership of Siemens Gamesa, a provider of onshore and offshore wind technologies and services. Siemens is also helping to enable greater renewable energy adoption via grid automation. MS analysts estimate that 6% of EBITA is related to utility fuel switching.

SunPower is a vertically integrated solar products and services company which designs, manufactures and markets solar electric power technologies. 100% of EBITA is related to utility fuel switching.

Titan Wind Energy Suzhou Co Ltd specialises in the production and distribution of wind towers and wind power related components and parts. 100% of EBITA is related to utility fuel switching.

TPI Composites manufactures composite wind blades. It has facilities in North America, Europe and Asia to make lightweight and durable wind blades. MS analysts estimate that 98% of EBITA is related to utility fuel switching.

Vestas is a leading provider of onshore wind turbines & services globally. 100% of EBITA is related to utility fuel switching.

Other

Bloom Energy designs, manufactures and sells solid-oxide fuel cell systems. It offers Bloom Energy Server, a stationary power generation platform that converts standard low-pressure natural gas or biogas into electricity through an electrochemical process without combustion. Bloom's fuel cells can be run on biogas from farms and landfills to capture methane and create renewable electricity.

Hannon Armstrong provides debt and equity financing to energy efficiency, wind, and solar projects in the US. The company is structured as a Real Estate Investment Trust. MS analysts estimate that 71% of EBITA is related to utility fuel switching and 22% to energy efficiency.

Landis Gyr Group is the market leader in smart electric metering worldwide, supplying metering infrastructure (AMI), software and services to ~3,500 utilities globally. MS analysts estimate that approximately 75% of revenues are exposed to smart meters.

New Energy Solar is an externally-managed pure-play renewables investment fund, with ~501MW of solar projects across the US and Australia. 100% of EBITA is related to utility fuel switching.

Sunrun is a dedicated residential solar company in the US. It designs, installs, finances, insures, monitors and maintains the system for the homeowners. MS analysts estimate that 95% of EBITA is related to utility fuel switching and 5% to energy storage.

Renewable Storage

CATL (Contemporary Amperex Technology) develops and manufactures batteries for energy storage systems (and EVs). It also has R&D and manufacturing capabilities in battery materials, battery management systems and battery recycling and reuse. MS analysts estimate that 5% EBITA is related to energy storage.

LG Chem is a diversified and vertically integrated chemical company. Within its Energy Solutions business it manufactures lithium-ion batteries for energy storage systems (as well as for electric vehicles). MS analysts estimate that 12% of EBITDA in 2019 is related to its Energy Solution mix, which includes EV batteries, Energy Storage Systems (ESS) and small-sized batteries.

Samsung SDI manufactures rechargeable batteries for various industries including energy storage systems. It also produces materials that are needed to make semiconductors and solar panels. MS analysts estimate that the company's revenue exposure to renewable storage was 7% in 2017 and 16% in 2018. MS analysts expect it to rise to 10% in 2019e and 11% in 2020e.

SK Innovation is an energy and petroleum company, but its Battery division manufactures lithium-ion batteries for the EV industry. MS analysts estimate that approximately 2% of revenues in 2019 is related to its EV battery business.

Tesla's Powerwall product is a battery for storing excess renewable energy generated during the day in order to then release it when it's needed. 100% of EBITA is related to alternative fuel vehicles.

Further reading on Renewables

Sustainability & Utilities: A Deep Dive into Decarbonization (September 24, 2019)

Utilities & Materials: Renewables – From Big Government to Big Business (June 5, 2019)

Sustainability & European Utilities: ESG Face Off: Oersted & RWE - Is RWE the new Energy Transition stock in Europe? (February 25, 2019)

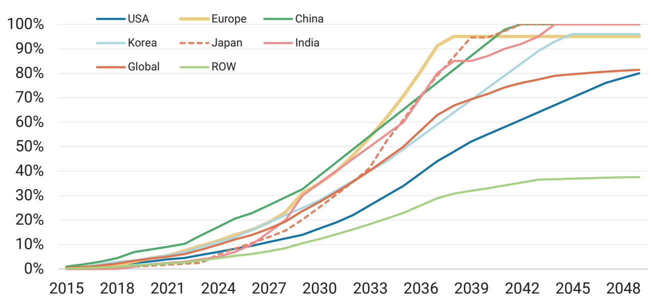
Electric Vehicles

Increasingly strict regulation and new products are driving electric vehicle (EV) penetration across Europe and China. We estimate $11 trillion capital investment in EVs and related infrastructure over the next thirty years. The exact contribution to net zero goals will depend largely on the investment in renewable power generation to power such vehicles. We forecast 2Gt emissions reduction by 2050.

Contributing equity analysts: Rahul Anand, Vincent Andrews, Harald Hendrikse, Craig Hettenbach, Tim Hsiao, Adam Jonas, Ryan Kim, Shawn Kim, Jack Lu, Javier Martinez de Olcoz Cerdan, Kota Mineshima, Dominik Olszewski, Masahiro Ono, Young Suk Shin, Takato Watabe, Charles Webb, Kazuo Yoshikawa, Rachel Zhang. Contributing commodity strategists: Susan Bates, Marius van Straaten.

Exhibit 35:

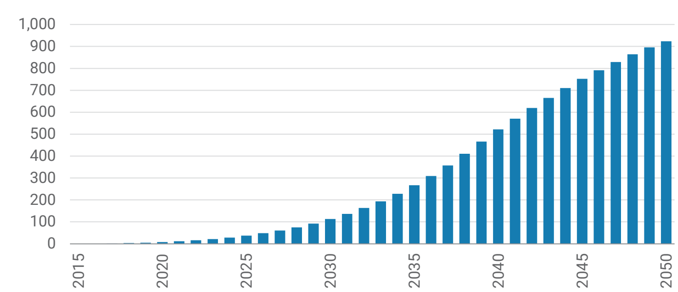
The US lags in terms of BEV sales penetration by country



Source: Morgan Stanley Research

Exhibit 36:

Rapid growth in the global BEV car park (million cars)



Source: Morgan Stanley Research

Contribution towards decarbonisation

Passenger cars account for around 7% of global greenhouse gas emissions [19] . Despite a growing focus on electrification of the road fleet, emissions have continued to increase due to 1) trends for larger and heavier cars (SUVs), 2) a switch away from diesel in Europe due to air pollution concerns, and 3) structural growth in car demand and car fleets in emerging markets (mainly China).

But there are signs of change. In July 2019, VW CEO Dr. Herbert Diess said: *"Volkswagen AG's passenger car brands alone are responsible for 1% of global CO2 emissions through the use of their vehicles. We aim to reduce this to 0."* Outside of regulatory limits, VW has set a target to reduce lifecycle CO2 per vehicle by 30% from 44T to 31.6T per vehicle by 2025. VW's new ID.3 model is being delivered completely carbon neutral to customers for the first time, and should be carbon neutral in use if consumers use a suggested renewable energy contract from VW. Elsewhere, four major automakers (Ford, Honda, BMW and VW) have stated their support for California to set its own more stringent tailpipe emission reduction targets in the US, targeting 3.7% annual reduction of emissions through 2026, which is far stricter than the targets proposed by the current administration.

We forecast 113 million EVs globally by 2030 and 924 million by 2050. To reach this level of electric vehicles requires significant growth in sales from ~1.3mn units in 2018 to 23.2mn in 2030. This represents a change from 1.5% sales penetration to 23.7% in 2030.

Geographically, Europe is likely to have the highest level of total car park and sales penetration driven by legislative requirements that cap CO2 emissions at 80g/km by 2025 and under 60g/km from 2030. We also forecast significant growth across China (due to the new energy vehicle (NEV) credit system mandating low emission vehicles) and India, with the US 5-10 years behind in terms of sales penetration rates.

19 Source: IEA, 2018

Under the IEA Sustainable Development Scenario (SDS), 14.5% of the global car fleet must be electric by 2030 – vs 8% on Morgan Stanley forecasts. Given that less than 5% of the car fleet is scrapped annually, achieving higher fleet penetration for BEVs will take a long time.

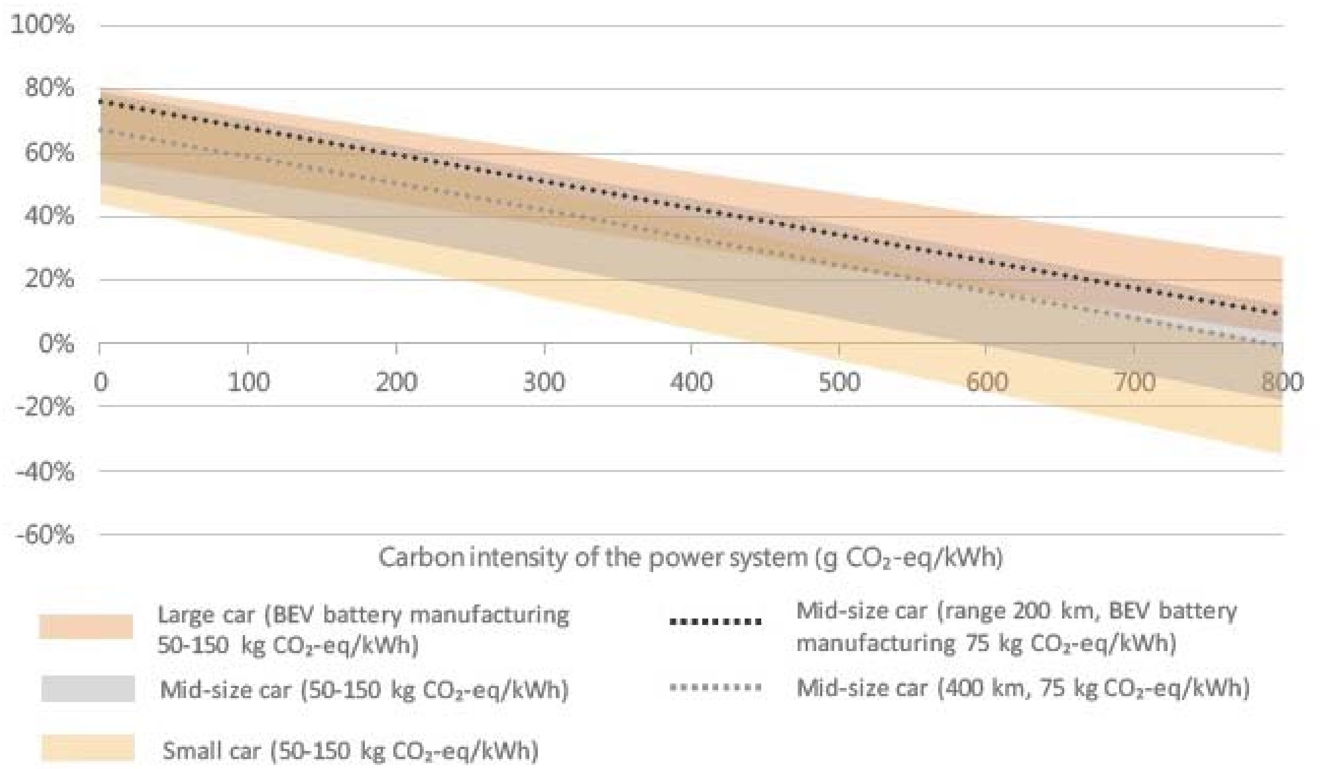
The actual contribution of EVs to reaching net zero emissions depends on the size of vehicles, battery manufacturing process and type of power generation. In principle, electric vehicles offer a clear route to low carbon mobility, with no direct emissions from the combustion of petrochemicals during the tank to wheel part of the life cycle. However, the actual net carbon benefit that adoption of EVs creates depends significantly on the size of the car, the greenhouse gas (GHG) intensity of the battery manufacturing process, and the carbon intensity of the electricity generation mix.

The IEA provides scenarios for carbon savings in EVs vs ICEs. As outlined in Exhibit 37 , a BEV could save 80% of life-cycle GHG emissions compared to an average internal combustion engine (ICE) vehicle of the same size. But in the worst case scenario, battery electric vehicles (BEVs) would actually have a higher carbon intensity than their ICE equivalent. VW's calculations suggest, however, that under its assumptions, BEVs are the most energy efficient alternative over the lifecycle of the vehicle.

We have estimated the impact of EV adoption on global emissions by taking direct emissions and emissions from power generation into account. In Exhibit 38 we outline the trajectory for passenger car emissions as EV adoption increases and power generation decarbonises.

Exhibit 37:

The contribution of EVs to achieving net zero emissions varies significantly depending on manufacturing process and type of power generation



Notes: In this figure, the upper bound of each area is relative to a BEV with 200 km range and a battery manufacturing GHG intensity of 50 kg CO_2-eq/kWh, while the lower bound is relative to a BEV with 400 km range and a battery manufacturing GHG intensity of 150 kg CO_2-eq/kWh. The intermediate lines in the area relative to the mid-size car refer to BEVs with battery manufacturing GHG intensities of 75 kg CO_2-eq/kWh. The carbon intensity of electricity generation varies only for the electricity used as a vehicle fuel; the power system GHG intensity for electricity used in vehicle cycle-related processes (i.e. manufacturing, disposal and recycling) is based on the GREET model and is constant.. The fuel consumption per km of small, mid-size and large cars is the same as in Figure 4.4. All other assumptions are the same as in Figure 4.2.

Sources: IEA analysis based on ANL (2018); IEA (2019a), (2019b), (2019c), (2019d).

Source: IEA 2019 EV outlook

Exhibit 38:

Net impact on emissions from EV adoption is minimal on our 2030 base case

	2018	MS 2030	2DS 2030	2DS 2040	2DS 2050
Direct Emissions					
# of ICEs (million)	1,181	1,226	1,145	992	449
Average emissions per ICE (t CO2)	3.1	2.9	2.7	2.7	3.0
Total direct emissions for ICEs (Gt)	3.6	3.5	3.1	2.7	1.3
Indirect Emissions					
# of EVs (million)	5	113	194	425	924
avg miles p.a.	12,000	10000	10,000	10,000	10,000
kwH per mile	0.275	0.25	0	0	0
kwH p.a	3300	2500	2,500	2,500	2,500
Total electricity (TWh)	17	373	641	1,403	3,049
CO2 emissions per TWh (Mt per TWh)	0.53	0.35	0.25	0.09	0.05
Total indirect emissions for EVs (Gt)	0.01	0.13	0.16	0.12	0.15
Total Emissions	3.6	3.6	3.3	2.8	1.5

Source: IEA, Morgan Stanley Research estimates

Looking out to 2050... For EVs, the big inflection point for adoption of the technology globally is around 2030, and by the mid point of the century Morgan Stanley forecasts nearly 1 billion electric vehicles globally. Morgan Stanley's global autos team currently forecasts 81% sales penetration for BEVs in 2050, resulting in a park penetration ratio of 67%. Within this, China is at 100% sales penetration, Europe 95% and the US 80%.

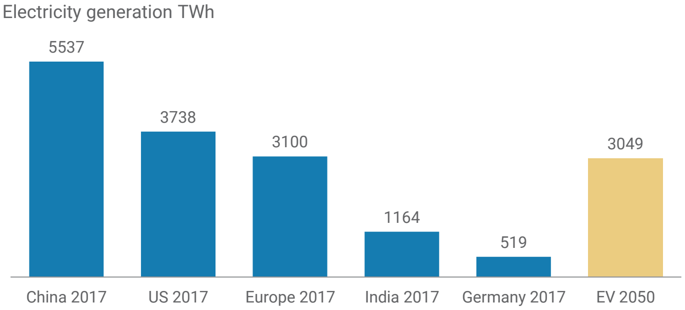
This level of EV adoption will require an additional 3000 TWh of electricity compared to today – a massive 12% increase on today's global electricity demand.

For electric vehicles to maximise their carbon reduction potential, this incremental power will need to be renewable, with implications for grid and network investment. We explore this in the **Renewables** chapter.

Exhibit 39:

Incremental electricity equivalent to European generation is needed by 2050 to power EVs

Electricity generation TWh



Source: IEA, Eurostat, Morgan Stanley Research

In addition to new renewable capacity, there will be a huge need for better network management. One of the main problems facing grid operators will be the potential additional demand at peak times. Reserve margins are built into the system so that there is enough generation to meet daily peak demand, and distribution networks are set up to be able to handle these peaks. Adding a new layer of demand from EVs at peak times could lead to greater system cost through the need for more generation capacity, as well as investment in new transmission and strengthening existing transmission and distribution networks.

There is also a strong likelihood that between now and 2050 there will be greater adoption of smart grids, 'time of use' tariffs and vehicle to grid capabilities. All of these should mean that the actual impact on peak demand is lower as there will be more ways to manage the grid to cope with peaks and troughs. In fact, smart chargers for BEVs could make use of the grid's spare capacity at low utilisation periods, rather than peak times, sharply reducing the need for new generation capacity.

ICE – Internal Combustion Engine Petrol or diesel-engined vehicle
AFV – Alternatively Fuelled Vehicle Vehicle not powered by traditional fuel
EV – Electric Vehicle Vehicle powered by e-chargeable battery and electric motor
BEV – Battery Electric Vehicle Vehicle powered by battery re-charged from the grid with range ~100 miles+
PHEV – Plug-in Hybrid Electric Vehicle Vehicle with plug-in battery and ICE engine - electric range ~30 miles
FCEV – Fuel Cell Electric Vehicle Vehicle powered by electric motor powered by fuel cell - range ~300 miles
NEV – New Energy Vehicle Plug-in hybrids and BEVs

Investment

Overall, to fully build out the required global infrastructure to support electric vehicles, we forecast $11 trillion of capital investment through 2050, or $350bn p.a. We model this across OEMs, gigafactories, battery components, electricity capacity and storage, and other infrastructure.

Exhibit 40:

EVs: Capital investment under 2DS could reach $11 trillion by 2050

	2020	2030	2040	2050
Number of BEVs sold (million)	3	23	80	102
Total Auto Unit Volume (000s)	87	98	116	125
ATP ($)	23,000	28,037	34,177	41,661
Revenue	2,009	2,735	3,965	5,216
Capex/Sales (%)	6.0%	6.0%	6.0%	6.0%
R&D/Sales (%)	4.5%	4.5%	4.5%	4.5%
Global Auto R&D + Capex				
Total Expenditure	211	287	416	548
Of which BEV (%)	25%	50%	55%	60%
Annual BEV Capex + R&D ($bn)	53	144	229	329
Cumulative BEV Capex + R&D ($bn)		982	2,845	5,632
Gigafactories				
# of battery purchases (million)	3	23	80	102
Gigafactory cost per car	10,000	10,000	10,000	10,000
Capex $bn	131	518	912	1,155
Material Suppliers Capex				
Copper Foil				
kg per KWh	0.70	0.70	0.70	0.70
$ per ton	12,500	12,500	12,500	12,500
Kg (million)	124	973	3,378	4,280
$billion	2	12	42	53
Cathode materials				
kg per KWh	1.65	1.65	1.65	1.65
$ per ton	8,000	8,000	8,000	8,000
Kg (million)	293	2,293	7,963	10,088
$billion	2	18	64	81
Anode materials				
kg per KWh	1.00	1.00	1.00	1.00
$ per ton	8,000	8,000	8,000	8,000
Kg (million)	178	1,389	4,826	6,114
$billion	1	11	39	49
Battery R&D				
R&D per kWh	10	8	4	4
kWh per car	60	60	60	60
Total kWh (million)	178	1,389	4,826	6,114
Cumulative R&D cost (billion)	2	13	33	38
EV Infrastructure				
Charging infrastructure				1,380
Electric Utility Infrastructure				615
Metals Mining Capacity Investment				352
Total $bn				2,347
Electricity generation and storage				
Total Electricity Needed TWh		641	1,403	3,049
Load factor		31%	31%	31%
Total Renewable power capacity vs 2018 (GW)		240	525	1,141
Capex per MW ($mn)		1.2	1.2	1.2
Capex $bn for renewables		287	630	1,368
Capex $bn for storage		10	76	266
TOTAL $		1,852	4,639	10,990

Source: IEA, Morgan Stanley Research estimates

Technology

There are already an estimated 5 million EVs on the road [20] . While this represents just 0.4% of the global car fleet, it is a three-fold increase since 2016, and grew by 40% in FY18 alone. Battery costs and range anxiety are two barriers to greater mass adoption, but we think these can be overcome to enable the mass adoption of electric vehicles.

Battery cost reductions

Cost reduction in EV battery cells is key for volume production and higher penetration. The biggest obstacle to mass adoption of electric vehicles is the cost of the battery, with cost parity between an EV and an ICE vehicle estimated across the industry to be around US$100 per kWh. Morgan Stanley analysts estimate that the current price of one EV battery pack is around US$150, although it does vary depending on the battery cell producer. VW has stated that it has achieved battery cell costs of under €100 per kWh for its electric vehicle programme.

The price of EVs is still much higher than for ICE vehicles – especially cheaper petrol technologies – but this may not remain the case. This is particularly true if rising regulatory requirements continue to push ICE vehicle costs higher, as well as raise the cost of driving ICE cars as governments price their CO2 footprint. Volvo's (and other OEMs') announcement that all launches after 2019 would be hybrid or BEV immediately reduces the BEV cost barrier significantly by eliminating the cheapest current petrol engine option. Hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs) bridge at least half the cost gap with full BEVs.

Original equipment manufacturers (OEMs) are increasingly incentivised to sell PHEVs and EVs to meet fleet emission requirements. Consumers on the other hand could conceivably benefit from lower annual road taxes, lower road tolls or congestion charges, or even use of dedicated traffic lanes for low- or zero-emission vehicles. This is quite apart from any direct government purchase subsidies and the much lower costs of driving – electricity charging costs are far lower than similar petrol or diesel fuel costs, in Europe especially (less so in the US). If global cities continue to regulate against the driving of diesel (and ICE) cars to improve air quality, then BEVs could become the only option for consumers in such cities.

Difference in total costs for EV vs ICE is surprisingly small. Morgan Stanley's battery materials analyst, Ryan Kim, has attempted to model the monthly running costs of BEVs to the consumer, including the much higher (current) transaction prices – see **Exhibit 41** . For more information, please refer to Initiating on EV Battery Material Suppliers: Be Selective (February 20, 2019).

He has assumed that (at least early on) EVs have much lower residual values than ICE cars. Car buyers may question the longevity of BEV batteries, and a fast rate of technological change (battery improvement) could cause a higher rate of obsolescence. This suggests that lease costs will be much higher for BEVs, as greater depreciation has to be covered during the life of the lease. Monthly lease costs for PHEVs and BEVs could therefore be 50-100% higher than the monthly lease costs for petrol-engined alternatives – if in fact non-hybrid petrol and diesel engines remain available in a tighter emission world.

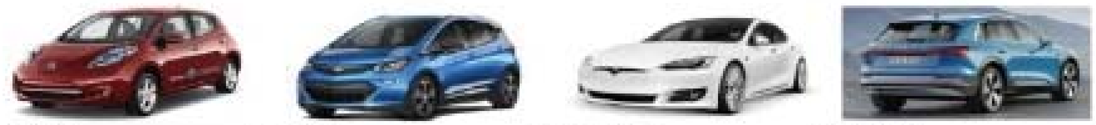
But if we bring in total running and ownership costs, BEVs can start quickly to close that gap. We assume PHEVs and BEVs have 75-80% lower fuel costs, somewhat lower insurance costs (due to lower costs to fix and potentially higher active safety content), and lower service costs than current ICE vehicles. On this basis, assuming European fuel prices, the fuel and running costs for BEVs could be as much as 75% lower than for current petrol or diesel engined cars. Lower fuel prices in the US mean that the running cost advantage for BEVs is much smaller.

If we add it all up, we calculate that, although hybrids and extended-range EVs are still 15-20% more expensive all-in, the BEV cost per month comes to just €534, versus €517 for petrol and diesel cars – not a huge cost difference. If we raise our annual mileage assumption, or assume any closing of the relative new car purchase price, BEVs could soon become very competitive with existing cars on attractive finance rates (at low current rates) and in high fuel-cost countries. If, as Volvo has indicated, pure petrol or diesel vehicles disappear, then BEVs could actually become the cheapest option for consumers, even at current cost levels. This would support why OEMs' BEV strategies have become so much more ambitious.

20 Source: IEA

Exhibit 41:

We estimate battery prices will fall from over US$400/kWh to around US$115/kWh in 2020



EV Model	Nissan Leaf	GM Bolt	Tesla Model 3	Audi E-Tron
Year model	2015	2017	2018	2020
Battery	**24kWh**	**60kWh**	**75kWh**	**95kWh**
Price	$30,000	$35,000		
Battery pack price	$10,000	$14,000		
Battery price ($/kWh)	**$417**	**$233**	**$190**	**$114**

Source: Morgan Stanley Research estimates

We believe that cost parity between EV and ICE vehicles is achievable by around 2025. This is driven by (i) advances in battery technology, which could help reduce battery costs to close to $100/kWh by the early 2020s; (ii) silicon carbide chips within EV powertrain components, which could save $1,000/car, or 8% of the average cost of an EV; and (iii) rising ICE content costs to meet tougher emission standards. However, we believe that ICE cars simply won't meet emission standards, and so whatever the outlook for costs, OEMs (and governments) will push consumers towards buying BEVs, and will simply level the cost playing field through tax and / or financing changes.

Improving battery density is key to cutting manufacturing costs. New technology has enabled cost reductions of 20-30% annually over the past seven years, and we expect the pace of decline to moderate to 14% in the next five years. Technical advances in cathodes, anodes, elecfoil, and electrolytes could increase the density of batteries over the long term. For instance, the use of nanotechnology to reduce the layering of cathodes and eliminate dead space could eventually improve battery cell capacity. New materials to replace current graphite anodes, such as high-capacity silicon, store up to 10x more lithium ions through swelling. Another approach is the combination of the cathode and electrolyte to increase voltage from the current 3.6V for NCA type batteries to more than 4.0V. At the cathode material level, nickel cobalt manganese (NCM) and nickel cobalt aluminium (NCA) have significant advantages over Li-phosphate (LFP) and Li-manganese (LMO), which are about 15% and 30% more dense in terms of kg/kWh, respectively.

To reduce battery cell costs and enhance safety measures, EV battery material suppliers are focusing their R&D on high-nickel cathodes – NCM622 and NCM811. The nickel price per kg (US$13) is more than 75% lower than that of cobalt (US$60), due mainly to the limited number of suppliers. In our view, high nickel is an essential material for EV cell producers, and according to key domestic cathode suppliers, they are developing NCM811 production lines with EV cell producers (Samsung SDI, LG Chem and SK Innovation). A higher mix of nickel increases the total energy density of an EV cell. According to BASF, the energy density of NCM111 is 154Ah per kg, while NCM811 could reach over 185Ah per kg.

In addition to the path we see to falling technology costs, we observe that other technologies have overcome similar obstacles in the past. The cost of solar panels has fallen from $70 per watt to less than $1 in the span of 40 years. Even since 1999, 20 years into the development of the solar panel, prices per watt have fallen 90%. The cost of lithium ion batteries, some 20 years after initial development, has fallen from over $1,200 per kWh initially to below $200 today. If solar panels are a guide, we believe lithium ion battery costs per kWh could easily fall below $100 by 2025, despite high material cost content.

Overcapacity of battery materials could also reduce the cost. Morgan Stanley European Chemicals analyst, Charlie Webb, expects the large volume market for cathode materials to commoditise, as a consequence of low barriers to entry, increasing competition, and the potential for meaningful oversupply in 2019-20. Furthermore, MS estimates that global EV cell producers' capacity expansion is much greater than that of demand growth, which would cause an oversupply of cathode materials.

Silicon carbide chips

Silicon carbide wafers are an alternative to traditional silicon material, with specific advantages for applications in automotive and (some) industrial settings. Silicon carbide (SiC) is a 'wide-band gap' semiconductor with specific properties appropriate for high thermal conductivity and low on-state resistance. Key features of SiC semis include: (1) ability to handle voltages 10x higher than those of silicon; (2) higher temperature operation – up to 400°C; (3) higher thermal conductivity as they can dissipate 3x more heat than silicon; and (4) faster switching. SiC-based power semis can be used in the on-board charging units and traction inverter in an electric car. SiC transistors help improve miles per charge through both raw efficiency savings, as well as reduced weight. They also enable greater power delivery, thereby reducing charging times. Their physical properties compare favourably to existing best-in-class insulated-gate bipolar transistor (IGBT) products.

Key global suppliers of SiC devices include STMicroelectronics, Infineon, On Semiconductor and Rohm. Today, silicon carbide is a nascent market which is likely to grow significantly. Among covered European companies, STM has been investing and developing SiC technology for many years. The company expects to achieve a doubling of SiC product revenues for 2019 to $200m (vs $100m in 2018), driven by orders at Tesla. Industrial estimates for the size of the SiC vary in the $1.5-3bn range by c2023, with STM targeting >30% market share.

Availability of raw materials

Cobalt

Rechargeable batteries are the main end-use for cobalt, representing 54% of 2018 global demand. Electric vehicles are taking over from a slowing consumer electronics sector as the key driver of cobalt demand growth. Morgan Stanley's forecast for EV sales to reach 9.6 million in 2025 will require 55kt cobalt – up from 3kt for 520,000 BEVs in 2016. We estimate that other EV types (pure/plug-in hybrid vehicles, e-buses) will require a further 14ktpa cobalt by 2025, up from 2.5kt in 2016.

The majority of cobalt is mined as a by-product of copper (67%) or nickel (31%), limiting the supply response to a high cobalt price (i.e. supply is price-inelastic). Copper by-product output is dominated by the Democratic Republic of Congo (DRC) (62%), while nickel-associated material is mined in Australia (5%), Russia (4%) and Canada (3%). Key sources of medium-term supply growth are concentrated in the DRC – any expansion in mine capability there would lift the DRC's market share to 65-70% of global mined supply by 2020.

The global dominance of DRC mine supply, and of China's refined supply, is a source of concern among cobalt's end-users – particularly auto-OEMs. The DRC's history of power shortages and political conflict pose ongoing risks for cobalt supply. In the near term, automakers' attempts to secure long-term supplies from elsewhere present upside risk to price, since little growth in mine supply is forecast ex-DRC – much of which is tied to the nickel price outlook.

Global cobalt resources are estimated by the United States Geological Survey at 25Mt Co (USGS), with reserves of 7Mt (48% DRC). The high price through 2017-18 encouraged considerable investment in new supply, driving the market into oversupply in early 2019. This has depressed the price, which in turn led Glencore to announce the suspension of its 25ktpa Mutanda copper-cobalt mine in the DRC by the end of 2019, due to 'reduced economic viability in the current market environment'.

In the long run, a cobalt-free battery future is possible, most likely via substitution by new technologies (lithium air and lithium sulphur are R&D themes). However, in the near term, the trend is towards increased cobalt usage per vehicle, as new regulations drive an industry shift towards higher energy density batteries (NMC/NCA).

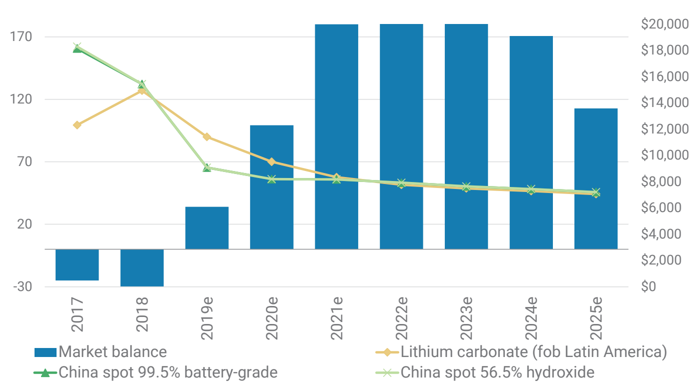
With the cut in capacity at the Mutanda mine and a recovery in China's demand for cobalt, our commodities analyst, Susan Bates, expects the market to return to balance in 2020, from 2019's substantial market surplus. This will drive a recovery in price from a low of $11.60/lb in mid-2019 back to $20-22/lb through next year. Beyond 2022, Susan sees continued support from the demand side, but the battery industry's propensity to thrift in response to sharply higher cost inputs, and the ongoing development of recycling flows, could act to limit upside price risk.

Lithium

We see 2025 EV sales penetration of 10% driving 682kt global lithium demand – a 20% CAGR. Yet despite the strong demand growth, lithium is not a scarce material – and lithium producers have responded to very strong prices through 2016-18 by bringing on new capacity, driving the market into persistent oversupply.

Exhibit 42:

Our Commodities team estimates an excess production of lithium equivalent in the coming years, which can be converted into hydroxide or carbonate



Source: Morgan Stanley Research estimates (e)

As the price has fallen in 2019, supply has begun to respond, with project delays and production cuts – particularly among Australia's producers of spodumene (a source of lithium). However, we continue to see oversupply of raw materials globally as growing conversion capacity means a greater portion of the lithium produced is reaching end markets. Costs are also falling, bringing further downward pressure on price.

While China's spot price is now close to the marginal cost of production, the current 25% premium for lithium carbonate fob Latin America ($10k/t) vs China ($7,700t) is unsustainable, in our view, and our commodities team sees a continued trend lower in the Latin America price, which is still well above the cost of production for the key brine producers. MS forecasts a fall in the price of lithium carbonate fob Latin America to $9,525/t in 2020, thereafter trending lower to $7,210/t by 2025 (see metal&ROCK: The Price Deck – 4Q 2019).

Copper

Electric vehicles are more copper-intensive than combustion engine vehicles, consuming up to 75kg of copper (of which 40kg in the battery; 35kg in the motor/wiring harness) vs 20kg in a combustion engine vehicle. By 2025, we estimate copper use in all types of electric vehicle will total 1.2Mtpa; rising to 8.3Mtpa by 2050. Risks to this growth arise from increased use of aluminium as automakers strive to lighten vehicles in order to extend range; and ultimately the potential for wireless technologies to substantially reduce the need for vehicle wiring.

Copper is also used in the associated charging infrastructure and power grid, although demand from these applications varies dramatically depending on the type of charging used. In the near term, we expect electric vehicles to be primarily city-based, with home charging the principal solution. This is unlikely to require an overhaul of grid infrastructure and slow, domestic charges use less than 1kg copper per unit, so gains are limited. However, in the longer term, as electric vehicles reach critical mass, ultra-fast charging solutions are more likely to be implemented. Current fast-charging units consume between 5-8kg per unit, as well as associated wiring to connect to the grid. Some countries may also need to invest further in grid upgrades to facilitate charging, which would further benefit copper demand.

If the power for EVs is to be derived from renewable sources, then the requirement for copper will be larger still. Current wind power generation uses 4-12x the volume of copper per MW vs conventional power generation (depending on whether turbines are on-shore or off-shore), consuming between 2.5-10 tonnes per MW. Large-scale photovoltaic solar power installations have a similar intensity of use to land-based wind power, although residential systems are lower in intensity of use and – as in electric vehicles – aluminium is gaining market share in some electrical components. Assuming demand per MW at the lower end of the possible range, though, still implies an additional 6Mt of copper required in renewable energy by 2030 - although netting off the loss of demand in conventional power generation brings this down to around 4.5Mt.

These gains form a bull case for long-term copper demand, offsetting declines from a maturing China economy, rising secondary material availability and substitution threats to ensure that copper's intensity of use vs economic growth remains stable into the long term.

Policy

The pace at which policy has driven carbon-related change in the autos sector has not been seen in any other industry group. Europe and China are leading the way on emissions regulations, but we believe that ICEs will generally be unable to meet the stringent CO_2 (and NO_x) targets that have been announced. As such, electric vehicles will be needed in order to meet the targets long term. As Herbert Diess, VW CEO, said in his 2017 Annual Roundup: *"Economically meaningful measures to lower CO_2 have been exhausted... That means: we need electric vehicles to meet fleet targets."*

Exhibit 43:

Cities are leading the way with measures to reduce CO2 emissions

City / Country	Legislation	Date Implemented
Pending Regulation		
New York	• Drivers will likely be charged >$10 per day for driving in Manhattan, south of Central Park	Expected 2021
San Francisco	• Developing Congestion Pricing Plan with recommendations for a $3 charge to drive into an established congestion zone during peaks, with a $6 cap • Wants to ban cars and add 2.2 miles of bike lanes to Market St, one of city's busiest streets	TBD
Seoul (incl. metropolitan area)	• Diesel / high-emission ban. Banned vehicles entering Seoul or the surrounding metropolitan area will be fined 200M won ($180), with a maximum penalty of 2MM won ($1,800).	2020
Existing Regulations		
Brussels	• Decreased number of parking spots by 16% • Increased parking prices from €1.50 to €3.50 per hour, with price increases every hour, and a parking duration limit of 2-3 hours	Decrease in Parking Spots: 2011 Increase in Parking Rates: 2011
India	• Has ordered Uber and homegrown competitor, Ola, to electrify 40% of fleet by 2026. Uber and Ola must convert 2.5% of their fleet of cars by 2021, 5% by 2022 and 10% by 2023	2019
London	• Ultra Low Emission Zone (ULEZ) charge of £12.50 per day • Incremental Congestion Zone charge of £11.50 per day between 7am-6pm Mon-Fri	ULEZ: April 2019 Congestion Charge: Feb 2003
Oslo	• Elimination of parking spaces in city • Rush-hour charges for diesel vehicles to NOK 59 ($7.50) per day during the morning commute	Elimination of Parking: 2017
Paris	• CO2 emissions "bonus-penalty" system is in place. Drivers of low-emissions vehicles receive €4,000-€6,300 per year in subsidies. Drivers of high-emissions cars pay between €150 and €8,000 in fees.	"Bonus-Penalty": 2015
Shanghai / Beijing / Guangzhou	• Shanghai: Licence plate quota with just 0.2% odds of obtaining a plate • Beijing: Online auction for licence plates for ICEs, with average winning bid of $14,022 • Guangzhou: Hybrid auction / quota system with just 0.8% chance of obtaining a licence plate	2010
Singapore	• Implemented Electronic Road Pricing to charge a fluctuating rate to each car entering the city's business center. A system of electronic tolls assesses fares based on traffic volume, the time of day, and a "golden range" of ideal traffic speeds.	Ongoing updates since 1975
Stockholm	• Permanently instituted congestion charging zone from 6:30 am to 6:30 pm on weekdays and drivers are charged between €1 and €2 per day to enter the city	Congestion Charge: 2007

Source: Various Cities, Morgan Stanley Research. This was originally published in Autos & Shared Mobility: The Climate Opportunity of Auto 2.0: How Big Tech Drives Faster EV Adoption (September 5, 2019)

Europe. In 2020, a new carbon limit of 95g/ km will be introduced across the region with penalties for any manufacturer failing to meet the regulation. Following on from this, in April 2019 the EU announced that light vehicle carbon emissions will need to fall by 37.5% by 2030 versus 2021.

There are now also planned carbon limits for heavy vehicles. In February 2019, the EU agreed on CO2 emissions limits for heavy-duty trucks with a 15% reduction mandatory by 2025 (vs 2019 actual emissions). There is also an aspirational cut of 30% by 2030, which will be reviewed in 2022. The rules will be extended to medium-duty trucks, buses and trailers by 2022 and there will be financial penalties for failing to meet the targets, while new technologies will be able to receive super-credits.

In addition to European carbon regulation, there are a growing number of city bans on diesel cars (ie Frankfurt, Berlin), which should make it increasingly difficult for OEMs to meet the CO2 limits with ICE technology. The UK, France, Portugal and Spain have all committed to either banning ICE sales or reaching a 100% EV sales target by 2040. [21]

In the UK, the Committee on Climate Change (CCC) has published its report on reaching net zero emissions by 2050. In this it stated that "2040 is too late for the phase-out of petrol and diesel cars and vans, and current plans for delivering this are too vague."

US. In 2018, the Environmental Protection Agency cancelled the planned 2022-25 fuel economy standards for passenger cars and light trucks. There are a limited number of financial incentives for the EV industry with federal and state tax credits for purchasing new EVs in the US. Major automakers have stated their support for California to set its own, significantly more stringent tailpipe emission reduction targets in the US, targeting 3.7% annual reduction of emissions through 2026, which is more far reaching than the targets proposed by the current administration. The OEMs continue to push for a single US national emission standard, and many have expressed the hope that the voluntary agreement closer to the California standards will help achieve this goal and avoid regulatory uncertainty.

China: The regulatory environment in China has been actively encouraging EV adoption through caps on ICE production capacity, tax incentives, and licence plate restrictions. Earlier this year, the Ministry of Finance (MoF) announced it would cut the EV subsidy for this year. The government set higher requirements for EV battery energy density in this new scheme. To qualify for the full amount of the subsidy, the battery pack energy density must be 160Wh/kg or above vs. 120-140Wh/kg in 2018. The lower energy density battery of 140-160Wh/kg can only get 90% of the benchmark subsidy. For energy density between 125Wh and 140Wh/kg, the subsidy is just 80%. Below 125Wh/kg, there is no subsidy at all.

- The ePV national subsidy has been reduced by over 50% for the range >=250km and 100% for the range <250km;
- the eBus national subsidy has been lowered by 50%;
- the eTruck national subsidy has been cut by 50-80% depending on loading weight; and
- local subsidies for both ePV and eTruck have been cancelled and will be transferred to subsidise charging stations, but the local subsidy policy for eBus remains unchanged.

We believe this is intended to help create a healthy EV market by reducing the price of batteries for EV manufacturers. We would not be surprised to see further subsidy cuts, given battery companies' healthy profits and resources for capex and R&D spending. Recently, VW and Ford presented their view of 85% BEVs in China as "rather early" relative to penetration in Europe, with the US likely "rather late" (see the companies' joint presentation for further detail). In October 2019, China announced its NEV development plan (draft for public feedback) for 2021-35, targeting NEV sales at 20% of total auto sales in 2025 and 40% in 2030, which is ahead of our auto team's EV forecast for 15.5% and 29.1%, respectively.

India: In India, the government has begun phase 2 of the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME 2) scheme. This includes income tax rebates on interest paid on loans to buy EVs, customs duty exemption on lithium-ion cells, and investment linked income tax exemptions for component manufacturers. See The Next India: India's Transport EVolution (May 31, 2018).

Japan. The Japanese government is aiming for an 80% reduction in GHG emissions from domestically produced vehicles (90% for cars). This will be achieved through a mix of hybrids, BEVS, PHEVs and fuel cell vehicles.

Brazil. Conversely, automakers in Brazil are still prioritising ICEs, due predominantly to an already developed ethanol market, which the government has committed to prioritising. For example, recently Brazil's legislature issued a series of tax incentives, named Rota 2030, which offers considerable benefits to auto manufacturers that choose to invest in ethanol research [22] .

Risks

Type of electricity used. Switching from an ICE vehicle to an EV clearly removes the emissions from burning petrol, with the vehicles powered instead by electricity. But if that electricity comes from a coal-fired power station, and this station needs to be running longer hours to generate more output to satisfy the EV consumption, is that an environmental positive?

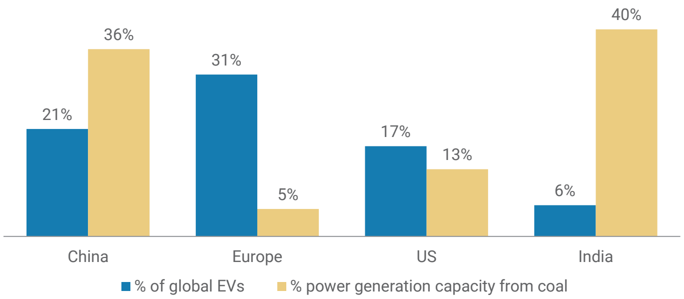
According to Morgan Stanley estimates, China will account for 21% of global EVs by 2030. Yet, 36% of its electricity generation is expected to come from coal.

21 Source: IEA Global EV Outlook 2019

22 Source: Reuters, March 26, 2019

Exhibit 44:

China is a key region for EVs by 2030, but over a third of power generation capacity is coal



Source: Morgan Stanley Research estimates

As highlighted earlier in this report, the life cycle emissions of an EV compared to an ICE can be anything from 80% lower to 30% higher depending on the size of the car, the manufacturing process and the type of electricity powering the car. In September 2019, the German Climate Cabinet therefore decided that as well as sustaining BEV subsidies in Germany, it would also remove obstacles to further investment in renewable power generation, and, at the same time, reduce the dependence on coal. Clearly, these policies need to go hand in hand.

Recycling of batteries. Post-consumption recycling of minerals from used EV batteries is needed for the products to have an environmentally positive life-cycle. Collecting e-waste has proven difficult – only 10-15% of gold in electronic goods is recycled, according to the United Nations Environment Programme (UNEP), compared with 70-90% of gold in industrial applications. Instead, much e-waste ends up in developing countries where it isn't processed appropriately; this leads to health and environmental problems. The size and cost of EV batteries should make this type of battery recycling somewhat easier – although at present, there are no large-scale facilities.

Tesla's recycling process with Umicore is an early example of recycling for EV batteries, which saves over 70% of CO2 emissions, and the recovery and refining stage for the core valuable metals. The most valuable material within the battery is cobalt, and Umicore's recycling process uses it to make lithium cobalt oxide – a product that can then be resold back to the battery manufacturers. According to Tesla, this has a positive economic as well as environmental impact. There is also a by-product from the recycling process, which is a lithium-based slag. This can be used in a number of different ways, including construction material. Cement manufacturing is a very carbon-intensive industry, and using this by-product instead of some traditional raw materials can reduce emissions as well as demand for incremental finite resource consumption.

One of the challenges of making battery recycling economically viable is the quantity of battery material that is needed to keep utilisation rates of recycling facilities sufficiently high. The risk, therefore, is that there may not be the necessary infrastructure in place in time for the first significant wave of EV batteries to reach end of life.

Sourcing of raw materials: The high concentration of cobalt supply in the DRC (51%) presents raised political and supply risk compared to other minerals that are sourced from a more diversified group of countries. Transparency International ranked the Democratic Republic of Congo at 161 out of 180 countries in its Corruption Perceptions Index in 2018, with a score of 20 out of 100. In addition, reports from various publications such as the Washington Post (September 30, 2016) and Financial Times (July 6, 2019) have highlighted human rights concerns within cobalt mining in the DRC.

Cobalt is not currently included in the US State Department's list of "conflict minerals", which are defined as those whose exploration and production are potentially connected to human rights violations in the DRC or adjoining countries. However, if there were an expansion of the list to include cobalt, the companies that use cobalt in their products would need to file conflict mineral disclosure reports to the SEC, under The Dodd-Frank Wall Street Reform Act of 2010.

For now, the responsibility lies with end users of cobalt to improve transparency of their supply chain. Companies using conflict minerals in their supply chain are vulnerable to reputational damage, increased regulation, stricter customer demands, and even operational disruption due to social unrest.

Lithium is mined primarily in Australia (35% in 2017, we estimate), South America (32%) and China (28% of global supply). It can be extracted in three ways: hard-rock mining (33% of supply), mineral conversion (32%) and extraction from salt lakes (35%). It is a very water-intensive process, which is a particular problem given that some of the major salt-lake lithium mines are located in regions of Argentina, Chile and China where there is medium to high risk of water scarcity, according to our analysis of water risk data from the World Resources Institute. This could have both environmental and social consequences, as local communities compete for use of limited water resources.

Safety: Lithium is highly flammable. If overheated or overcharged, Li-ion batteries may suffer thermal runaway and cell rupture which could, in extreme cases, lead to combustion, which is a cause of vehicle fires. To reduce these risks, lithium-ion battery packs contain fail-safe circuitry which disconnects the battery when its voltage is outside the safe range of 3–4.2V per cell.

Reliability: EV batteries degrade progressively, with reduced capacity, cycle life, and safety due to chemical changes to the electrodes. Capacity loss could amount to 30% after 1,000 cycles and capacity fades as a result of the passage of time and usage. Degradation is strongly temperature-dependent; it increases if batteries are stored or used at higher temperatures.

Disruptive new technologies: Alternative technologies such as fuel cells may become a more competitive option than EV in the distant future.

Stock Implications

OEMs

The transition to EVs requires higher R&D and capex investment spend for all of the OEMs, which has already diluted earnings and FCF and could eventually result in heavy costs from running down the legacy operations and restructuring the business. This restructuring of the legacy business is now starting, with OEMs sharply reducing 'complexity' through reduced ICE model offerings, fewer engines and transmissions, and sharply lower ICE development costs. Even on the BEV side, lower margins on BEV products may mean increasing margin dilution for OEMs if BEV penetration rises too quickly.

The OEMs are also cutting legacy costs and embracing consolidation through the sharing of technologies. Examples of this include the agreement between VW and Ford in the Argo autonomous mobility unit and in sharing the VW MEB platform, as well as the cooperation in autonomous software between BMW, Mercedes, and Audi, and sharing of electric drivetrain technology between Toyota, Suzuki, Mazda, Subaru and Daihatsu.

Long term, our Autos team believe **VW** and **Toyota** are best positioned for the transition to EVs, with VW also having the most ambitious BEV strategy and most developed BEV model roll-out plans. VW's ID.3 will be the first ever carbon neutral car delivered to consumers (carbon neutral in sourcing and production), and it will also have the ability (using renewable energy) to be carbon neutral in use.

Tesla is the only pure play EV company – see here for our latest thoughts.

Exhibit 45:

Latest BEV targets from major OEMs

OEM	Targets	Model launches
BMW	12 BEV models to be launched by 2023 and 13 PHEVs. Up to 25% of sales to be electrified by 2025. MINI could become an all-electric brand. 500k sales by 2019.	late 2019: Mini BEV; 2020: electric X3. 2021: iNext autonomous
Daimler	15%-25% of sales as EV by 2025 with 10 individual electric models by 2022. Mercedes: all models to have an electrified version by 2022. At least 130 electrified variants of cars.	2020: all smart models in EU to be electric; first in the all-electric EQ range (SUV), all-electric portfolio 2022
Volkswagen	2m-3m battery EV sales by 2025 (>25% of sales), with 50 pure BEVs to be launched, 30 PHEVs. All 300 models to have an electrified version by 2030. Audi: >30% sales as EV by 2025. 30 models of VW brand SUVs to be electric by 2025.	2018: Porsche Mission E; 2019: Audi e-tron; 2020: VW ID; SEAT to launch first pure electric car in 2020
Porsche AG	Investing EUR 6bn+ in Electromobility by 2022. May increase capacity for Mission E beyond 20,000 cars. Potentially electrifying Macan SUV.	2019: Porsche 1st all electric (Taycan)
Audi	Joint EV platform with Porsche, building 2 sedans and 2 SUVs	2025: Add 20 electric models (sell ~800k BEV/PHEV)
PSA	Five electrified models will be introduced by 2021, the first of which will reach the market in 2019. Seven plug-in hybrids by 2021. 80% of core models to have hybrid and/or BEV by 2023 with 40 new electrified models offered by 2025. 100% models electrified 2025.	2019: 208, DS 3 Crossback BEV; 2020: 2008 BEV; 2021: Partner BEV
Renault	21 new models by 2022. 30% of Alliance sales to be "electrified", 8 new pure BEV models, 12 electrified vehicles by 2022.	Leaf best-selling BEV. Zoe sold 30k in 12m
Tesla	Model S, X and 3 on sale.	
Ford	16 BEVs and $11bn investments in EVs by 2022, including hybrid F-150 and hybrid Mustang. 100% electrified by 2025 in China. Collab with Mahindra on SUV/EV.	2020: new small SUV BEV, 24 new hybrid and 16 BEV models by 2022
GM	Zero-emission vehicles would make up 15% of the new vehicle fleet in 2025 and 25% by 2030.	2016: Chevy Bolt. 2018: 2 new BEVs by end of year. 18 more by 2023.
FCA	Half of all Maserati volume to be electric by 2022. Over 30 nameplates to utilize 1+ EV systems by 2022 (FCA CMD 2018). They are targeting a €9bn spend in electrification by 2022.	After 2018: Chrysler Portal minivan. 2020: Fiat 500e, Maserati Alfieri. 2021: Jeep Grand Commander. 2022: Maserati Quattroporte
JLR	All models to have alternative or BEV drivetrains by 2020.	2018: Jaguar iPace (SUV)
Honda	Two thirds of sales to be hybrid or electric by 2030; all new European vehicles to have electrified option 2018	New China BEV in 2018. global 2019
Mazda	All of vehicles produced by 2030 electrified, while 5% of its cars will be BEVs. Mazda is focussed on developing its ICE fuel efficient tech but will add BEVs and electrification to its range from 2019. Mazda is working with Toyota on some of its new technologies.	Plans to market an all-battery EV in 2020. Will develop two battery EVs, one which will be powered solely by battery and another which will pair a battery with a range extender powered by the automaker's rotary engine.
Nissan	Launch 3 low-cost EV's under Venucia name by 2019. 12 BEVs by 2022 (Alliance. 10% of Europe BEV by 2020.). 20 electrified models by 2022.	
Subaru	Electrified strategy is starting but expensive. Subaru may join Toyota/Mazda in its JV.	New PHEVs in US in 2018, hull BEVs in 2021 starting with Outback, Forester.
Suzuki	JV with Toyota on Evs for India -first models 2020.	
Toyota	2022 BEV products on solid state battery; 10 BEVs sold in "early 2020s", all model electric option 2025; 1m annual by 2030, 5.5m annual BEV/PHEV by 2030. China production 2019.	2020: BEV ready for market from Toyota/Mazda/Denso JV
Hyundai	Hyundai and Kia are expected to introduce 31 eco-friendly models (10 HEV, 11 PHEV, 8 BEV, 2 FCEV) by 2020 Annual production target of 300k EVs(including HEV, PHEV, BEV, FCEV) by 2020	14 BEV models 2025, 38 electrified total - 2016: Hyundai, Ioniq EV (available in hybrid and battery EV variants) 2018: Hyundai, Kona EV (SUV-B segment) 2018: Kia, Niro EV (SUV-B segment) 2018: Kia, Stonic EV (SUV-A segment) 2021: Hyundai, Genesis EV(High-end sedan)

Source: Company data, Morgan Stanley Research

Battery Material Suppliers

Our analysts prefer leading anode and separator players over other segments in the global EV battery value chain because of the better supply structure, customised features of products and their position in mainstream EV value chains.

Beijing Easpring Material Technology Co is a China-based company engaged principally in the research and development, manufacture and sale of cathode material for lithium-ion batteries. MS analysts estimate that 60% of EBITA is related to alternative fuel vehicles.

Ecopro has focused historically on the development of eco-friendly core materials and parts related to air pollution control, but has started to diversify its product portfolio to core cathode materials for secondary battery cells. It is also involved in the manufacturing process of lithium cells for EVs. In 2018, MS analysts estimate that ~88% of its revenues were exposed to cathode materials.

Hitachi Chemical manufactures functional materials for the electronics industry. MS analysts estimate that currently ~1% of its EBITA is relates to utility fuel switching.

Iljin Materials is a Korea-based company mainly engaged in the production and sales of elecfoils, which are a key component of EV batteries. In 2018, MS analysts estimate that ~40% of revenues were exposed to copper foils used in electric vehicles.

Johnson Matthey is developing a battery technology platform. JMAT's eLNO cathode material remains a concept but, if it receives approvals, could prove disruptive. MS analysts estimate that revenue exposure to battery materials currently makes up a very small proportion of group sales.

L&F manufactures NCM cathode materials (80% of revenues), which are widely used in battery EVs. Lithium Cobalt Oxide or LCO batteries (18~19% revenues) are likely to remain dominant in consumer electronics applications

Ningbo Shanshan provides lithium battery cathode materials, anode materials and electrolytic solutions. MS analysts estimate that currently, ~74% of the company's EBITA is related to alternative fuel vehicles.

POSCO Chemtech is an integrated EV battery supplier in Korea. In 2018, only 8% of revenues were exposed to EV batteries but it aims to transform into a one-stop shop for EV battery materials, from graphite/synthetic anode to NCM cathode materials.

Shanghai Putailai New Energy Technology is a China-based company principally providing lithium battery anode materials, battery coating machines, separator coating and aluminum pouches, with customers in both domestic and overseas market. MS analysts estimate that 85% of the company's EBITA is related to battery material supply and 15% is related to battery equipment supply.

Umicore manufactures active materials for cathodes in EV batteries and MS analysts estimate that approximately 20-25% of EBITA is related to this theme.

Yunnan Energy New Material manufactures separators for EVs batteries and MS analysts estimate that this represents 70% of group revenues.

Battery Manufacturers

BYD researches, develops and manufactures rechargeable batteries and MS analysts estimate that over 40% of its EBITDA is related to alternative fuel vehicles.

CATL (Contemporary Amperex Technology Co. Ltd.) develops and manufactures batteries for energy storage systems (and EVs). It also has R&D and manufacturing capabilities in battery materials, battery management systems, and battery recycling and reuse. MS analysts estimate that 5% of EBITA is related to energy storage and 95% to alternative fuel vehicles.

Cummins has made a series of investments in EV batteries and has outlined $500mn for investment in electrification / alternative propulsion.

Guoxuan High-tech is a China-based company engaged principally in the manufacture of lithium-ion batteries and power equipment. The company's lithium-ion battery is used in electric buses, passenger vehicles and energy storage. MS analysts estimate that 5% of EBITA is related to energy storage and 95% to alternative fuel vehicles.

LG Chem is a diversified and vertically integrated chemical company. Within its Energy Solutions business it manufactures lithium-ion batteries for energy storage systems (as well as for electric vehicles). In 2019, 12% of EBITDA is related to its Energy Solution mix, which includes EV batteries, Energy Storage Systems (ESS) and small-sized batteries.

Panasonic is a global consumer electronics manufacturer. One of its many businesses is manufacturing automotive lithium-ion batteries. MS analysts estimate that 5% of EBITA is related to battery manufacturing for EVs.

Samsung SDI manufactures rechargeable batteries for various industries including energy storage systems. It also produces materials that are needed to make semiconductors and solar panels. MS analysts estimate that revenue exposure to alternative fuel vehicles was 15% in 2018. The Asia technology team forecasts the mix to rise further to 22% in 2019 and 26% in 2020.

SK Innovation is an energy and petroleum company but its Battery division manufactures lithium-ion batteries for the EV industry. MS analysts estimate that approximately 2% of revenues in 2019 is related to its EV battery business.

Semicons

SiC-based power semis can be used in the on-board charging units and traction inverter in an electric car. SiC transistors help improve miles per charge through both raw efficiency savings, as well as reduced weight. They also enable greater power delivery, thereby reducing charging times. Their physical properties compare favourably to existing best-in-class IGBT products. Today, silicon carbide is a nascent market but we expect it to grow significantly.

Analog Devices Inc., Maxim Integrated Products Inc and **NXP Semiconductor NV** sell battery management systems (BMS) into EVs. BMS measures the energy that goes in and out of a battery and constantly monitors voltage of various battery cells. These products improve the efficiency of battery packs, helping OEMs reduce costs in one of the most expensive parts of the EV. MS analysts estimate that Analog Devices Inc currently has low single digits of revenue exposure to alternative fuel vehicles, but the Semiconductors team expects this to rise to mid single digits. MS analysts estimate that Maxim Integrated Products Inc currently has 5% of revenues exposed to alternative fuel vehicles, which the team estimates to increase to 10% over time. Lastly, MS analysts estimate that NXP Semiconductor NV currently has low single digits of revenue exposure to EV semiconductors, which the team expects to rise to mid single digits.

Cree (not covered) is an innovator of semiconductor products. It has announced plans to build the world's largest silicon carbide fabrication facility in order to support the electric vehicle industry.

Infineon (not covered) offers a range of electric powertrain components ranging from solutions for fast electric vehicle charging to inverter controls in electric motors.

Rohm began research into SiC power devices in 2000 and has been producing technology in this area since 2010. MS analysts estimate that approximately 3% of revenues are exposed to EV/HEVs.

STMicroelectronics has already been investing and developing SiC technology for many years. The company expects to achieve a doubling of SiC product revenues for 2019 to $200m (vs $100m in 2018) – driven by orders at OEMs (notably including Tesla, though other OEMs have also signed agreements).

Mining - Lithium

Our analysts believe the market is still overestimating demand, and expect the lithium cycle to trough in 2025. With new technologies lowering costs, the source of lithium (brine or hard rock) should matter less. Looking at the asset profile exclusively, we prefer integrated companies with conversion capabilities over pure mining, spodumene producers.

Albemarle is a vertically integrated company within the lithium and lithium derivatives market. It operates across the industry from raw material extraction to specialty product manufacturing. Lithium accounts for 37% of sales.

Galaxy Resources is an Australian-listed global lithium company. GXY has 100% interest in Mt Cattlin, a hard rock lithium mine with ~6 year mine life located in Western Australia. GXY also has a number of growth projects including Sal de Vida (DFS stage lithium brine project in Argentina) and James Bay (early stage hard rock project in Canada). 100% of EBITA is derived from lithium.

Ganfeng operates across the lithium value chain with businesses including upstream lithium extraction, midstream lithium compounds and metals processing as well as downstream lithium battery production and recycling. MS analysts estimate that lithium accounted for 85% of Ganfeng's FY18 revenue, and they expect it to account for 80-85% in the following years.

Mineral Resources is a diversified Australian commodities and mining services business. MIN has interests in two long-life hard rock lithium mines, Mt Marion (50% interest, 50% Ganfeng) and Wodgina (40% interest, 60% ALB), both located in western Australia. In addition, MIN will have exposure to lithium hydroxide production from June 2021 through its 40% interest in the first two modules at ALB's Kemerton hydroxide facility. Lithium accounted for 19% of FY19 EBITDA, which could move to 34% in FY22 as the Wodgina project ramps up production.

Orocobre is an Australian-listed global lithium company. ORE has a 66.5% interest in the Olaroz lithium brine project located in Argentina. In addition, ORE is partnering with Toyota Tsusho Corporation to construct a lithium hydroxide plant in Japan, allowing the company access to battery grade lithium hydroxide production from 2HFY21. 100% of EBITA is from lithium.

SQM has a number of different business units including Lithium. It produces Lithium Carbonate, which is used as a cathode material in lithium-ion batteries which accounts for 26% of revenues.

Mining - Cobalt

China Molybdenum operates one of the largest copper and cobalt mines, Tenke Fungurume, in the DRC. The mine accounts for ~12% of global cobalt supply per annum. ChinaMoly processes cobalt ore to cobalt intermediate products in the DRC and sells the product to downstream cobalt refiners from Europe and China.

Other

Nexans S.A. provide cabling for the electrification of electric vehicles and also supply charging station units. MS analysts estimate its revenue exposure to electric vehicles is 2%.

TPI Composites Inc operates in the composites structure industry, enabling the light-weighting of electric transportation. MS analysts estimate that approximately 2% of its revenues is exposed to the theme of electric vehicles.

Further reading on Electric Vehicles

Autos & Shared Mobility: BEV inflection point coming forward? (September 26, 2019)

Autos & Shared Mobility: The Climate Opportunity of Auto 2.0: How Big Tech Drives Faster EV Adoption (September 5, 2019)

European Automotive Sector: Cyclical – Recession or not? Structural – Electrification "Emission Troubles" part 2 (August 16, 2019)

Lithium: New Technologies, Same Oversupply (July 12, 2019)

EV Batteries: Better Anode, Safer Batteries (June 26, 2019)

EV Batteries: Cathode Evolution: Are Volume and Price mutually exclusive? (June 7, 2019)

Autos and Shared Mobility: Introducing the Morgan Stanley Global Electric Vehicle Market Monitor (April 12, 2019)

EV Battery Materials: Initiating on EV Battery Material Suppliers: Be Selective (February 20, 2019)

Investor Presentation: Disruption Decoded: Global Autos 2.0 (November 22, 2018)

Electric Vehicles: On the Charge (August 31, 2017)

Carbon Capture & Storage (CCS)

Carbon Capture and Storage (CCS) technology offers a significant opportunity to reduce global emissions by capturing carbon from the world's largest emitters – power stations and industrials – and storing the carbon permanently underground. However, without increased incentives for carbon reduction, the complexity and high capex requirements of CCS projects, in addition to ongoing operational costs, will likely continue to deter sufficient private investment. We forecast $2.5 trillion upfront capital investment by 2050 to build sufficient capacity to capture 4Gt of CO2 p.a.

Contributing equity analysts: Vincent Andrews, Allison Binns, Devin McDermott, Charlie Webb, Benny Wong.

Contribution towards decarbonisation

Widescale adoption of carbon capture and storage will enable the decarbonisation of existing fossil fuel generation capacity. Even under the IEA's Sustainable Development Scenario (SDS), Coal and Gas will still account for around a quarter of power generation capacity in 2040, contributing ~3Gt of global greenhouse gas emissions. CCS technology enables the removal of carbon emissions from these power stations until the combination of renewables plus storage becomes a cheaper alternative to gas power as a way to 'firm-up' the intermittency of renewable power generation.

CCS also has the potential to play a significant role in removing carbon emissions from industrial processes. The industrial sector accounts for ~25% of global carbon emissions. Around a quarter of these are process emissions, particularly in the steel, cement and chemicals industries. There are some other options available for decarbonising these sectors: electric arc furnaces or electrolytic hydrogen can reduce emissions in the steel industry; switching from dry-process kilns to wet-process kilns improves the energy efficiency of cement production; or steel and recycling plastic can cut the carbon intensity of the chemicals sector. But CCS is a viable technology that can be used in industrial processes where emissions cannot be avoided.

But the adoption of the technology is falling significantly below the trajectory needed to meet the IEA's SDS target of capturing 850 million tons of carbon per year (MTPA) in 2030 from power generation and industrial sources. There are currently 18 large-scale facilities in operation globally, capturing ~33 MTPA of CO2 per annum. Another 24 projects are in construction or early development stage. But even if these projects achieve full capacity of 91 MTPA per annum, they would only reach 11% of the IEA's SDS 2030 target.

Exhibit 46:

Pipeline of carbon capture projects

Name	Country	Operating Date	Max storage capacity (MTPA)
Operational			
Petrobras Santos pre-Salt Oil Field CCS	Brazil	2013	2.50
Boundary Dam Carbon Capture and Storage	Canada	2014	1.00
Great Plains Synfiels Plant and Weyburn Midale	Canada	2000	3.00
Quest	Canada	2015	1.00
CNPC Jilin Oil Field CO2	China	2018	0.60
Sleipner CO2 Storage	Norway	1996	1.00
Snøhvit CO2 Storage	Norway	2008	0.70
Uthmaniyah CO2-EOR	Saudi Arabia	2015	0.80
Abu Dhabi CCS (Emirates Steel Industries)	UAE	2016	0.80
Air Products Steam Methane Reformer	USA	2013	1.00
Century Plant	USA	2010	8.40
Coffeyville Gasification Plant	USA	2013	1.00
Enid Fertilizer	USA	1982	0.70
Illinois Industrial Carbon Capture and Storage	USA	2017	1.00
Lost Cabin Gas Plant	USA	2013	0.90
Petra Nova	USA	2017	1.40
Shute Creek Gas Processing (LaBarge)	USA	1986	7.00
Terrell Natural Gas Processing Plant	USA	1972	0.50
In-Construction			
Gorgon Carbon Dioxide Injection	Australia	2019	4.00
Alberta Carbon Trunk Line	Canada	2019	14.60
Sinopec Qilu Petrochemical CCS	China	2019	0.40
Yanchang Integrated Carbon Capture and Storage Demonstration	China	2021	0.41
In Early Development			
Carbonnet	Australia	2020s	5.00
Port of Rotterdam CCUS	Netherlands	2020s	5.00
Norway Full Chain CCS	Norway	2020s	0.80
Lake Charles Methanol	USA	2020s	4.20
South West Hub	Australia	2020s	2.50
China Resources Power	China	2020s	1.00
Huaneng Greengen IGCC	China	2020s	2.00
Shanxi International Energy Group CCUS	China	2020s	2.00
Shenhua Ningxia CTL	China	2020s	2.00
Sinopec Shengli Power Plant	China	2020s	1.00
Ervia Cork CCS	Ireland	2020s	2.50
Hydrogen 2 Magnum	Netherlands	2020s	2.00
Korea CCS 1	Korea	2020s	1.00
Korea CCS 2	Korea	2020s	1.00
Acorn Scalable CCS Development	UK	2020s	4.00
Caledonia Clean Energy	UK	2020s	3.00
HyNet North West	UK	2020s	1.50
Northern Gas Network H21	UK	2020s	1.50
Teesside Collective	UK	2020s	0.80
Sinopec Eastern China CCS	China	2020s	0.50

Source: Company data, Morgan Stanley Research

To reach the IEA's 2030 SDS scenario of 850MT captured per year, around 380 new, large-scale CCS facilities would need to be operational – almost certainly an impossibility. The average capture capacity of CCS projects expected to be online by 2030, is 2.2 Mtpa. Assuming future projects would have similar average capacities and build cost per Mtpa, the new facilities needed by 2030 would cost $585 billion.

CCS projects require protracted project timelines and high up-front capital expenditures, which MS analysts believe will hinder private investment without strong government incentives or public-private partnerships. To make CCS attractive to investors long term, national-level policies need to incentivise emission reductions and put a price or credit on emissions avoided and stored.

The IEA estimates that an incentive of $40 per ton of CO2 would enable the commercialisation of 450 MT of carbon for permanent geological storage. Exhibit 47 shows the current state of carbon pricing globally. Only seven countries have carbon pricing schemes that would be conducive to investment in CCS projects in line with the IEA estimates, and only two of those countries have CCS expertise. Notably, new IRS tax credits (discussed in detail in the Policy section below) may boost CCS investment in the US in the medium term, but we do not believe there are sufficient incentives globally to reach much more than 11% of the SDS target.

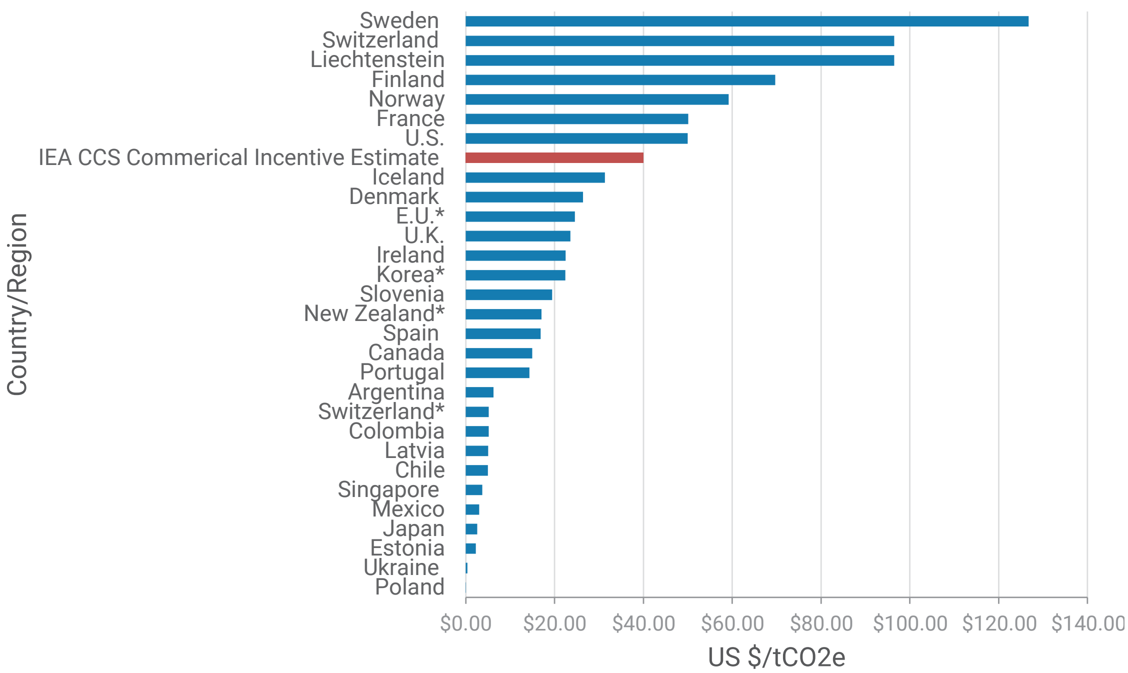
Our base case for 2030 is that CCS will account for ~ 80 Mtpa of CO2 captured and stored or utilised. This allows for the completion of CCS projects in the pipeline and assumes they will operate near capacity, but does not account for new projects coming online. Given the long timelines for scoping CCS projects and carrying them to completion, even if there is a surge in CCS investment in the medium term, we believe projects would be unlikely to be operating in 2030.

CCS can also be a conduit for clean hydrogen… There are plans for six large-scale CCS facilities in Europe that would enable the production of clean hydrogen. Four are in the UK (H21 North of England, HyNet North West, Ervia Cork CCS and Acorn Scalable CCS Development) and two in the Netherlands (Port of Rotterdam CCUS Backbone Initiative and Hydrogen 2 Magnum).

…and could help to facilitate direct air capture. CCS removes carbon generated during industrial processes and power generation. However, direct air capture (DAC) takes carbon dioxide out of the atmosphere, thus enabling negative emissions. The technology is in its early stages, but Carbon Engineering and Climeworks are two companies that have facilities in operation.

Exhibit 47:

Carbon price/credits by country, 2019



Source: World Bank, Morgan Stanley Research

Note: This chart indicates the highest carbon price in each country. It may not be applicable to all products and industries.

Investment

Fulfilling the potential of CCS under a 2DS would require upfront capital investment of nearly $2.5 trillion by 2050. Analysing a collection of global CCS projects due to be operational by the end of 2019, we estimate the current cost of CCS to be ~$711 mn per Mtpa, although there is a wide range of $82mn to $1.6 billion capital investment per Mtpa. This range is due to a couple of reasons. First, ethanol & fertiliser CCS projects generally tend to be much cheaper (less purification of the captured carbon is required) than power generation CCS. Second, there are significant differences between first generation and second generation CCS projects. We would expect the costs of building CCS plants to reduce over time and so have assumed a 15% saving by 2040 and 30% saving by 2050. On our estimates, 4GT of CO2 emissions could be removed by using CCS in 2050.

For CCS we also need to consider the ongoing costs. For all of the other technologies discussed in this report there is a clear opportunity to make a return on investment. However, CCS is different in that it is essentially always going to be an incremental cost for the operator. We estimate that the total annual cost would be around $400 billion by 2050. Exhibit 50 shows the cost per tonne of CO2 captured over the life of a CCS facility.

Exhibit 48:

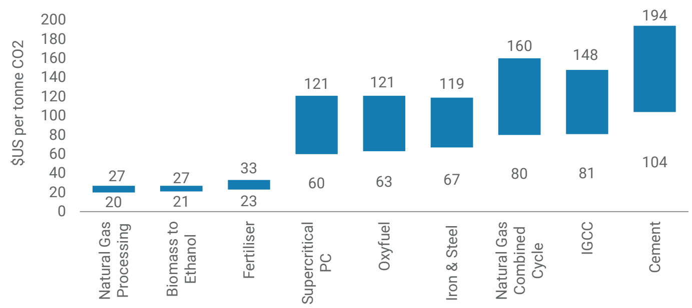
Capital investment in CCS projects under a two degree aligned scenario

	2017	2030	2040	2050
Volume of CO2 (Mt)				
Industry	29	500	1,600	2,200
Power	2	350	1,488	1,763
Total	31	850	3,088	3,963
Cost $mn per Mtpa		711	605	498
Cumulative Capex $bn		583	2,056	2,538

Source: IEA, Global CCS Institute, Morgan Stanley Research

Exhibit 50:

First-of-a-kind CCS costs in different industries



Source: Global CCS Institute

Exhibit 49:

Examples of capital investment required for CCS projects

Name	Country	Op. Date	Status	MTPA CO2	EOR	Emission Source	Capex ($bn 2019)	$mn capex per tonne CO2
Gorgon Carbon Dioxide Injection	Australia	2019	Construction	4.0	Y	Natural Gas processing	1.9	475
Alberta Carbon Trunk Line	Canada	2019	Construction	2.0	Y	Fertilizer production	1.2	600
Boundary Dam CCS	Canada	2014	Operational	1.0	Y	Power Generation	1.6	1626
Great Plains Synfuels Plant	Canada	2000	Operational	3.0	Y	Natural Gas Processing	1.6	546
Quest	Canada	2015	Operational	1.0	N	Hydrogen Production	1.5	1462
Sleipner CO2 Storage	Norway	1996	Operational	1.0	N	Natural Gas Processing	0.8	768
Snøhvit CO2 Storage	Norway	2008	Operational	0.7	N	Natural Gas Processing	1.0	1446
Air Products Steam Methane Reformer	USA	2013	Operational	1.0	Y	Hydrogen	0.5	474
Century Plant	USA	2010	Operational	8.4	Y	Natural Gas Processing	1.3	154
Coffeyville Gasification Plant	USA	2013	Operational	1.0	Y	Fertilizer	0.1	91
Illinois Industrial CCS	USA	2017	Operational	1.0	N	Ethanol Production	0.2	218
Lost Cabin Gas Plant	USA	2013	Operational	0.9	Y	Natural Gas Processing	0.6	640
Petra Nova	USA	2017	Operational	1.4	Y	Power Generation	1.0	748
Total				26.4			13.3	
Total (with ACTL @ full capacity)				39.0				
Average cost per tonne CO2								711

Note: The Alberta Carbon Trunk Line (ACTL) is shown with a capture capacity of 14.6MTPA. The ACTL currently has 2MTPA of carbon dedicated to the project, but will be built with the capacity for 14.6MTPA. Any carbon emitters in central Alberta will be able to pipe carbon through the ACTL for end utilization. Source: Global CCS Institute, Morgan Stanley Research

Technology

CCS value chain

There are three main phases to an integrated CCS value chain, each with varying levels of complexity and associated costs.

Phase 1. The first phase involves capturing, purifying and compressing the CO2 produced as a byproduct from the following primary sources:

1. natural gas or coal-fueled power stations;
2. industrial processes like steel, iron and cement production;
3. bioenergy sources like ethanol and other biomass; and
4. direct air capture.

This first step in a CCS value chain is the most technologically difficult and capital intensive part of the process, as each source produces CO2 with differing levels of carbon density and purity, requiring site-specific purification and compression processes with varying cost profiles. For instance, ethanol production results in much fewer CO2 emissions than steel production, but produces a CO2-H2O by-product which requires little additional purification. This characteristic provides ethanol cost advantages over power generation and industrial sources, which require costly separation and purification processes to make the carbon by-product suitable for transport and storage.

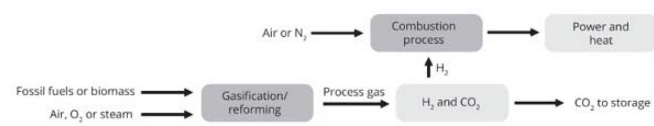
Phase 2. The second phase of the process involves transporting the CO2 for storage or utilisation. This phase traditionally involves high-pressure CO2 pipelines, a well-developed technology used for years in the fossil fuel industry. Pipeline costs vary by length, capacity, location on- or offshore and difficulty of transit territory. Norway has a full-chain CCS project currently under development which may incorporate transport via ship for offshore injection, but that strategy has a limited track record.

Phase 3. The third phase in the process involves storage or utilisation of the CO2. For storage, the captured CO2 is injected into stable geological reservoirs permanently. Identifying geological formations that are suitable for permanent storage requires long-term greenfield site testing to ensure safety and evaluate reservoir impermeability. Alternatively, the CO2 can be sold and piped to oil fields for enhanced oil recovery (EOR) or used as a component in the production of products such as plastics, cement and fuels.

There are three main techniques that are used to capture carbon dioxide:

Pre-combustion. The fossil fuel is separated into carbon dioxide and hydrogen before the process of combustion. The carbon dioxide can be captured and stored while the hydrogen is combusted to produce energy.

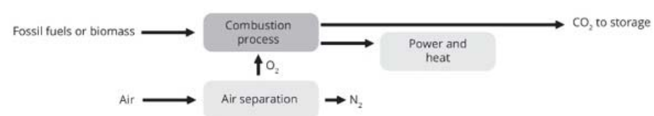
Exhibit 51:
Pre-combustion CCS



Source: IEA

Oxy-fuel combustion. The fossil fuel is burnt in nearly pure oxygen (rather than air) to produce a free flue gas which is high in carbon dioxide.

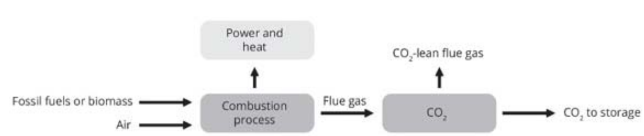
Exhibit 52:
Oxy-fuel combustion CCS



Source: IEA

Post-combustion. The carbon dioxide emissions are separated or removed from the 'exhaust' of the combustion process.

Exhibit 53:
Post-combustion CCS



Source: IEA

Carbon Capture & Storage (CCS)

According to the Global CCS Institute, there is more underground storage capacity available than is needed to meet the Paris climate goals.

Every individual CCS value chain will vary widely in the characteristics of each of the three phases, resulting in a site specificity that has hindered learning curve progress and has essentially made each new CCS project to come online a 'first of its kind.' As the number of CCS projects grows, we expect project timelines and costs to fall as best practices emerge.

Exhibit 54:

Availability of storage for carbon dioxide globally

Country	CO2 Storage Resource (GT)
US	8150
China	2400
Brazil	2000
Canada	400
Australia	400
Europe	300
South Africa	150
Japan	140
Mexico	100
India	50

Source: The Global Status of CCS 2018

Carbon Utilisation in Enhanced Oil Recovery (EOR)

While CCS could be used for decarbonising the power and industrial sectors, it is important to note that at present ~90% of carbon captured in operational projects is used for enhanced oil recovery (EOR). The utilisation of CO2 for EOR is a practice that has been in commercial use since 1972, when operators injected carbon sourced from natural domes to improve production from a declining Permian Basin field in west Texas. This field, now operated by Kinder Morgan, still produces roughly 28,000 bpd of oil today using the same CO2 flooding process. At the time of first CO2-EOR use, oil prices were high and the cost of carbon for EOR was low, and the success of that field spurred the growth of EOR infrastructure, namely high pressure CO2 pipelines in the Permian area.

According to estimates from the Department of Energy's Office of Fossil Energy (May 15, 2019), 3% of crude oil production in the US used CO2-EOR techniques for recovery in 2017 — equivalent to roughly 300,000 barrels per day (bpd). This rate of recovery requires an estimated 70MT of CO2 per year to accomplish, according to the DOE. The DOE estimates that by 2025, oil production using CO2-EOR will increase to 390,000 bpd in the US. Further estimates suggest that there are 137 billion barrels of oil that are recoverable using CO2-EOR in the US, which would require more than 30 billion tons of CO2 to produce. EOR is used after primary (pumping) and secondary (waterflooding) methods of production are exhausted. The technology can help to recover an additional 20% more oil than the first two methods alone, and carbon is the cheapest tertiary method of EOR. However, it is still more expensive than hydraulic fracturing and its commercial viability depends on the price of oil and the price of carbon.

According to an IEA database (November 28, 2018) on EOR use, 84% of CO2-EOR projects globally are currently located in the US, and this will continue to be the primary market for this technology. Most of the demand for captured carbon will be derived from the EOR market as other carbon utilisation markets (i.e. for products/fuels) are underdeveloped, and CCS for permanent geological storage is not yet broadly commercially sustainable. Currently, most carbon used for EOR is sourced from natural domes (source: ScienceDirect) as opposed to anthropogenic sources (captured carbon), and it's unclear how a switch to captured carbon would affect the economics of EOR for oil and gas companies. DOE estimates suggest that the CO2 used in EOR can account for between 25% and 50% of the total cost to produce a barrel of oil, and these costs may increase if anthropogenic carbon cannot be efficiently captured and transported to oil fields. Also, operators seek to recycle the CO2 as long as possible and any improvements in carbon recycling technology will inevitably affect the demand for new carbon.

While CO2-EOR will extend the viability of fossil fuel extraction, academic estimates (e.g. ScienceDirect) suggest that 95% of the carbon injected during EOR remains underground, and IEA life cycle analysis has determined that oil produced using CO2-EOR results in 37% fewer emissions than conventional oil.

Suitability of CCS technology: Current state of adoption

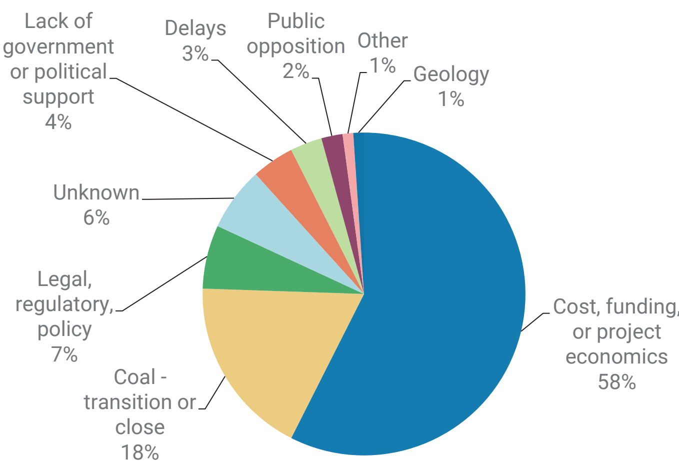
While CCS technology itself is sufficiently advanced for broad applications to large carbon emission sources, there are a number of challenges to CCS project implementation which hinder its scalability globally: cost, value chain complexity and protracted project timelines.

Cost

The single largest barrier to adoption of CCS is cost. Up-front capital requirements are high for CCS projects, and cost uncertainty and overruns have deterred private investment. Cost – specifically, high capital expenditures, lack of funding and poor project economics – combined to be the leading cause of CCS project cancellation or suspension between 2004 and 2019 (see Exhibit 55).

Exhibit 55:

Primary and secondary reasons cited for 69 CCS projects cancelled between 2006-19



Source: NETL, Morgan Stanley Research

A review of capex costs associated with 13 large-scale CCS facilities currently operating or in advanced development, showed that each 1MTPA of CO2 capture capacity cost roughly $711mn. This level of capex intensity for projects without a guaranteed ROI underscores the need for public-private partnerships to risk-share, as well as incentives and carbon market development, such that the captured carbon produces returns for investors.

Despite current high costs associated with CCS projects, we expect cost to decline steeply over time as the technology advances along the learning curve. The CCS learning curve is steep, and currently the technology is high on the curve. Academic estimates and post-project assessments suggest that moving from a first-of-a-kind (FOAK) CCS operation to an Nth-of-a-kind (NOAK) CCS operation may result in significant cost savings; the current consensus view is at least 30% cost savings. Post-completion analyses from the Boundary Dam CCS facility in Canada – the first power station to use CCS technology – report that the next similar CCS facility built would likely see a 65% reduction in costs over its initial capital expenditures of $1.5bn necessary for its completion in 2014, according to the International CCS Knowledge Centre. This would indicate that a new 1MTPA CCS facility could be expected to be built for $569mn today.

Given the current 'first-mover' penalty, investors may avoid FOAK projects where probabilities for cost overruns are high, especially if a NOAK facility will be substantially less risky and capital intensive. However, this provides some optimism that investment in CCS might accelerate over the long term as investors are attracted by the improving cost margins of next-generation CCS operations. Capture, separation and purification costs are likely to decline over time as the technology improves and becomes more efficient. Transport infrastructure via high-pressure pipeline, on the other hand, is already on the tail end of the learning curve, and is unlikely to be reduced significantly over time. Similarly, the injection technology is unlikely to see only incremental cost improvements over time, as it is already a well-developed technology in the oil and gas industry.

Because of the cost challenges, sectors with high purity CO2 by-products that require minimal (i.e. low-cost) purification will likely be most incentivised to seek carbon capture solutions. Ethanol and fertiliser production creates high-purity, highly concentrated waste CO2 that would be ideal for EOR or permanent storage. The challenge for these lower-intensity emitters will more likely be organising with similar carbon producers to build the infrastructure to pipe their carbon to EOR or storage sites. There is an opportunity for these low-intensity, high-purity emissions sources to follow the lead of Canada's Alberta Carbon Trunk Line (ACTL), which is the largest-capacity CCS project under development globally. The ACTL is a multi-stakeholder CCS project which will carry CO2 from two large industrial emitters to Alberta oil fields for EOR, at an initial rate of 2MTPA. However, the project is being built with the potential to carry up to 14.6 MTPA of CO2, and will allow any CO2 producers in central Alberta to add their carbon to the trunk line. If the ACTL reaches full capacity, it will have the lowest cost per MPTA of any CCS project to date, at just over $82mn.

Complex legal & regulatory environment

The legal and regulatory framework that underpins the CCS value chain must be robust enough to efficiently sort risk and rewards among the numerous counterparties involved. Items of concern include rights-of-way for new-build pipelines, ownership and liability of stored CO2, long-term storage, permitting and regulatory issues. Managing the long CCS value chain from production to capture to transport to storage/EOR requires numerous counterparties who must agree on frameworks to manage risks and revenues. Existing insurance schemes may be inadequate and insurance companies must become educated on risks and opportunities in this space in order to establish commercially viable storage sites. End markets for EOR and product creation must continue to develop, as well at the mechanisms to monitor storage long term.

Lengthy timelines

CCS projects are generally completed on a lengthy timeline, up to 10 years. For example, the Gorgon project in Australia was greenlit in 2009 and began first capture in August 2019 after numerous delays and cost overruns. Most projects should be expected to take 10 years to complete, from initial greenfield studies to point of first carbon capture, or 5-7 years if they have the advantage of co-opting existing infrastructure such as pipelines for EOR. As such, even if there was a surge in investment in CCS pilots and demonstrations in the medium term, those projects would be unlikely to come online until after the IEA's SDS 2030 benchmark.

This could be particularly an issue for adding CCS to coal power generation capacity where its remaining useful life may be less than the total of the planning, construction and payback periods needed for CCS.

Infrastructure

For CCS to be deployed commercially, the correct infrastructure needs to be in place to pipe the CO2 to the relevant storage sites. In order to create the transportation network required there will be increased costs as understanding of the network required for CO2 emissions is developed. In the past, development of natural gas infrastructure has required government coordination. However, it is uncertain if a systematic and coordinated approach will be provided by governments globally. There is a further risk around the most suitable pipe size to use since the growth of CCS is uncertain and pipe size will affect the flow of carbon dioxide into the store.

Where EOR is unavailable, CCS requires greenfield studies to identify geological formations for storage, and government oversight of storage will be necessary long term. Geology that seems suitable at the outset still requires a long process of storage validation to prove storage resources at the country level. This 'proven storage' process is similar to the difference between estimated reserves and proven reserves in the oil and gas industry. Currently, storage lacks commercial viability outside of EOR, and consistent permitting processes are generally evolving and untested in most areas around the globe. Despite these challenges, the IEA reports that globally there are more than enough safe geological sites for 'permanent storage', which it defines as one thousand years.

Direct Air Capture

Our analysis focuses purely on capturing CO2 as it is emitted from industrial processes or power generation. However, there are various projects underway globally to research and develop technologies that can remove carbon dioxide straight from the air.

Direct Air Capture has already been used in specific situations such as submarines or space travel. However, the ambition is there to refine the technology and reduce its costs in order that carbon dioxide molecules can be removed from air at scale. These can then be used (for example, in Enhanced Oil Recovery of soft drinks) or stored underground.

There is some regulatory support for Direct Air Capture (DAC) in California, where the low carbon fuel standard now includes DAC. As discussed above, 45Q tax credits are also helping to incentivise investment in carbon capture technologies.

Key companies working on this:

Climeworks: A swiss based company which captures carbon in the atmosphere using a filter. Once the CO2 has saturated the filter, it is then heated to around 100 degrees celsius which enables the Co2 to be released from the filter and collected. The company has three small commercial plants in Zurich, Italy and Iceland.

Carbon Engineering: Early investors included Bill Gates. The company is now partnering with Occidental Petroleum with a DAC plant capable of capturing 1 million metric tons of carbon p.a. in the pipeline for 2022. The company estimates this can be done at a cost of $100-150 per ton of CO2 captured and processed. Chevron is also an investor.

Global Thermostat: GT's technology captures CO2 in conjunction with heavy industrial processes. In addition to capturing CO2 from the industrial or power generation plant, it uses residual hat to remove extra carbon dioxide from the air. ExxonMobil invested in this company in June 2019.

Policy

In order to improve the continued development and adoption of CCS projects, there need to be systems in place to reward the capture and storage of carbon or, conversely, a financial penalty to sufficiently disincentivise excessive emissions. Such a system could manifest in a number of ways: an emissions trading system, national level carbon prices, tax credits for capture and storage/utilisation, or development of a robust CO2 commodity market for end utilisation. However, as demonstrated in **Exhibit 56**, only seven countries have carbon price/tax credit schemes sufficient to incentivise CCS development, and only two of these appear to have the relevant experience and pipeline projects to advance CCS adoption in the near term – Norway and the US.

Policies and financial stimuli that support early-stage CCS R&D and feasibility studies are also necessary tools to successfully grow the universe of CCS projects under development. Small pilot programs are needed to demonstrate the commercial scalability of CCS operations, but these are expensive and are less likely to receive sufficient private capital. After the global financial crisis, the American Recovery and Reinvestment Act (2009) provided the Department of Energy with more than $3.4bn in funding to R&D and pilot projects throughout the CCS value chain – storage suitability, industrial applications, carbon reuse development and CCS pilot projects. Without this stimulus, the US might not be the leader in CCS technology that it is today. Even so, $1.4bn of this stimulus funding went unspent as projects were cancelled for permitting issues, poor project economics, and legal challenges, highlighting the numerous barriers to success even when funding is available. Notably, Archer Daniels Midland's (ADM) CCS project in Illinois, the first in North America to capture CO2 by-product from ethanol for permanent storage, received $141mn from the DOE to develop the pilot project, which resulted in a full-scale operation.

The US's new tax credit for CCS, discussed in detail in the following section, is likely to be the most meaningful global legislative development to advance the commercialisation of CCS technology and implementation broadly.

Exhibit 56 highlights the current state of national policies and incentives among key CCS stakeholder countries globally.

Exhibit 56:

Global carbon capture & storage: National policy, incentives & drivers

	Legal Regulatory Framework	Carbon Reduction Incentives/Regs	Carbon Price Incentives	CCS Drivers
US	Partial	No	Sufficient (IEA estimate)	EOR
UK	Comprehensive (under EU)	Insufficient	Insufficient	H2 Storage
Norway	Comprehensive	Sufficient	Sufficient (IEA estimate)	Storage
EU	Comprehensive	Insufficient	Insufficient	Storage
China	Comprehensive	No	Insufficient	EOR
India	Partial	No	None	Storage
Japan	Comprehensive	Insufficient	Insufficient	Storage
Brazil	Partial	No	None	EOR

Note: Sufficiency of carbon reduction incentives (penalties) and carbon price incentives are based on whether frameworks meet the IEA estimate that a $40 carbon credit/price would incentivise commercial CCS. Source: Morgan Stanley Research.

US: New 'carbon price' may spur CCS adoption. In 2018, the IRS Code Section 45Q was amended to increase the tax credits for CCS. The new law has more than doubled the available tax credit for capture and permanent storage of CO2, from $22.66 per ton to $50 per ton. This has effectively set a 'price of carbon' at $50 per ton when it is permanently stored, and may incentivise more large emitters to use CCS technology to reduce their emissions footprint. The tax credit for carbon that is captured for use in EOR is $35 per MT, given that the captured carbon will be eventually sold to energy companies.

To avoid greenwashing allegations, 45Q tax credits are available only to large emitters that capture the emitted carbon; the biggest beneficiaries here are likely to be power plants that emit more than the required 500K tons annually, and industrials emitting over 100k tons per year. Power plants, which are the largest commercial emitters in the US, are best positioned to take advantage of these tax credits depending upon their proximity to geologic formations for permanent storage or transport pipeline to oil fields for EOR. The largest emitters in industrials are iron and steel producers (25% of industrial emissions), cement manufacturers (24% of industrial emissions), and petrochemicals (17% of industrial emissions). These industries could also seek to take advantage of the 45Q tax credits, but the decision to do so will likely depend not only on proximity to storage or EOR sites, but also on the purity of the CO2 by-products available for capture. One of the most expensive and technically difficult stages of the CCS process is the purification of the CO2 before transport and storage.

US Department of Energy modeling on the effects of the 45Q tax credits suggests that the new change would increase the CO2 captured from US power plants to increase to just over 50MTPA by 2030. Currently, only one power station has CCS capabilities in the US – Petra Nova in Texas – with 1.4 MPTA of carbon captured per year. CCS project operators seeking to claim the 45Q credits must begin construction prior to 2024, a feature of the legislation that may accelerate CCS adoption in the near term. If most of the post-45Q CCS projects adopt a Petra Nova-like system, the DOE model suggests that there would be more than 30 new CCS projects online by 2030.

EU: Regulatory framework set, but CCS adoption left to states. The EU established a Carbon Capture and Storage Directive in 2009 which set the legal and regulatory framework for safely storing CO2 in order to achieve climate targets. While the Directive sets a detailed legal and regulatory framework, it does not include provisions to incentivise member nations to adopt CCS to achieve their climate targets. These types of policies, likely because of their capital-intensive nature, are largely left to member states to resolve. Phase IV of the EU's Emissions Trading Scheme includes an Innovation fund which will invest at least 450 million emission allowances into new decarbonisation technologies.

Across Europe as a whole, the CCS strategy is being led by the UK, Norway and the Netherlands. There is an opportunity for industrial cluster around the North Sea storage options, which could reduce the costs of CO2 storage.

United Kingdom: The CCUS Cost Challenge Taskforce published a report in 2018 called 'Delivering Clean Growth'. Subsequently, the UK's Committee on Climate Change released its recommendations for reducing emissions to net-zero, stating that the development of CCS transport and storage should be a priority.

Netherlands: Feasibility and planning studies have been conducted in the Port of Rotterdam in the Netherlands to capture and store the carbon from a high concentration area of industrial emitters. However, the final investment decision in the project will depend upon whether the economics of the project can work under the subsidy restrictions in the new Dutch Climate Accord.

Norway: Heavy carbon emissions penalties led the way for early CCS development in Norway, which boasts the world's first CCS operations developed for permanent storage. According to Norway's Ministry of Petroleum and Energy, the current Norwegian system has a two-pronged approach to incentivising emissions reductions. First, companies must purchase emissions allowances of around NOK 200 per ton of CO2 equivalents, as part of the EU's Emissions Trading Scheme (ETS). Then, there are further taxes on emissions by sector, ranging from $0 for emissions from agriculture to NOK 500 per ton of CO2e from the oil and gas sector. For an oil and gas firm, the total cost of carbon emissions is roughly NOK 700 ($78.58) per ton. Norway is now focusing its state-led efforts on promoting technology development and reducing costs, with plans underway to construct two full value chain CCS projects. These CCS projects are to capture 0.8 MTPA of carbon, which is expected to be transported via ship for storage in North Sea geological formations. Norway recognised early the need for public investment to advance CCS implementation and has both a government-owned research company, Gassnova, which focuses on CCS development, as well as Technology Centre Mongstad, a long-term CCS technology testing center.

China: Broad development, with focus on EOR. Similar to the US, China has clearly linked its CCS projects to EOR rather than using CCS for storage purposes to reduce its carbon footprint, which is estimated to be 29% of global emissions. Despite this, China's 13th Five Year Plan does include language about combating climate change and managing natural resources efficiently, while specifically highlighting the need for developing a market to trade in carbon rights. While this may help to establish a more robust and specific regulatory framework for CCS implementation, current carbon prices in China, which are regionally based, are insufficient to incentivise commercial scaling of CCS. However, with strong government support, there are currently 29 CCS-related projects under development, in construction, or operational in mainland China, according to the Global CCS Institute's CO2RE database.

India: Government plans not yet formulated, which could hinder adoption. India is the fourth largest emitter in the world, after China, the US and the EU, with 6.6% of global emissions according to an EU Commission report. In 2017, then-Minister of State for Power and Renewable Energy Piyush Goyal announced that India would begin to take advantage of carbon capture technology. Currently, the government has established a partial legal & regulatory framework but has not yet announced incentives that would make CCS attractive for either domestic or foreign investors. Carbon Clean Solutions (CCSL), a privately-owned British company, has a commercial project based in Chennai which captures roughly 97% of carbon emissions from a power plant. Studies have questioned the feasibility of CCS in India due to the high costs of CCS infrastructure, the possible lack of suitable geology for carbon storage, as well as the potential that the technology might not be accepted by the public (sources: ScienceDirect, RESET).

Brazil: Technical know-how, but no policies to support broad CCS adoption. Brazil does not have a comprehensive legal or regulatory framework for CCS deployment. CCS has not been recognised as a strategic part of climate mitigation in Brazil and, as such, there are few incentives for businesses to pursue CCS strategies. This may be because Brazil has lower emissions per capita than other large nations due to its significant utilisation of hydroelectric power generation. With a lower volume of stationary emitters like coal-fired electricity plants, CCS may appear to be less of a priority. However, state-owned Petrobras has been a long-time proponent of CCS technology for EOR – which it has used since 1987 – and the oil company now operates two large-scale CCS facilities. Petrobras has invested heavily in CCS technologies, international knowledge-sharing and R&D on the entire CCS value chain. CCS might eventually garner a regulatory framework that allows it to be scalable, but there is no evidence to suggest it is a high priority in the near term.

Japan: Government support advances CCS pilot projects. In its 2018 Strategic Energy Plan, Japan outlined an ambitious strategic plan for developing and deploying a practical CCS system by 2020, by conducting state-sponsored research, development and testing of all three critical steps of the CCS value chain. An early mover in CCS, the Ministry of Economy established the Japan CCS Company to develop CCS technology in Japan, and four years later it was commissioned to build the Tomakomai CCS Project. Japan CCS Co offered its first tour of the Tomakomai facility to coincide with the G20 ministerial meetings in June 2019. The company is also working with the Ministry of the Environment to identify geological formations throughout Japan and offshore which might be suitable for long-term carbon storage.

By 2030, Japan will require any new coal-fired plants to be equipped with CCS. Also, Japan is developing a regulatory framework for regional carbon trading schemes, following on its ETS in Tokyo and Saitama Prefecture. The country had previously set a carbon price of JPY289 (~$3.7) per ton of CO2 in 2012, which is far below the price necessary to incentivise commercial development of CCS, in our view.

Risks

If CCS-EOR continues to be the leading driver of CCS adoption, a sustained low oil price environment may derail pipeline CCS projects that are under consideration. Between 2000 and 2019, at least 10 CCS projects were cancelled due to concerns about energy prices, and their effects on projects' economics. Although EOR can meaningfully extend the lives of declining oil fields, and produce nearly as much oil and primary and secondary production methods, it is a substantially more expensive process than hydraulic fracturing. As the cost of carbon can amount to between 25-50% of the cost of each barrel of oil produced with CO2-EOR, a low oil price environment may reduce margins far enough to challenge the viability of these projects. Power stations in particular need a stable, long-term price for the carbon they capture in order to reduce the cost of the energy used to capture, purify and compress the carbon for end-use sale – energy that would otherwise be sold through the grid. Decreased demand for carbon for EOR due to low oil prices may reduce the commercial viability of some CCS projects long term.

One recurring criticism of CCS technology – despite its nearly universally acknowledged ability to reduce anthropogenic carbon emissions – is that it may detract from the development of renewable energy sources and allow fossil fuel-powered emitters and fossil fuel extraction to persist long term. NGO sceptics have argued that the substantial capex required to advance CCS deployment might be better used to aid in the energy transition to carbon-free renewables. The Dutch Climate Accord, released in July 2019, underscores this point by limiting the subsidies available for CCS, so that CCS technology does not succeed to the detriment of green energy sources. The Dutch view CCS as a short-term solution to reach 2030 climate targets, by reducing emissions from sectors with no near-term alternatives. In the long term, they are preparing for a significant social shift away from fossil fuel-based activity.

Amendments to the London Protocol need to be ratified to enable offshore transboundary CO2 storage projects. The London Protocol was introduced in 2006 with the aim of preventing the pollution of the sea by dumping waste and other materials. This regulation was interpreted as prohibiting the exportation of CO2 from one contracting party to other countries for injection into sub-seabed geological formations. Amendments were made in 2009 but still haven't been ratified by the required two-thirds of contracting parties.

Stock Implications

The commercial case for CCS becomes viable when carbon is priced at such a level that having CCS technology is economically attractive. As such, companies that are investing in research and development of CCS technology should be well positioned over the long term. In addition, companies who operate across the value chain – for example, industrial gases and CO2 transportation – could have long-term revenue potential.

Air Liquide and **Air Products**: the deployment of oxycombustion, one of the three capture technologies, should present significant market potential for industrial gas companies. For both, MS analysts estimate that currently CCS makes up a very small proportion of sales.

Archer Daniels Midland (ADM) spearheaded the Illinois Industrial Carbon Capture and Storage (ICCS) project, which captures the CO2 from ADM's corn processing facilities in Decatur Illinois and transfers it to permanent storage in a saline reservoir. In 2018, the company injected and sequestered 525,000 metric tons of CO2. MS analysts estimate that currently revenues from CCS are not material.

Bloom Energy Corp is developing carbon capture technology for its products to eliminate carbon emissions, a technology that MS analysts think will be very important to the company going forward.

Denbury (not covered) is an oil and natural gas company which focuses specifically on using CO2 EOR to develop depleted reservoirs, mainly in the Rocky Mountain and Gulf Coast areas. It operates a vertically integrated CO2 supply and distribution business while 60% of its production is via CO2 EOR. The company states that 25-30% of its CO2 is industrially sourced. MS analysts estimate that currently, revenues from CCS are non material.

Linde is exploring the possibility of CCS technologies through the deployment of oxyfuel combustion.

Occidental Petroleum is an international oil & gas exploration and production company with operations focused in the US, Middle East, and Latin America. The company has 2 million barrels of reserves to recover using EOR with the CO2 coming largely from natural domes. Oxy is planning to roll out a Direct Air Capture facility in the Permian by 2021 with a capacity of 0.5 MTPA, which could allow it to use CO2 from anthropogenic sources. In January 2019, Oxy invested in Canada-based Carbon Engineering along with Chevron. Carbon Engineering is developing technology to capture CO2 from the atmosphere.

There are a number of energy and industrials companies involved in early stage CCS projects. This is not an exhaustive list but highlights some examples of the investments being made.

ArcelorMittal has signed a memorandum of understanding with Equinor to develop value chains in carbon capture and storage, including the capture of CO2 from ArcelorMittal's blast furnaces. At the end of 2019, the partnership aims to drill a wildcat well for CO2 storage in the Johanson formation to study the reservoir's suitability and capacity for CO2 storage.

BP has made several small investments in CCS technology including C-Capture and Carbonfree Chemicals.

Chevron has a 47% stake in the Gorgon project, a 20% stake in the Quest CCS project and in January 2019 invested in Carbon Engineering along with Occidental Petroleum.

Drax is operating a pilot bioenergy carbon capture and storage project with an investment of £400,000.

Exxon operates one of the largest CCS projects in the US, the Shute Creek Treating Facility, which has a capture capacity of 7 MTPA. In 2019, Exxon announced two new partnerships on CCS technology and scalability with Mosaic Materials and Global Thermostat.

Shell is a partner in the Gorgon LNG project, which is expected to capture and store 100 million tonnes of CO2 over the life of the project. In addition, it operates the Quest integrated CCS facility in Canada, while it co-owns a research technology centre along with Gassnova, A/ S Norske, Sasol and Equinor.

Total has invested in Inventys, a carbon technology company, and is part of a consortium of 11 stakeholders that has launched the '3D' project to develop an innovative way to capture CO2 from industrial activities.

Further reading on CCS

Sustainable and Responsible: Carbon Capture and Storage: A degree of progress? (May 27, 2015)

Sustainable and Responsible: Carbon Capture and Storage - A Realistic Solution? (August 28, 2014)

Hydrogen

Interest in hydrogen is a relatively recent trend, however we see it as a key enabler of decarbonisation across industry, mobility and power generation beyond 2030. Our analysis of the build out of electrolyser capacity and power generation capacity suggests up to $20 trillion of capital investment by 2050, which would enable emissions to be reduced by 6Gt.

Contributing equity analysts: Vincent Andrews, David Arcaro, Stephen Byrd, Lisa De Neve, Ethan Ellison, Timothy Ho, Eva Hou, Ryan Kim, Rob Koh, Simon Lee, Jack Lu, Mayank Maheshwari, Janaki Narayanan, Rob Pulleyn, Miguel Rodrigues, Anna Maria Scaglia, Arthur Sitbon, Ben Uglow, Takato Watabe, Charlie Webb, Courtney Yakavonis.

Contribution towards decarbonisation

Clean hydrogen is not currently a commercial technology contributing towards decarbonisation. However, it offers a material opportunity to reduce carbon emissions in three key areas:

- Industry: to reduce emissions on existing industrial processes (chemicals, energy, mining, food producers);
- Mobility: from light vehicles to buses, trucks and ships; and
- Utilities: green hydrogen can help manage electricity grid stability with increasing participation of renewables, and be used for heating and cooling.

From grey to blue to green: Today, most of the hydrogen produced is from fossil fuels (mainly methane from natural gas). This can be either merchant hydrogen (produced in a central industrial plant and distributed to customers) or captive hydrogen (produced by the consumer on site). However, there is growing interest in the ability to produce hydrogen using low carbon techniques.

Blue hydrogen is produced by separating hydrogen from methane, with carbon dioxide as a by-product, which is then captured and stored. It is estimated by the IEA that the price of carbon capture, utilisation and storage (CCUS) is currently between €50-€70 per ton of CO2, although it can be lower in certain cases such as the production of ammonia. Blue hydrogen is currently a little more expensive than grey hydrogen but this could change with scale and higher carbon prices.[21]

Green hydrogen requires the use of renewable energy to power the process of water electrolysis. Under the water electrolysis method, water molecules (H2O) are decomposed into oxygen (O2) and hydrogen gas (H2) and an electric current flows through water in a device called an 'electrolyser'. If the electricity used in the process is generated using renewable sources, then this can be viewed as a clean way to produce hydrogen, which can then be referred to as 'green hydrogen'. The key to the cost of green hydrogen is the price of electricity.

What is water electrolysis?

Water electrolysis is the decomposition of water molecules (H2O) into oxygen (O2) and hydrogen gas (H2) as an electric current is passed through water. It is a clean way to produce hydrogen, whereas currently, a high share of commercial hydrogen is produced from fossil fuels through a process called steam methane reforming (SMR). SMR is the reaction of methane (contained in natural gas and whose chemical formula is CH4) with steam (H2O), leading to the production of hydrogen gas (H2) and carbon monoxyde (CO). Water electrolysis is a chemical process run by electrolysers.

The rise of green hydrogen could open a whole new range of applications from transportation to energy storage, and help several sectors reach their decarbonisation targets.

21Source: IEA Newsroom, April 23, 2019

Utilities: As discussed in the **Renewables** section, it is difficult to store electricity, which is a potential barrier to the decarbonisation of the power sector. While progress in energy storage is being made, batteries remain a short-term flexibility provider (acting as a back-up) rather than a seasonal storage device. However, hydrogen, being a gas, can be used as a means of transporting and storing energy. Hydrogen systems could theoretically enable the transformation of electricity into gas and vice versa (due to fuel cells), thus providing more flexibility to both the electricity and gas sectors. It also offers a solution for decarbonising the heating sector too.

Industry: Hydrogen is a key component for industrial processes in various industries, including oil and gas, chemicals, glass, polysilicon and food. For example, refineries use hydrogen to lower or eliminate sulfur from diesel fuel, while in the chemicals industry, hydrogen is used to produce a variety of commodity chemicals such as ammonia or methanol. At the moment though, 96% of the 70mtpa of commercial hydrogen used annually is produced from fossil fuels, which is obviously carbon intensive. If green hydrogen could be used instead, the above sectors could achieve material decarbonisation. According to the IEA, carbon emissions from the production of hydrogen amount to some 830 million tonnes p.a., i.e. c2.5% of the world's total CO2 emissions.

Mobility: Hydrogen also has potential applications in the mobility sector. Fuel cell vehicles (FCVs) store hydrogen in their tanks and convert it into electricity via fuel cells. Essentially, FCVs are electric cars. However, instead of storing electricity in batteries, FCVs store hydrogen. One of their main advantages is that with current technology, it is much faster to refill a hydrogen tank than to charge a battery. Hydrogen is also starting to attract increasing interest as a fuel for trucks, buses, trains, taxis and ferries.

The Hydrogen Council aims for a $2.5 trillion hydrogen economy by 2050. The 2050 Vision for Hydrogen envisions significant investment, driving $2.5 trillion sales by 2050. The Hydrogen Council is an independent industry association launched in 2017 by a group of energy, transport and industry companies (including Air Liquide, Alstom, Engie, Daimler, GM, Honda, Shell, Statoil, Linde, among others) to help hydrogen facilitate the energy transition. The Council's vision is for hydrogen to account for 18% of final energy demand by 2050, which would imply a tenfold increase in hydrogen demand (to 550mn tons a year) and create an industry with $2.5 trillion of revenues globally (from hydrogen and related equipment).

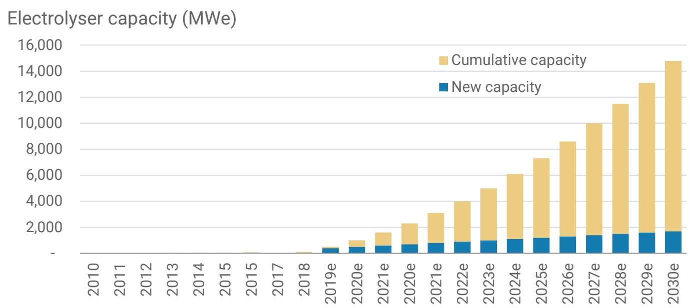
To achieve this requires more active government support to incentivise investment in infrastructure and reduce the cost of clean energy needed for the production process.

We estimate a very small carbon offset from clean hydrogen by 2030. While the long-term prospects for hydrogen are exciting, there are a number of challenges to overcome in the short term. As such, we are relatively cautious about the volume of clean hydrogen that can be produced by 2030.

Between 2010-18, 80 MWe of electrolyser capacity has been installed globally.[22] It is difficult to have a clear view on hydrogen adoption by 2030, but we have assumed a significant ramp up from 33 MW of new electrolyser capacity in 2018 to over 1000 MW p.a. by 2023. As such, we estimate total capacity would reach almost 15,000 MW by 2030 (**Exhibit 57**). This amount of capacity would generate around 1.8 million tonnes of clean hydrogen; this would be a big increase from current levels, but would still represent only 2% of the 98 million tonnes of hydrogen estimated by the Hydrogen Council to be produced in 2030. The carbon saving from producing this hydrogen with electrolysis would be around 19 million tonnes of carbon p.a.

Exhibit 57:

We assume a rapid acceleration in new electrolyser capacity over the next decade – but this still only enables 2 million tonnes of clean hydrogen production



Source: IEA, Hydrogen Council, Morgan Stanley Research estimates (e)

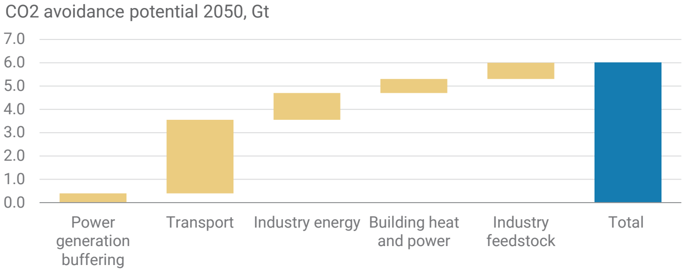
The Hydrogen Council has significant ambitions for clean hydrogen adoption by 2050. It is targeting 14EJ of hydrogen by 2030 (versus 10 EJ in 2018), and we assume this incremental 4EJ is all clean hydrogen.

By 2050 this increases to 78 EJ or ~550 million tonnes of hydrogen with a carbon saving of 6Gt. The council's vision is for hydrogen to account for 18% of final energy demand by 2050, which would imply a tenfold increase in hydrogen demand (to 550mn tons a year). In **Exhibit 59** we show the Hydrogen Council's view of the carbon savings by sector.

22 Source: IEA

Exhibit 59

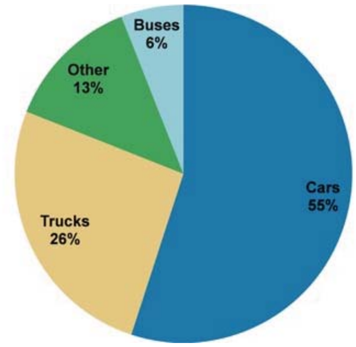
Hydrogen could reduce annual CO2 emissions by 6 Gt in 2050



Source: Hydrogen Council

Exhibit 58:

Split of emissions avoided in the Transport sector due to adoption of hydrogen by 2050



Source: Hydrogen Council

Passenger cars account for the lion's share of the Hydrogen Council's 2050 target, with up to 400 million light vehicles expected to run on hydrogen. Morgan Stanley analysts see most potential for fuel cell electric vehicles in the heavy-duty vehicle sector.

Different types of electrolysis

Alkaline electrolysis

Alkaline electrolysis is named after the type of electrolyte it uses. Alkaline electrolysers use an alkaline solution as the electrolyte, usually sodium hydroxyde (NaOH) or potassium hydroxyde (KOH).

On the cathode side, water molecules react with electrons provided by the cathode to form hydrogen gas and hydroxide ions (OH-). The hydroxide ions formed are then transported through the electrolyte from the cathode to the anode. On the anode side, hydroxide ions react as electrons are attracted by the anode to produce water molecules and oxygen. As a result, the alkaline electrolysis process allows hydrogen gas and oxygen to be produced from water molecules.

PEM electrolysis

PEM stands for polymer electrolyte membrane. Unlike alkaline electrolysis, which uses an alkaline solution, PEM electrolysers use a solid specialty plastic as the electrolyte to conduce the electrical current in the water. In a PEM electrolyser, this membrane plays the role of both the electrolyte and the separation material between the anode and the cathode.

In PEM electrolysis, water (H2O) reacts at the anode to form oxygen molecules (O2), hydrogen protons (H+) and electrons (e-). The hydrogen protons then go through the plastic membrane to the cathode side of the electrolysis cell. In the meantime, the electrons produced flow through an external circuit to the cathode. On the cathode side, hydrogen protons (H+) combine with electrons (e-) to form hydrogen gas (H2). As a result, similar to the alkaline electrolysis, the PEM electrolysis produces oxygen and hydrogen.

Investment

Hundreds of billions of dollars investment in electrolysers, renewable energy and infastructure. There is a significant direct and indirect cost of green hydrogen production. The IEA estimates that electrolysers require an upfront capital investment of around $0.85-1.5mn per MW depending on whether alkaline or PEM technology is used. In addition, green hydrogen systems would require heavy investments in wind and solar power generation capacities in order to become scalable.

The cost of building a hydrogen economy. To reach the 2050 Hydrogen Council's target of 550 million tonnes of hydrogen production, we estimate ~$5.3 trillion would need to be invested in electrolysers, depending on whether they use alkaline or PEM technology, using the IEA capex estimates outlined above. In addition, significant investment in renewable power generation capacity would be needed to ensure the hydrogen produced is green. We estimate this would require $13 trillion of investment in new capacity by 2050. Other investment would be needed for infrastructure such as storage, transportation and distribution. We note the Hydrogen Council estimates that $280 billion investment is needed by 2030.

Exhibit 59:

Hydrogen: Capital investment needed by 2050 under a 2 degree aligned scenario

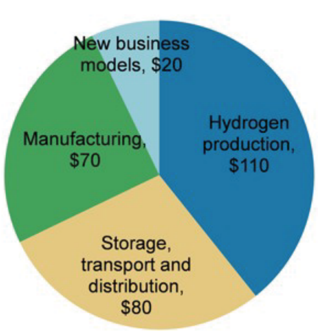
		2030	2040	2050
Electrolyser costs				
Electricity demand per million tonnes of hydrogen (TWh)	51			
Capacity (MW) per million tonnes	8,387			
Efficiency of electrolyser systems	60-81%			
Average efficiency	0.7			
GW electrolysis capacity per million tonne of green hydrogen	8.4			
Average capex ($mn/Mw)	1.2			
Clean hydrogen production (million tonnes)		98	196	546
Electrolyser capacity (Gw)		822	1,644	4,579
Total Electrolyser Capex ($bn)		966	1,932	5,381
Electricity costs				
Electricity demand p.a. TWh per GW of electrolysis capacity	6.5			
Load factor (average wind and solar)	31%			
Renewable power capacity (GW) per GW of electrolysis capacity	2.4			
Capex	$mn			
Renewables average (per MW)	1.2			
Wind (per MW)	1.1			
Storage (per GWh)	0.2			
Total incremental renewable power capacity (GW)		1,995	3,991	11,117
Total Electricity Capex ($bn)		2,393	4,785	13,330
Total Storage Capex ($bn)		36	224	1,133
Total Capex $bn		3,394	6,940	19,843

Source: Hydrogen Council, IEA, Morgan Stanley Research estimates

Exhibit 60:

The Hydrogen Council estimates $280 billion investment is needed by 2030 to be on track for 2DS

Investment by 2030 ($bn)



Source: Hydrogen Council

Technology

The technology is proven. Water electrolysis is not a new industrial process. It has been known for years and several electrolysers were built by NEL Hydrogen starting in the 1920s. Historically, water electrolysis has used alkaline technology predominantly. However, there is now much more attention and focus on PEM technology. This uses a solid specialty plastic to conduce the electrical current in the water. Although they remain more expensive at this stage, PEM electrolysers are safer and can operate in a broader range of conditions than alkaline electrolysers.

And there are a number of hydrogen projects in operation or being developed.

- Enagas is co-developing a green hydrogen generation plant in Mallorca.
- Engie and Gasunie are analysing the potential construction of a 100MW electrolyser in Groningen (Netherlands).
- Several projects in Norway have received funding to develop solutions for zero emission maritime vessels based on green hydrogen.
- Engie is carrying out a feasibility study with the goal of designing a green hydrogen plant that would be integrated with one of Yara's existing ammonia plants.
- Oersted included green hydrogen production for industrial use in a recent offshore wind auction bid in the Netherlands.
- NikolaMotor unveiled several new fuel-cell vehicle models in April.
- Verbund is testing the potential for the partial substitution of natural gas with hydrogen at its 838MW Mellach power plant.
- SNCF – France's national railway company – will stop using diesel locomotives in 2030-35 and replace them with hydrogen trains.

But at present green hydrogen is not cost effective. For both methods of producing green hydrogen, the cost of electricity is the most important input cost. We estimate that the most efficient alkaline electrolysers need 1.1MWh of electricity to produce 25kg of hydrogen, while at current productivity levels PEM electrolysers need c.1.5MWh of electricity. There is scope for improvement in the energy intensity of these processes, but nevertheless we would expect electricity to continue to be a key input in hydrogen production.

Morgan Stanley's Utilities team has built a model to estimate the levelised cost of hydrogen for various applications: gas grid injection, on-site use (for the chemical industry, for example) and transportation. While the team adapts the variables used to model the economics of each usage, the cost of electricity is a very relevant part in all production chains: assuming prices at €40/MWh and no grid fees, electricity currently accounts for c50% of the input costs of green hydrogen.

However, we do expect the cost of electricity to fall. First, the cost of producing electricity from renewables has been falling dramatically in Europe, based on recent EU renewable auction data. While the economics of renewables vary considerably across geography and power generation type, generally speaking a similar trend can be seen in the US and Brazil, where the capex associated with wind and solar has been decreasing significantly over the past 10 years or so. In China, conversely, our analysts are more cautious, particularly with respect to wind, where they expect IPPs to have a relatively challenging high base in 1Q19, and due to government policy. For more information on renewable energy costs, please refer to the **Renewables** section.

Second, we expect renewable capacity to continue to increase globally, which could result in more pressure on power prices. As outlined in the **Renewables** section, we expect ~2,700 additional GW of renewables capacity to be installed over the next decade. Part of this is dependent on the roll-out of storage technologies (including hydrogen) and an increase in interconnection capabilities.

Key regions suited to the development of hydrogen. Reducing the cost of green hydrogen is actually linked more to local power prices than national prices. In some regions where conditions for renewables are ideal (strong winds, or high usable sunlight rates), the share of renewable power in the local energy mix is unusually high. In these regions, weather changes or inadequate grid capacities can lead to curtailment. Curtailment is the temporary shut down (whether voluntary or not) of renewable installations, usually due to network congestion (i.e. the local mismatch between power production and grid capacity to transport the electricity produced). Curtailment is negative for renewable operators as shutting down wind/solar farms is costly. In some cases, renewable operators can be willing to sell electricity volumes at negative prices if it can keep them from shutting down their plants. Electrolysers could be used to pull excess electricity generated by wind/solar farms at times when electricity prices are close to zero or even negative in some extreme cases to produce hydrogen. In these specific cases, our Utilities team's analysis shows that water electrolysis appears much more competitive than alternative technologies.

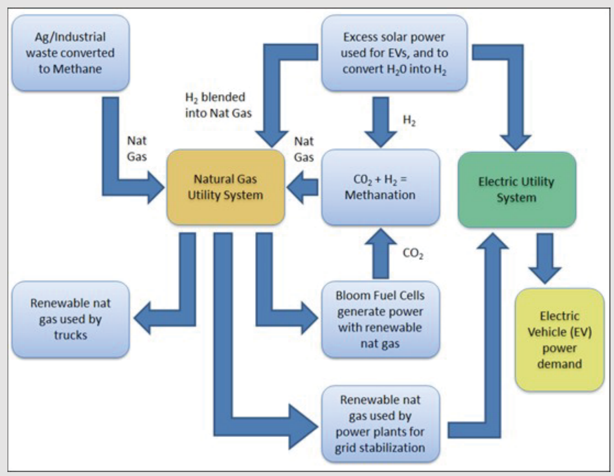
In sites with excess renewable capacity, when electricity prices are at zero, our utilities team sees the levelised cost of hydrogen at €2.7/kg based on current technology. This is c30% below the price of cheap merchant methane hydrogen and in line with the middle of the range of biomethane gas grid injection guaranteed tariffs.

How cheap will hydrogen be in 2025-30? MS' Utilities team has built a cost curve for hydrogen up to 2030, taking into consideration the evolution of marginal electricity prices, as well as the power consumption and required investments for the electrolysers. In the model, the team assumes that hydrogen producers are built jointly with wind/solar farms and can draw power without incurring grid fees, taxes and levies. They estimate that the levelised cost of hydrogen for grid injection should decrease by c70% by 2030 to a level of c€1.7/kg or c€42/MWh. Regarding industrial applications, they forecast a levelised cost of hydrogen of €1.8/kg by 2030, almost in line with the cost of producing hydrogen from methane on site, hence opening a large end-market to the hydrogen industry.

Hydrogen's role in establishing a sustainable energy loop: a case study using California based energy companies

Our US Utilities team recently spent time with Patricia (Patti) Wagner, CEO of SoCalGas (a natural gas utility in California), and was able to discuss the long-term energy paradigm shift that might be seen in states with likely large levels of solar penetration, EV growth and the growth in customer adoption of Bloom Energy's fuel cells (there is significant overlap among these drivers). MS analyst Stephen Byrd and his team developed a diagram which charts their view of the potential "energy flow" associated with this paradigm shift, a shift that will be most pronounced in the coastal United States where EV adoption rates will be higher and where solar power adoption rates have been relatively high. In the long term, they see the potential for both (1) continued above average growth among electric utilities, as EV infrastructure spend becomes significant in the early 2020s, and (2) greater gas utility growth as gas utilities harness hydrogen generated by excess solar power (via water electrolysis), harness methane generated by agricultural and industrial processes, and potentially absorb the methane that could be generated from a combination of solar-derived hydrogen and the CO2 by-product from Bloom's fuel cells.

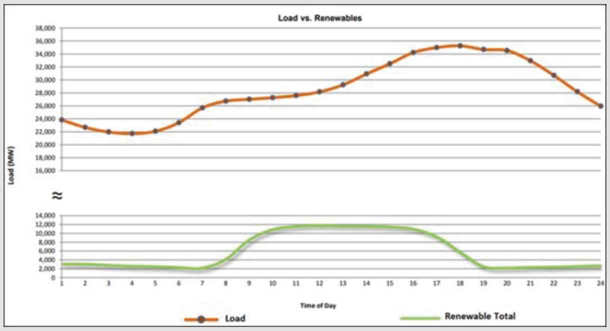
The following diagram reflects their views of the future energy flow in (predominantly coastal) states with high solar, EV and fuel cell penetration:



Source: Morgan Stanley Research

Energy Source #1: Solar Power

As they have highlighted in numerous reports, the cost of solar power continues to drop rapidly, which they expect will continue for many years to come. California is blessed with an abundant solar resource (i.e. insolation), and when deployed at large scale, they believe solar power can be economically attractive to the state, and to many other US states. As solar penetration continues to rise, the classic 'problem' of the 'duck curve' will continue to grow – here is a diagram of solar power output throughout the day as compared to power demand in California:



Source: CAISO, Morgan Stanley Research

The key long-term questions for California with respect to solar power will be: (1) what will the state do with the excess solar power produced in the middle of the day? (2) how will utilities and the California Independent System Operator manage the volatility/intermittency of solar output? and (3) what will California do during extended overcast periods during which solar output is very low?

Interestingly, both the gas utility business and electric vehicles could be part of the answer to these questions. Excess solar power could be used to charge vehicles during the day, and also to split water into hydrogen and oxygen (known as electrolysis). With this hydrogen, the utility could then (1) inject the hydrogen into the natural gas system (where it can blend with methane at a roughly 1:10 hydrogen:methane ratio), and/or (2) combine this hydrogen with CO2 produced from sources such as Bloom Energy's fuel cells (these fuel cells convert natural gas into electricity and generate carbon dioxide as the output – over time, our Utilities team believes Bloom may be able to capture this CO2) in a process known as methanation. The chemical equation for methanation is:

$CO_2 + 4H_2 \rightarrow CH_4$ (methane) + $2H_2O$ (the process is exothermic, meaning it releases energy)

The beauty of using excess solar power to create hydrogen: the resulting hydrogen energy is derived from a renewable source, and in the case of using this hydrogen in methanation, can be used not only to capture CO2, but also to harness the CO2 and convert it into methane which can be used within the existing gas utility system. As can be seen from the diagram, if Bloom Energy can capture the CO2 from its fuel cells (over time, our team believes the company may be able to do so), then Bloom's energy cycle is completely sustainable, but also (and this is a benefit that is sometimes overlooked) dispatchable and highly reliable. As California reaches increasingly high levels of renewables penetration, these latter qualities will in our team's view become increasingly valuable.

By injecting the hydrogen created from solar power-driven electrolysis into the gas utility system, California can secure what our team thinks of as "cloud insurance at low cost." In the event that California experiences multiple days of overcast conditions, electricity storage alone may not provide enough power in a cost effective way relative to relying on natural gas-fired power plants to step in and provide the needed power during such unusual weather periods (and weather volatility is something that numerous scientists predict will only increase).

Why is electricity storage not necessarily cost effective relative to hydrogen and methane for the purposes of a multi-day need for power when it's cloudy? Here is a mathematical example:

Assume that a house uses 30 kWh of power per day, and assume that the house relies primarily on solar power. Assume that the skies are overcast for 3 contiguous days, and that the all-in capital cost to install power storage would be $250/kWh (the current cost is much higher than this, especially at small scale). The capital cost of 3 days' worth of battery storage would be $22,500. This is effectively the cost of the 'cloud insurance policy' for the homeowner. Applying a cost of capital of 8% for this insurance policy, the cost per kWh of power the customer uses per year would be $.16/kWh, equal to almost the entire utility bill for a residential customer in California. If the utility instead used excess, midday solar power generated (during sunny periods that precede overcast periods) from low-cost, large-scale solar farms to generate hydrogen that is blended with the methane stored and delivered by Sempra's gas utility system, the cost of such an approach would be much less. For example, given the excess amount of available, already installed gas fired power generation in CA, the cost of producing the power from such an approach would in our view likely be well below $.04/kWh on an annualised basis. Assume: (1) the gas-fired plant runs just once annually for 3 days straight, (2) peak load in the example house is 6 kW during the busiest hour of the day, (3) a gas-fired power plant capital cost of $800/kW, a cost of capital of 8% and a heat rate of 9,000 Btu/kWh, (4) a cost of a hydrogen/natural gas blend of $6/mmBtu (above the wholesale price, to factor in the potential cost of electrolysis - as you will see, the analysis is not very sensitive to changes in this assumption). The total annual cost for this 'cloud insurance policy' would be ~$390 (~$5 for gas + $384 capital charge for the backup gas-fired power plant). This $390 annual cost, divided by hypothetical house annual power usage of ~11,000 kWh = an annual insurance cost of 3.5 cents per kWh, much lower than the battery-based cloud insurance cost of $.16/kWh.

It is fair to point out that, in the gas-based approach to protection against the loss of solar power, there would be CO2 emitted by a conventional natural gas-fired power plant, whereas a solar + battery approach would not emit any carbon dioxide. However, there are two countervailing points:

1. The state could easily afford to purchase carbon offsets for this, given the large amount of economic savings versus a solar + battery approach. In our team's example, the delta in annual cost would be close to $16/kWh (or $16,000/MWh) for each unit of power (in this example, 90 kWh) generated by the gas-fired turbine (assuming the turbine were called upon once annually to address a 3-day period of cloud cover). Given that the carbon emitted by the gas-fired turbine annually in this example would be just ~.04 tons of CO2 annually, the state would technically be indifferent if it could purchase a carbon offset at a cost of ~$30,000/ton or less. Even if one assumed many more times per year in which there is an extended period of cloud cover requiring the gas-fired turbine to run, the economic benefit of a solar + hydrogen insurance approach versus a solar + battery approach would still be significant, in our view.

2. If Bloom Energy could capture the CO2 emitted by its fuel cells (and over time, our team believes this may be possible), then the solar + hydrogen insurance approach would emit no carbon at all. In addition, while Bloom's all-in cost of producing power is above that of a conventional natural gas-fired power plant, its cost is still below the all-in cost of service for power delivered by electric utilities to its utility customers in California.

Energy Source #2: Renewable natural gas from ag/ industrial waste that generates methane

Given that uncombusted methane is ~30x more harmful than a greenhouse gas relative to CO2, and given that California is the largest agricultural producer in the US, there could be significant benefits from capturing and using this methane within the utility system. This methane could be injected into Sempra's gas utility system and used as:

1. Heating;

2. Fuel for large trucks converted to natural gas;

3. Fuel for conventional power plants that serve as 'cloud insurance' as per the above example; and

4. Fuel for Bloom Energy's fuel cells.

These uses of renewable natural gas would all generate CO2, but given the 30:1 damage of uncombusted methane versus CO2, this appears to be a worthy trade given California's greenhouse gas (GHG) reduction targets. In addition, if Bloom Energy could capture the CO2 by-product of its fuel cells (which our team believes may be possible), then we would have a 'closed carbon loop' in which the state of California both eliminates the very harmful methane emissions from agricultural and industrial sources and eliminates carbon from power generation sources.

For more information please see Clean Tech & Yieldcos: Refreshing our Thoughts on Key Themes & Debates (November 30, 2018).

Policy

Overall there are still very few explicit and effective policies for incentivising significant investment in hydrogen and hydrogen-related technologies. However, we are seeing a surge of interest, which makes the long-term outlook encouraging.

We are seeing increasing signs of support in Europe, and more projects in Japan, China, the US and Australia. We outline some of these in **Exhibit 61** .

Exhibit 61:

A selection of global hydrogen projects

Country	Type of project	Companies involved	Description
Australia	Power to gas	AquaHydrex	Electrolysis pilot project using excess renewable electricity to generate H2 for the gas grid
Australia	Coal to hydrogen	AGL Energy and Kawasaki Heavy Industries	Working on a trial project for lignite-to-liquid hydrogen conversion
Austria	Power to gas Industrial	Siemens and Verbund	Building a 6MW green hydrogen production plant at steelmaker Voestalpine's Linz plant
Austria	Electricity	Verbund	Testing the partial substitution of natural gas with hydrogen at the 0.8GW Mellach power plant
Belgium	Power to gas	Parkwind, Eoly and Fluxys	Planning to build a power-to-gas plant that converts renewable electricity into green hydrogen
Denmark	Green Hydrogen	Orsted	Orsted has included a green hydrogen component in its latest Dutch offshore wind project
Italy	Gas networks	Snam	Launched a test of introducing a 5% hydrogen and natural gas blend in the gas transmission network
France	Power to gas	Hydrogene de France	Build electrolysers in Guiana to transform electricity produced from 55MW of solar power into H2
France	Mobility - Buses	GNVert (an Engie subsidiary) and Van Hool	A consortium made of GNVert and Van Hool will launch a hydrogen bus route in Pau.
France	Mobility	Air Liquide	Built several new taxi hydrogen refuelling stations in the Paris region
Germany	Gas networks	Uniper	Uniper will add a methanation plant to its existing power-to-gas facility in Falkenhagen
Germany	Refinery	ITM Power and Shell	Build a 10MW PEM electrolyser at Shell's Wesseling refinery in Germany
Germany	Power to gas	Amprion and Open Grid Europe	Looking into the construction of a 100MW power-to-gas plant at Lingen
Germany	Power to gas	Vatenfall	Plans build a 50MW power-to-gas unit in Brunsbuttel in Germany
Global	Mobility	Hyundai	Plans to invest c.€5.9bn in fuel cell vehicles R&D and facility expansion by 2030
Japan	Mobility - refuelling stations	Toyota, Nissan and Honda	Build 80 new hydrogen refuelling stations in Japan in the next four years
Japan	Mobility - Cars	Toyota	Build a dedicated line for the production of hydrogen tanks
Netherlands	Power to gas	Akzo Nobel	Investigating the potential construction of a 20MW electrolyser unit for Delfzijl in the Netherlands
Netherlands	Power to gas	Engie and Gasunie	Analysing the potential construction of a 100MW electrolyser in Groningen
Netherlands	Power to gas	RWE/Innogy	Feasibility study to build a 100MW power to hydrogen plant
Norway	Mobility-Ferries	Norled, Fjord1 and Boreal	The National Road Administration launched a program to develop a hydrogen-electric ferry by 2021
Norway	Supply chain	NEL	Plans to expand its electrolysis manufacturing capabilities to 360MW pa, with the potential to go beyond 1GW pa
Pan-Europe	Mobility-Trains	Alstom	Alstom is developing hydrogen fuel cell trains to replace highly polluting diesel locomotives
South Korea	Mobility	Air Liquide	The co. has announced the installation of 4 new H2 stations for mobility in South Korea
Spain	Power to gas	Enagas	Enagas will participate in developing a green hydrogen generation plant in Mallorca
Sweden	Power to gas	NEL Hydrogen, Vatenfall, SSAB and Luossavaara Kiirunavaara	Order from Hybrit Development for an electrolyser solution (4.5MW) for a steel plant in Sweden
UK	Gas networks	Cadent	Plans to invest around £900m building the UK's first large-scale hydrogen network in the UK
UK	Integrated		The Big Hit project is a €11mn project that will create a replicable hydrogen territory in Orkney
UK	Power to gas	Engie/ITM Power	Will work with ITM Power on a feasibility study to deploy a 100MW electrolyser at Runcorn (UK)
USA	Power to gas and Mobility	NEL and Nikola Motor	NEL was awarded a contract to deliver fueling equipment and up to 1GW of electrolysis capacity
USA	Mobility	Nikola Motor and Anheuser-Busch	Nikola Motor received an order of 800 hydrogen semi-trucks from Anheuser-Busch

Source: Company data, Morgan Stanley Research

Europe. There is increasing support for hydrogen from European governments. Hydrogen pathways have been included in the EC's long-term decarbonisation strategy, while 28 European countries signed the Linz Declaration 'Hydrogen Initiative' promoting co-operation on sustainable hydrogen technology. Spain's new energy guidelines (published on April 9) included a provision to promote the injection of hydrogen generated from renewable electricity in gas networks. In Germany, proposals were made to allow electricity grid operators to build power-to-gas projects and designate them as necessary for network stability. France confirmed its national hydrogen plan in its draft multi-annual energy plan: the French government intends to invest as much as €100mn in the hydrogen industry in the next few years.

US. The 45Q tax credit, which rewards the storage of CO2 in geological storage sites, now includes provisions to incentivise the conversion of CO2 to other products, including through combination with hydrogen. The California Fuel Cell Partnership has announced targets for 1,000 hydrogen refuelling stations and 1 million FCEVs by 2030.

China. In China, the State Council announced several revisions to the annual Government Work Report on March 15, including one to promote the development and construction of fueling stations for hydrogen fuel-cell cars. On a recent trip to Rugao – a new energy/ hydrogen economy pilot city – our analysts found that 1) fuel cells (FC) are receiving greater support now than BEVs were at an equivalent stage; 2) the government views FCEVs as cleaner and advantaged in long distance, commercial applications; 3) a total of ~3bn yuan has been invested in the hydrogen economy in the region, mainly private; 4) a 30% subsidy exists on hydrogen prices; 5) there will be a targeted roll out of 20/200 hydrogen fueling stations by 2020/25 in the Shanghai/ Rugao corridor; 6) there is a view that the 2025 50,000 FCEV target could be met 2-3 years earlier.

India. The Supreme court of India has asked that Delhi considers the potential use of fuel cell buses in order to reduce air pollution. In addition, the government has made an INR 60 million request for research proposals on hydrogen and fuel cells.[23]

Japan. Under its presidency of the G20, Japan requested that the IEA publish a report on the future of hydrogen. This has now happened.

Brazil. The 22nd World Hydrogen Energy conference was held in and supported by Brazil in 2018. Furthermore, hydrogen is included in the country's Science, Technology and Innovation Plan for Renewables and Biofuels.

Risks

In addition to the cost challenge, there are a number of other risks to the commercial large-scale roll-out of hydrogen.

Infrastructure: At present there is very little infrastructure in place for the storage and transportation of hydrogen, putting aside already existing natural gas networks. Electric vehicles could be charged at home prior to commercial charging stations being built, but for hydrogen mobility there is no such option. In addition, it is difficult to envisage hydrogen charging stations being developed without government subsidies due to the small size of fleets in the early days.

Safety: Hydrogen is flammable, colourless and odorless, which makes safety checks more difficult.

Energy intensity: Around 70% of energy in the electricity used to produce green hydrogen is wasted.

Water intensity: Around 27 litres of water are needed to produce 1kg of hydrogen, according to ITM. This is about twice as much water than is needed for the steam methane reformer, which is the most common type of production today.

Stock Implications

Industrial Gases

Air Liquide sees scope for hydrogen to be used more widely in the global energy mix as well as in other markets such as automotive (fuel cells) and industrials (replacing coke in steel mills). It generates around 10% of its sales from hydrogen at present. It has invested in fuel cells and biomethane capacity.

Air Products (24% sales from hydrogen) is the global leader in hydrogen refuelling infrastructure and also a leading developer of hydrogen energy services and equipment.

Linde (5% of sales from hydrogen) operates in hydrogen mobility operating over 200 hydrogen production plants and building ~35% of worldwide hydrogen refuelling stations. It has entered into a new 50/50 joint venture with ITM Power to deliver green hydrogen to large-scale industrial projects.

23 Source: IEA: The Future of Hydrogen

Utilities

In utilities, increasing hydrogen demand could drive further renewables investment as well as the need for investments in grids. For stock implications please see the **Renewables** chapter.

Other sectors

Alstom has manufactured the world's first hydrogen train, the Coradia iLint. While currently hydrogen makes up a small proportion of the group's revenues according to MS analysts, the MS European capital goods team expects it to increase significantly in the mid term as orders are completed.

CNH manufactures LNG/ CNG trucks and has announced an investment in and partnership with Nikola, a fuel cell truck manufacturer. MS analysts estimate that currently, the investment is not generating any revenue/EBITA.

Cummins acquired Hydrogenics in June 2019 for $290m. Hydrogenics is a hydrogen fuel cell developer and manufacturer with capabilities in transportation (trains, buses, trucks, aerospace), power-to-Gas, grid balancing, refueling solutions and critical power (backup and critical).

Johnson Matthey has established a fuel cell component manufacturing facility in the UK. MS analysts estimate that currently, hydrogen makes up a small percentage of sales.

ITM (not covered) is a pure play hydrogen technology company manufacturing electrolysers.

McPhy Energy (not covered) designs, manufactures and integrates hydrogen solutions including electrolysers, hydrogen stations and services.

Nel ASA (not covered) is a pure play hydrogen technology company. It manufactures alkaline and PEM electrolysers and hydrogen fuelling stations.

Plug Power make hydrogen fuel cells - predominately for forklifts that usually run on propane. 100% of revenues are derived from hydrogen.

Siemens manufactures PEM electrolysers and MS analysts estimate that 6% of its EBITA is exposed to utility fuel switching.

Yara launched the N-Tech Platform in 2016 to decarbonise ammonia production. Over the past two years, revenue exposure to hydrogen has been ~12% (although this is volatile in nature given its dependence on the price of natural gas in a given year). While Yara is in growth mode, which should initially increase absolute hydrogen exposure, the company is also carrying out an Improvement Program which will reduce the number of units of natural gas required to produce a ton of ammonia from 34.5Gj/ton in FY15 to 32.7Gj/ton by FY23 on a group level.

Further reading on Hydrogen

Chemicals: Hydrogen: Bridging The Gap (June 17, 2019)

Regulated Utilities: The Intersection of EVs, Solar, Fuel Cells, Hydrogen and Energy Storage (October 18, 2018)

Utilities: Hydrogen: new projects and push back (October 15, 2018)

Global Hydrogen: A US$2.5 trillion industry? (July 22, 2018)

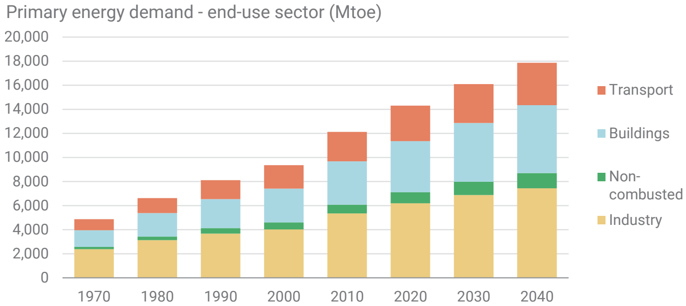
Biofuels

Increasingly aggressive carbon emission targets in the transport sector have necessitated the integration of biofuels in the transportation fuel mix. At present, the autos sector is the key end user, but in the long term biofuels may be the primary solution for the decarbonisation of the aviation industry. We estimate $2.7 trillion capex is needed by 2050 to reduce emissions by 1.7Gt. However, in the context of struggling economics and significant cost premiums, meaningful uptake of biofuels will depend largely on regulatory support.

Contributing equity analysts: Lucy Beauvallet, Roberto Browne, Sasikanth Chilukuru, Steven Hayes, Mayank Maheshwari, Andy Meng, Javier Martinez de Olcoz Cerdan, Benny Wong.

Exhibit 62:

Transportation is likely to account for ~20% of total energy demand in 2040



Source: BP Energy Outlook 2019

Contribution towards decarbonisation

Global energy demand from the transportation industry is expected to rise 19% between 2020 and 2040, accounting for 16% of the total incremental demand in primary energy. Road transportation is likely to account for nearly 80% of total transportation energy demand, and aviation is forecast to grow at the fastest rate in the sector, driven by a rapidly growing middle class. [24]

The sector is carbon intensive, with over 90% of energy used by transportation coming from oil. This is likely to reduce over the next decade, driven by a rise in electric vehicles, and possibly fuel cell vehicles later in the century. But biofuels can also present an additional opportunity for decarbonisation.

24Sources: BP Energy Outlook 2019

Biofuels currently represent ~3% of global transport fuel demand and provide a low carbon solution for the continued use of the combustion engine. They are transportation fuels made from biomass materials, most commonly in the form of liquid fuels such as ethanol and biodiesel. These fuels are usually blended with petroleum fuels (gasoline, diesel and jet fuel), but can sometimes be used on their own. Biofuels are generally considered both renewable (as they depend on renewable feedstock sources) and sustainable (as they burn cleaner than fossil fuels). Currently, they are the only viable replacement for petroleum transportation fuels as they can be used within legacy internal combustion engines.

Currently, biofuels are used predominantly in road transportation, but are also technically viable for aviation and marine biofuels adoption. The economics are currently more favourable for use in road transportation given policy support. While biofuel production for airplanes and ships is technically viable, the availability of suitable fuels is low. Additionally, the uptake is constrained as a result of significantly higher costs than fossil fuels at current prices; more detail is provided on this throughout the chapter.

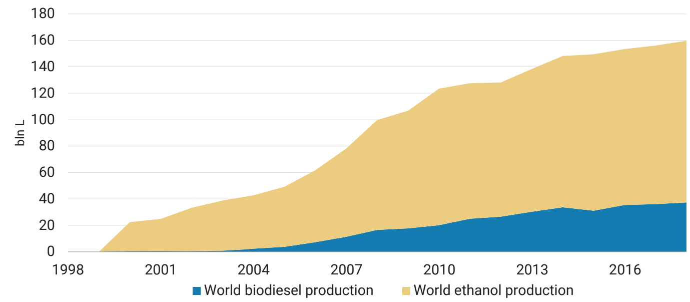
Depending on the type of feedstock, biofuels are categorised as either first, second or third generation. The two most commonly produced biofuels are currently ethanol and biodiesel.

- **Ethanol** – alcohol formed by fermentation. This is the most common biofuel worldwide (representing 70% of the market), and the US and Brazil produced ~80% of total ethanol world-wide in 2017 (**Exhibit 63**). Ethanol can be used in petrol engines as a replacement for gasoline (anhydrous ethanol), and it can be mixed to any percentage depending on the model of the engine and the fuel system of the vehicle. Most existing car petrol engines can run on blends of up to 10% ethanol (E10 blends), as most vehicles don't need to be modified for this blend. However, given that ethanol is corrosive and can degrade some of the materials in the engine and fuel system, higher blends (E25 and above) usually require specially designed vehicles/ modifications. Some specially designed vehicles can run on pure hydrous ethanol as a fuel.
- **Biodiesel** – there are two main types of biodiesel. **FAME** (fatty acid methyl esters) generally has to be blended with traditional diesel to be used for transportation purposes. Nearly all OEMs approve the use of up to 5% biodiesel (B5), and in most cases the industry view is that blends of up to 20% (B20) will not be detrimental to performance. In contrast, **HVO** (hydrotreated vegetable oil) can be used instead of fossil fuel based fuels. Biodiesel is produced using vegetable oils (e.g. rapeseed, palm, sunflower, soya), animal oil/fats, tallow and waste cooking oil. Biodiesel is the most common biofuel used in Europe (making up ~65% of its biofuel mix), but it still makes up only ~30% of biofuels worldwide.

Exhibit 63:

Ethanol makes up ~70% of the total biofuel market globally

Development of the biodiesel and ethanol market



Source: OECD

Exhibit 64:

Biofuel types produced by major players

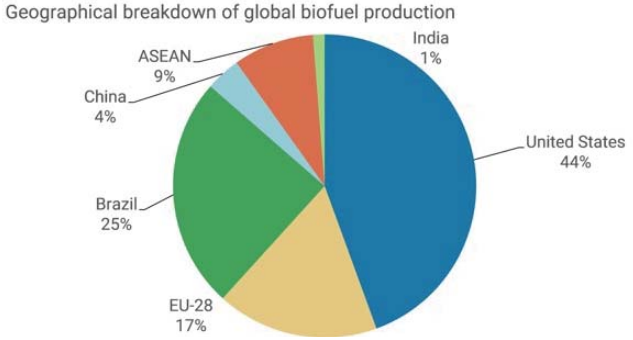
Company	Biodiesel/ ethanol	Type Produced
Neste	Renewable diesel, Aviation biofuel	US; Neste MY Renewable Diesel™ is classified as both advanced biofuel and biomass-based diesel Europe; classifies as a traditional biofuel ROW; classifies as second generation
Adecoagro	Sugarcane Ethanol	US; Brazilian sugarcane ethanol classifies as advanced biofuel ROW; classifies as second generation
São Martinho SA	Sugarcane hydrous and anhydrous Ethanol Corn Ethanol	US; Brazilian sugarcane ethanol classifies as advanced biofuel ROW; classifies both corn and sugarcane ethanol as second generation
Cosan SA	Sugarcane Ethanol	US; Brazilian sugarcane ethanol classifies as advanced biofuel ROW; classifies as second generation
Raízen	Sugarcane ethanol	Considered second generation.
Diamond Green Diesel (JV between PSX and VLO)	Renewable diesel	VLO US; classified as both advanced biofuel and biomass-based diesel Europe; classifies as a traditional biofuel ROW; classifies as second generation PSX US; classified as both advanced biofuel and biomass-based diesel Europe; classifies as traditional biofuel ROW; classifies as second generation
BP Plc	Sugarcane Ethanol	US; Brazilian sugarcane ethanol classifies as advanced biofuel ROW; classifies as second generation
Royal Dutch Shell	Sugarcane Ethanol	US; Brazilian sugarcane ethanol classifies as advanced biofuel ROW; classifies as second generation
China Petroleum Chemical Corp	Biodiesel, Aviation biofuel	Considered second generation.
Bharat Petroleum Corp	Bio-Mass, agri-waste rice straw and soya stock ethanol	Considered second generation.
PTT	Primarily sugarcane ethanol.	Predominantly first generation.

Source: Company data, Morgan Stanley Research

Exhibit 65:

The US, Brazil and the EU produce 86% of biofuels globally

Geographical breakdown of global biofuel production

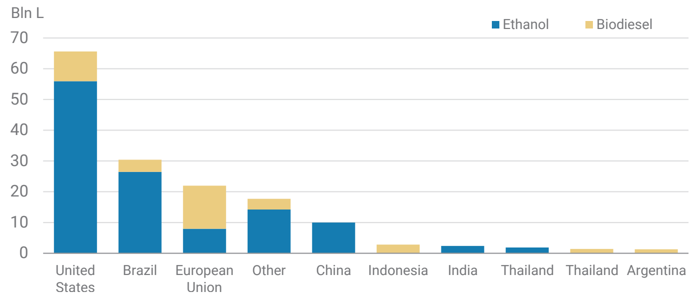


Source: IEA, 2018

Exhibit 66:

The US is the largest ethanol producer and Europe is the largest bio-diesel producer

Geographic split of biodiesel and ethanol production

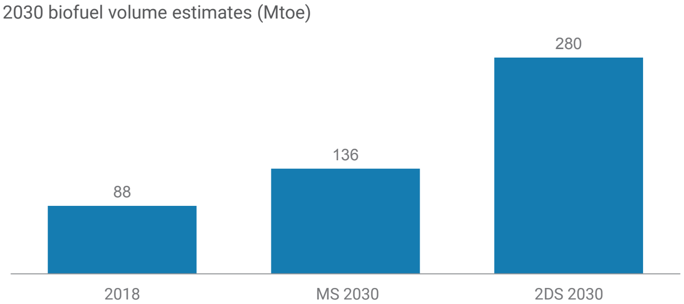


Source: OECD, 2017

Exhibit 67:

Morgan Stanley Sustainability team estimates that the total volume of biofuels will fall short of the parameters laid out in the IEA's Sustainable Development Scenario

2030 biofuel volume estimates (Mtoe)

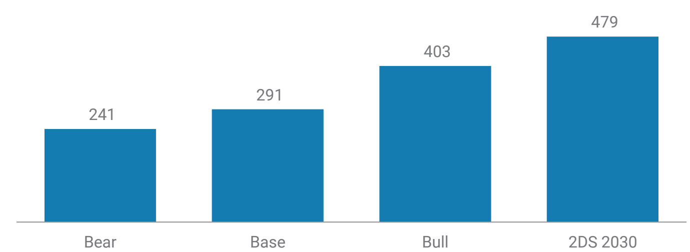


Source: IEA, Morgan Stanley Research estimates

Exhibit 68:

Morgan Stanley's base case estimate of the carbon emissions savings falls significantly short of the parameters laid out in the IEA's Sustainable Development Scenario

2030 carbon emissions savings (m/t)



Source: IEA, Morgan Stanley Research estimates

We estimate that ~4% of global transportation fuels will come from biofuels in 2030. MS estimates suggest that by 2030, the HVO biodiesel market will reach 20 M/t, while the rest of the biodiesel market will grow at a 4% CAGR and the ethanol market will grow at a 3% CAGR, in line with 5-year historical growth rates. Despite recent aggressive targets set by governments (Exhibit 71), looking at current commissioned projects we expect that ethanol and biofuels globally will continue to grow at the same pace. The exception is HVO biodiesel, which we forecast will quadruple by 2030, given the increasing focus of governments on transitioning to advanced biofuels.

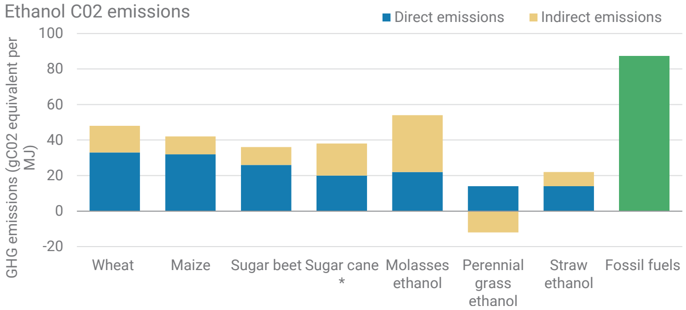
This presents a potential carbon saving of 295 m/t of carbon from biofuels by 2030. The choice of feedstock will greatly affect the decarbonisation potential of both ethanol and biodiesels (Exhibit 69 and Exhibit 70). First-generation feedstocks have higher emissions, particularly when we take into account their indirect emissions, which are calculated looking at the indirect land use change (ILUC). ILUC looks at cases where biofuels are produced on existing agricultural land, where demand for food and feed crops remains, which may lead to the production of more food and feed elsewhere. This can imply land use change (for example, by changing forest into agricultural land by cutting down trees), which means that a substantial amount of CO2 emissions may be released into the atmosphere (by releasing CO2 previously stored in biomass).

We estimate a range of carbon savings of ~240 m/t to ~400m/t depending on the mix of feedstocks (Exhibit 68).

- **Bear case**: using the average carbon emission from all current available feedstocks.
- **Base case**: assuming a transition to relying more heavily on advanced feedstocks: 60% reliance on second/third generation feedstocks, and 40% reliance on first generation (vs almost 100% reliance on first generation at present).
- **Bull case**: assuming a total transition to reliance on only second and third generation feedstocks.

Exhibit 69:

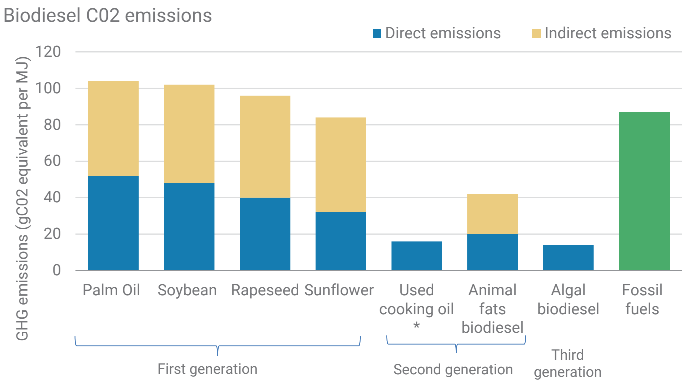
Ethanol provides significant decarbonisation potential across both first generation and second



Source: International Food Policy Research, ICCT, Europa and Morgan Stanley Research, *Brazilian sugar cane ethanol is considered first generation by the US

Exhibit 70:

Second generation biodiesel provides decarbonisation potential



Source: International Food Policy Research, ICCT, Europa and Morgan Stanley Research, *used cooking oil is considered first generation in Europe

Our biofuel volume base case is c50% below the IEA's Sustainable Development Scenario (SDS) which is aligned with a 2DS. The IEA's scenario outlines the need for biofuels used in the transportation industry to triple by 2030, which would imply a 413 m/t carbon saving and over $750bn investment by 2030, on our estimates. Current biofuel policies and projects in total assume 3% global growth in production over the next 5 years, which falls significantly short of the sustained annual growth of 10% needed through to 2030 to keep pace with the IEA's SDS. Our base case estimates imply 4% global growth in production over the next 10 years. While this is slightly more optimistic than the 5-year forecast implied by current projects, it still falls significantly short of the IEA's SDS.

Exhibit 71:

IEA's forecast annual production growth vs growth required to meet the SDS in 2030

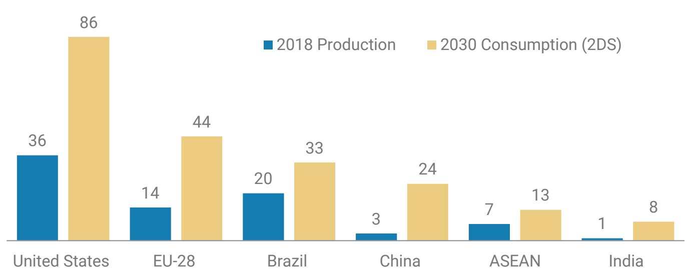
Country/region	Forecast annual production growth (2019-24)	Annual production needed to meet 2DS (2019-2030)
United States	1%	6%
European Union	0.5%	8%
Brazil	3.5%	6%
India	11%	22%
China	16%	17%
ASEAN	9%	8%

Source: IEA, Morgan Stanley Research

Exhibit 72:

Alignment with the Sustainable Development Scenario will require more widespread development of the biofuel market production, especially in India and China

Biofuel production in 2018 compared with 2DS consumption in 2030 (Mtoe)

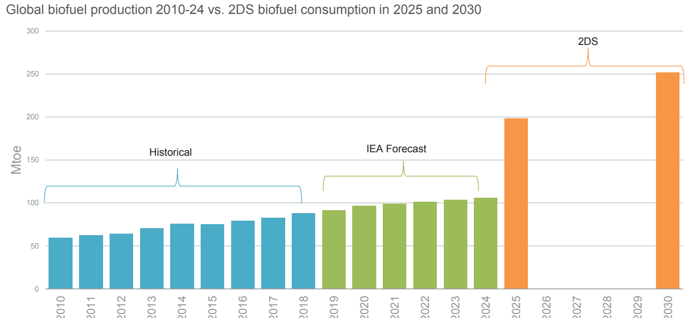


Source: IEA

Exhibit 73:

Current transport biofuel production expansion forecast against the sustained 10% output growth per year needed until 2030 to align with the IEA's SDS

Global biofuel production 2010-24 vs. 2DS biofuel consumption in 2025 and 2030



Source: IEA

Investment

Achieving the carbon saving that we forecast in our base case will require an investment of ~$300 bn. Over the next 10 years we assume an additional 48 million tonnes of oil equivalent (Mtoe) (22 Mtoe of ethanol and 26 Mtoe of biodiesel) of biofuel capacity due to increasing commitments from governments to increase the percentage of biofuels within their transportation fuel mix. To reach the IEA's SDS, an additional 144 Mtoe of capacity would be required, implying ~$750 bn of capital expenditure by 2030.

Our capex estimates range from $2 per gallon of annual capacity to $9 depending on whether the biofuel is ethanol or biodiesel and also depending on which feedstock type is used. We note that the technology for second and third generation ethanol facilities requires much higher capex. For example, Bharat Petroleum Corp's recently announced second generation rice straw ethanol facility comes at a $20 /annual gallon expense. In **Exhibit 74** we highlight some selected biofuel projects, which helps to provide some colour around our capex assumptions.

Exhibit 74:

Selection of recently announced biofuel projects

Project	Description	Biofuel type	Country	Due to open	Annual capacity (MM gallons)	Cost (USD Mil)	USD/ gallon
Attis Industries	Attis has purchased Sunoco LP's corn ethanol plant in Fulton. Producing first generation ethanol, the plant is expected (by Attis Industries) to generate over $150 million in revenue under its current operating conditions.	Ethanol	N.America	Already open	100	20	0.2
Bharat Petroleum Corporation Ltd (BCPL)	State-run BPCL plans to commission its second generation (2G) ethanol bio-refinery in Odisha. The plant will use 200,000 metric tons of rice straw as feedstock annually.	Ethanol	India	2020	7	135	20.4
Diamond Green Diesel (DGD)	In 2018, DGD (a joint venture between a Valero subsidiary and Darling Ingredients) announced a project to expand their Louisiana capacity to 675 million gallons per year. The facility will also produce 50 to 60 million gallons of renewable naptha a year.	Biodiesel	N.America	Unconfirmed	400	1,100	2.8
Hindustan Petroleum Corporation Ltd (HPCL)	In 2017, the company announced its 100,000 litres a day second generation ethanol plant in Bathind. Its facility will use 400,000 metric tons of sugarcane bagasse and other crop waste as a feedstock.	Ethanol	India	Unconfirmed	8	92	11.5
India Oil Corporation (IOC)	IOC is planning to set up a biomass-based second generation ethanol production facility at its Panipat refinery facility. The proposed plant will utilise rice straw and other ligno-cellulosic feed stock, requiring around 473 tonne of raw material every day.	Ethanol	India	Unconfirmed	8	101	12.6
Neste	Neste is expanding its Singapore-based renewable diesel facility, bringing total capacity to almost 3.5 million tons per year (2,250 million gallons).	Biodiesel	Singapore	2022	650	1,560	2.4
NewEnergyBlue	This new plant, known as New Energy Spirit Biomass Refinery LLC, will be located in North Dakota and will be adjacent to Dakota Spirit AgEnergy LLC (an existing 70 mm gallons a year corn ethanol facility). The plant will be second generation (2G) using cellulosic ethanol technology. The plant will use approximately 280,000 tons per year of wheat straw as feedstock.	Ethanol	N.America	2021	16	170	10.6
Next renewable Fuels, Inc	NEXT has invested in the production of an Oregon-based second-generation advanced biodiesel facility. It has also entered into a long-term purchase and sale agreement with Shell.	Biodiesel	N.America	2021	600	1,000	1.7
POET	In 2018, POET was reviewing the proposals for a new ethanol facility in Indiana.	Ethanol	N. America	2020	80	160	2.0
Sao Martinho	Reuters reported (19 June 2019) that Sao Martinho plans to invest in a new corn ethanol facility, which would be co-located with its Boa Vista mill.	Ethanol	Brazil	Unconfirmed	44	94	2.1

Source: Company data, Morgan Stanley Research

Exhibit 75:

Capital investment implied by a 2 degree aligned scenario

Biofuels	$/ gallon	$/mt	
Ethanol			
First generation	2	1,000	
Second/ third generation	9	4,500	
Average	5.5	2,750	
Biodiesel			
Next renewable Fuels, Inc	1.67	833	
Diamond Green Diesel (DGD)	2.75	1,375	
Neste	2.40	1,200	
Average	2.27	1,136	
Production (million tons)	**2030**	**2040**	**2050**
World biodiesel production	220	273	774
World ethanol production	127	163	461
Capex $bn			
Biodiesel	605	751	2,129
Ethanol	144	185	524
Total Capex $Bn	750	936	2,653

Source: IEA, Morgan Stanley Research, Company Data

Technology

Biofuels

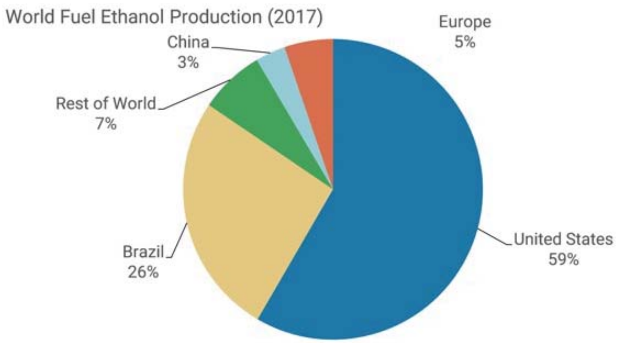
First generation biofuels are produced using food crops. Using naturally occurring vegetable oils such as starch, sugarcane, soy beans, corn, and canola as feedstock present sustainability challenges due to the impact on land and water usage, but also the impact it could have on the food supply if it were produced at large scale. The majority of ethanol is first generation. The US, for example, produces 59% (Exhibit 76) of total ethanol globally and 98% of its feedstock is maize. The second largest producer, Brazil, produces 26% (Exhibit 76) of global ethanol and relies primarily on sugarcane as a feedstock. Traditional biodiesel (also known as fatty acid methyl ester or FAME) is considered to be first generation. Given that ethanol makes up the majority of the biofuels market (~70%) and that 80% of biodiesels are first generation (Exhibit 77), currently the market is almost entirely made up of first generation biofuels.

Second generation biofuels, commonly known as advanced biofuels, are produced using non-food feedstock such as waste, wood, animals fats, grasses and inedible parts of plants (lignocellulosic biomass). The only time that food crops can act as second generation biofuels is if they have already fulfilled their food purpose. For the most part, this material tends to be more difficult to break down via fermentation and therefore requires a pre-treatment before it can be processed. In Europe, however, under the Renewable Energy Directive II (RED II), hydrotreated vegetable oil (HVO) is not considered to be an advanced biofuel.

Third generation biofuels are derived from algae. Previously, algae came under the umbrella of second generation biofuels. However, due to its ability to produce much higher yields using fewer resource inputs than other feedstocks (Exhibit 70 and Exhibit 71), it was suggested that it be moved into its own category. This is also considered as an advanced biofuel.

Exhibit 76:

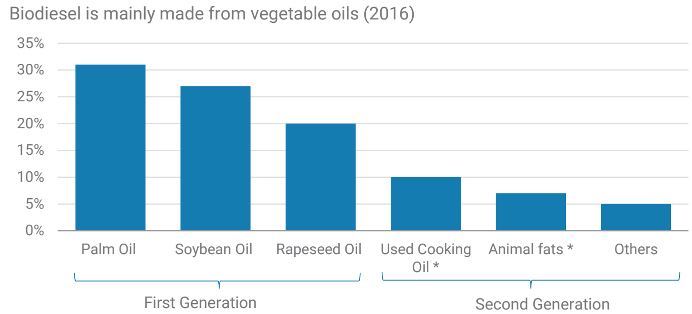
Ethanol produced in the US and Brazil is almost entirely first generation



Source: Renewable Fuels Association (RFA) (2017) World Fuel Ethanol Production

Exhibit 77:

Approximately 80% of biodiesel is first generation



Source: Oil World, Morgan Stanley Research, * considered first generation in Europe

Ethanol

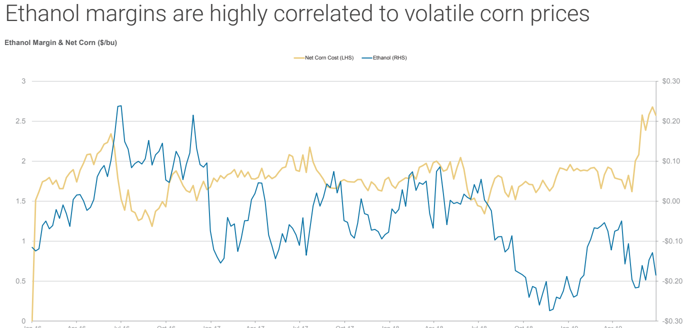
Ethanol represents nearly 80% of the total biofuel market globally. Ethanol fuel is ethyl alcohol, which is the same type of alcohol found in alcoholic beverages. Although it can be used in its pure form as a fuel for vehicles, it is most commonly found as a gasoline additive. Almost any plant-based material can be an ethanol feedstock. The sugars in the plant can be fermented to make ethanol through 'biochemical conversion'. As it stands, the majority of ethanol is produced using starch and sugar based feedstocks, with corn being the most common feedstock for the US, sugarcane for Brazil and wheat or sugar beet for Europe. As such, the majority of the ethanol market is classified as first generation, given its reliance on food crops as a feedstock.

The link with corn and sugar cane prices will always limit the size of the market. Production volumes are cyclical in nature depending on global inventories (which will impact profitability). For example, sugarcane ethanol volumes will depend on whether it is more attractive for producers to convert sugarcane into ethanol, or sugar. It is worth noting in terms of the cyclical nature, that cane has much longer cycles than corn (4-6 years vs. 1 year). The volatility of commodity prices has a major impact on the profitability of the biofuel market. For example, in the Brazilian market where the primary feedstock is sugarcane, the market has recently been through a long trough cycle with sugarcane prices below production cost, forcing many producers into bankruptcy. According to our LatAm Agribusiness team, feedback from the Brazilian Ethanol industry suggests that more than 15% of plants have declared bankruptcy.

That said, public policy also has the potential to significantly influence sugarcane and ethanol prices. Structurally, if biofuel demand were to increase significantly due to public policies (for example, due to increases in the blend mandates), ethanol prices would also increase and push up sugar and corn prices (sugar and corn consumers would have to incentivise production). The ceiling to this price increase is usually Brent, as biofuels are generally an alternative to gasoline and other derived products (the cheaper gasoline becomes, the more the demand for ethanol falls).

Exhibit 78:

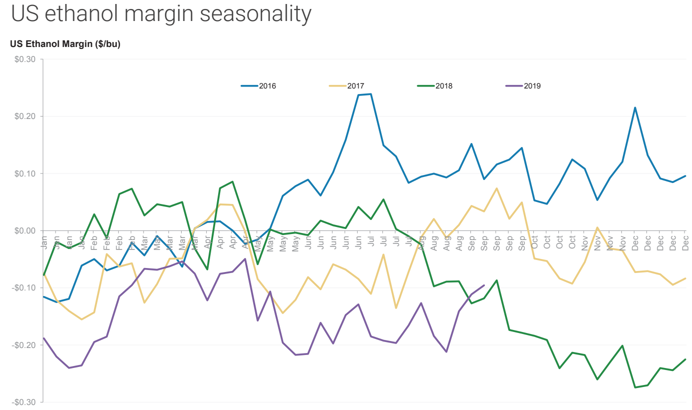
Ethanol margins are highly correlated to volatile corn prices



Source: Bloomberg, Morgan Stanley Research

Exhibit 79:

US ethanol margin seasonality



Source: Bloomberg, Morgan Stanley Research

Biodiesel

Feedstock costs are also an issue for the biodiesel market. Falling crude prices, together with increasing tallow prices, put pressures on margins for biodiesels. The biodiesel market has recently suffered from rising costs of second/third generation feedstocks, compared to falling prices of first generation, thus making the transition to advanced biodiesel less profitable than it once was. For example, Neste's recent decline in Renewables sales margins (from $692/t in 1Q19 to $568/t in 2Q19) was partially attributed to higher feedstock prices. Neste spends 70% of its R&D investments on the development of new raw materials, especially waste & residues, to reduce its vulnerability to feedstock price inflation. The company is focused on using even lower quality waste and residue materials, as well as exploring new materials such as algae and microbail oils.

Premium biodiesel prices are limiting demand growth. The cost of technology and feedstocks within the biodiesel market is restricting demand growth. There is a tangible premium for biodiesel products, as compared with traditional diesels. Even in Helskini, which allows a considerable tax break for renewable fuels, we estimate that the Neste MY Renewable Diesel™ still comes at a 10% premium to regular diesel. Without further incentives from governments (either subsidising more sustainable fuels, or taxing traditional fuels with a high carbon footprint), the potential for growth in biofuel penetration is unlikely to be realised.

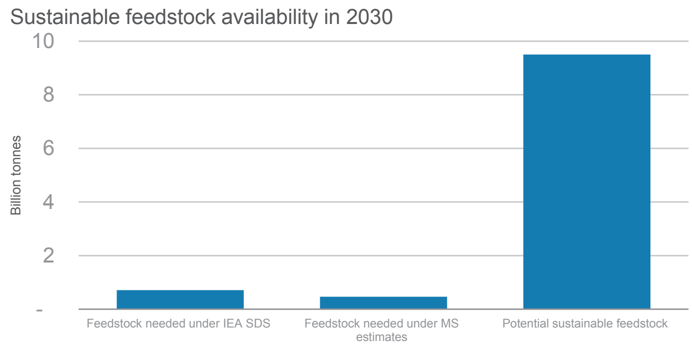
Technology for producing biodiesel from waste oil and animal fat feedstock is commercially viable, but technological progress is still needed. Technically speaking, the market for technology that produces biodiesel and hydrotreated vegetable oil (HVO) from waste oil and animal fat feedstocks is mature and accounted for 6-8% of all biofuel output in 2018 (source: IEA). Technological progress is still needed, however, to enable other types of novel advanced biofuels, which would allow the utilisation of feedstocks with high availability and limited other uses (e.g. agricultural residues and municipal solid waste).

Feedstocks

Feedstock availability is not an issue. The World Energy Outlook 2018 estimates that by 2030 9.5 billion tonnes of sustainable feedstock (meeting requirements for advanced biofuels) will be available (Exhibit 80). By 2030, we estimate that just 466 million tons of feedstock will be needed to address the biofuel market, which would represent just 5% of this total feedstock availability. Even by 2050, we estimate that less than 30% of available feedstocks will be utilised under the IEA's SDS.

Exhibit 80:

Availability of sustainable feedstock in 2030 using advanced processes



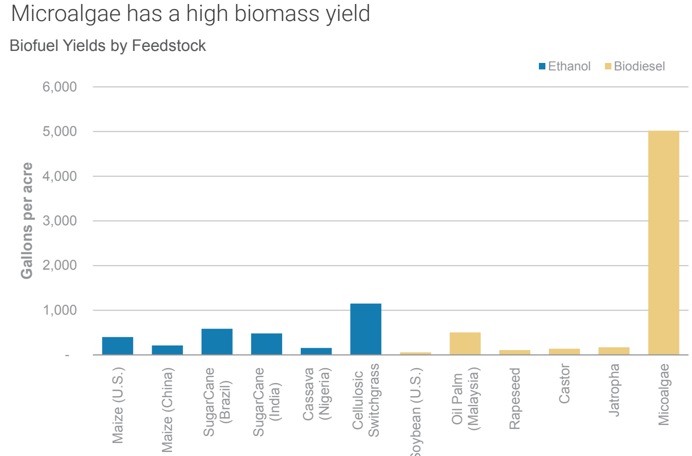
Source: World Energy Outlook 2018, IEA, Morgan Stanley Research

Third generation biofuels

While manufacturing advanced biofuels from other feedstock such as algae could provide significant solutions, it is still in its infancy. Algal biomass has the potential to be turned into a variety of biogas and biofuel end products and is an attractive feedstock due to its high biomass yield (Exhibit 81). Algae uses sunlight and water to convert CO2 into lipids and thus offers potential co-location opportunities with industries producing CO2. As such, from a sustainability perspective, algae offers significant potential. However, for it to achieve its potential, prices will need to decrease.

Exhibit 81:

Microalgae has a high biomass yield



Source: Center for Sustainable Systems, University of Michigan, Morgan Stanley Research

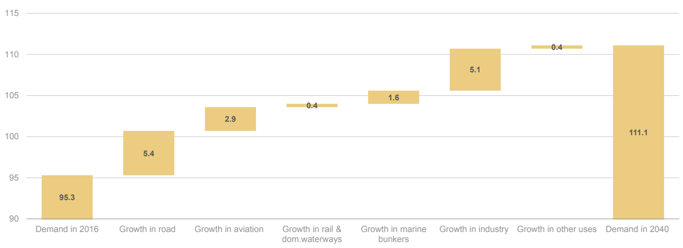
Potential for use in shipping and aviation

Shipping and aviation together account for ~10% of global fuel demand in the transport sector, but represent 28% of growth over the coming 20 years. Aviation is the fastest growing sector, driven by both a rapidly growing middle class (especially within developing countries) and the increasing penetration of low-cost carriers (LCCs).

Exhibit 82:

Aviation and shipping account for 28% of the incremental increase in oil demand globally

Sectoral oil demand growth 2016 to 2040 (mb/d)



Source: OPEC

Biofuels are the primary solution for the decarbonisation of the aviation industry. While we highlight electrification and liquefied natural gas (LNG) (read more here) as further potential solutions for the decarbonisation of the shipping industry, we note that the aviation industry is limited in terms of the technologies available to enable scaled decarbonisation. Relatively heavy electric batteries currently act as a major barrier to successfully electrifying the aviation industry, particularly with respect to long haul flights. For example, an electric aircraft flying between London and New York would require a 250 ton battery [25] . 'Lightweighting' offers some decarbonisation potential, but it will always be limited when used in conjunction with fossil fuels.

25 Source: Energy Transition Commission

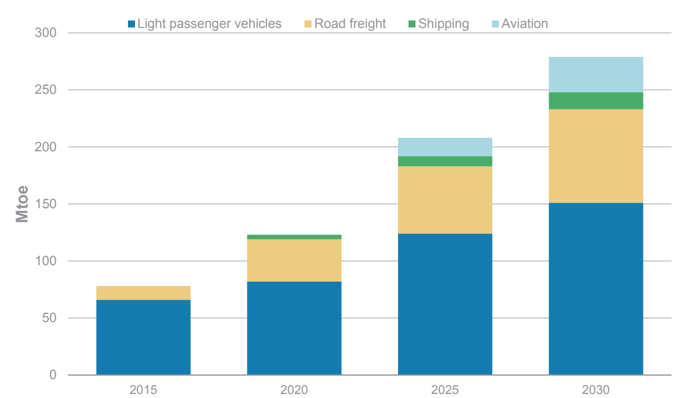
More development is needed in biofuels for the shipping and aviation industries. Under the IEA's SDS, by 2030 low-carbon fuels account for 7% of international shipping and 10% of aviation fuel (47 Mtoe). Currently, the supply of such fuels is minimal. More progress has been made in aviation biofuels, with the number of flights using such fuels having surpassed 200,000 since 2008 and biofuels are currently supplied by ten airports. Having said that, aviation biofuel consumption of about 15 million litres accounted for less than 0.01% of aviation fuel demand in 2018. Under the IEA's Sustainable Development Scenario, sustainable aviation fuel will need to account for almost 20% of total jet fuel.

Neste offers a renewable jet fuel product, which is fully compatible with existing jet engine technology and fuel distribution infrastructure when blended with fossil jet fuel. The fuel produces up to 80 percent fewer emissions over its life-cycle compared with conventional jet fuel. The company is ramping up its renewable jet fuel production. While it currently has the capacity to produce up to 100,00 tons per year in total, with its planned Singapore refinery expansion it will have the capacity to produce up to 1 million tons of low-emission renewable jet fuel by 2022 (source).

Exhibit 83:

Significant expansion in shipping and aviation is needed under the IEA's SDS

Biofuel consumption under the IEA's 2DS



Source: IEA

Biofuels

Policy

Exhibit 84:

Key biofuel policies globally. China is the only country on track to achieve the SDS, taking into account its current projects

Geography	Policy	Are current projects on track for the 2DS?
Europe	EU Renewable Energy Directive (RED II): member states must require fuel suppliers to supply a minimum of 14% of the energy consumed in road and rail transport by 2030 as renewable energy.	No
North America	Renewable Fuel Standard (RFS): American federal program that requires transportation fuel sold in the United States to contain a minimum volume of renewable fuels. California Low-Carbon Fuel Standard: goal is to reduce the carbon intensity of the transportation fuel pool by 10% by 2020.	No
China	E10 National Blending Mandate: expands the mandatory use of E10 fuel (gasoline containing 10% ethanol) from 11 trial provinces, to the entire country by 2020.	Yes
India	National Policy on Biofuels: an indicative target of 20% blending of ethanol in petrol and 5% blending of biodiesel in diesel proposed by 2030.	No
Japan	Mandate to use 500 million liters (crude oil equivalent) of biofuels per year until 2022.	No
Brazil	Renovabio policy: sets decarbonization targets for fuel distributors, expected to come into force in 2020.	No

Source: IEA, Morgan Stanley Research

Europe: On November 13, 2018, the European Parliament voted on the post-2020 EU Renewable Energy Directive (RED II). As per the Directive, member states must require fuel suppliers to supply a minimum of 14% of the energy consumed in road and rail transport by 2030 as renewable energy. This includes a minimum 3.5% requirement to be met by advanced biofuels in 2030 (0.2% in 2022 and 1% in 2025). Currently, advanced biofuels in Europe are considered to be those originating from lignocellulosic feedstocks (i.e. agricultural and forestry residues), non-food crops (i.e. algae and grasses), or industrial waste and residue streams (low CO2 emissions, or high GHG reduction). Note that HVO biodiesel (as produced by Neste) is not currently considered as advanced under the RED II directive. Advanced biofuels will be double-counted towards both the 3.5% target and the 14% target. Conversely, plant-based biofuels are required to decrease from 7.0% in 2021 to 3.8% in 2030. Member states must transpose RED II provisions into national legislation by June 30, 2021.

- **Finland**: The Finnish parliament approved a law on February 6, 2019 that sets a gradually increasing 30% biofuels target for 2030. Furthermore, the law sets a world-leading advanced biofuels target of 10% in 2030.
- **Sweden**: In its third biennial report to the United Nations Framework Convention on Climate Change (UNFCCC), the Swedish government set a goal of a 70% reduction in GHG emissions in its domestic transport by 2030 compared to 2010. On March 4, 2019, the government announced a proposal to introduce greenhouse gas reduction in the aviation sector, which if approved could lead to a mandate of 5% GHG reduction in aviation fuel by 2025 and 30% by 2030.
- **Norway**: Norway's government aims to increase the use of biofuels in the road transport sector by 20% in 2020 and to 40% by 2030. In October 2018, the Ministry of Climate and Environment mandated that the aviation fuel industry must mix 0.5% advanced biofuel into jet fuel from 2020 onwards. It added that by 2030, 30% of the aviation fuel should constitute biofuels.
- **Italy**: According to Italy's National Integrated Plan for Climate and Energy 2030, presented in January 2019, Italy will aim for a 10% share of renewables in transport in 2020 and a 21.6% share by 2030.
- **Denmark**: In 2009 the country implemented a mandate for biofuel road and rail transportation fuels of 5.75% (which is still the current level of the mandate). The country has additionally implemented a 0.9% mandate for advanced biofuels starting in 2020.
- **Germany**: Germany has had a biofuel mandate in place since 2009 with a target of 6.25% for biofuels in road and rail transport (in 2016 biofuels accounted for 4.7%) and specifically, a 0.5% mandate for advanced biofuels by 2025.
- **The Netherlands**: In 2018, the Dutch government raised the biofuel mandate to 16.4% by 2020. The country increased the advanced biofuels mandate from 0.6% in 2018 to 1% by 2020.

- **United Kingdom**: The UK's mandate aims to double renewable fuels in road and non-road mobile machinery transportation from 6% in 2017 to 12.4% in 2032.

N. America: On November 30, 2018, the US Environmental Protection Agency published a final ruling covering renewable fuel volume requirements under the Renewable Fuel Standard (RFS) program for 2019 and biomass-based diesel for 2020. The goal is to cut greenhouse gas emissions, expand the US renewable fuels, and lower dependence on imported oil. The Environmental Protection Agency (EPA) implements the program with the intention to increase the amount of biofuels in gasoline by establishing blending targets (Renewable Volume Obligation, or RVO) for each refiner or importer of petroleum-based gasoline or diesel fuel. A Renewable Identification Number (RIN) is the mechanism to prove compliance with the RFS. The final and proposed rulings for the RVO are outlined in **Exhibit 85** as per the EPA. In October 2018, the current administration ordered the EPA to lift the Reid Vapor Pressure Limit, which restricts sales of gasoline with over 15% ethanol (E15) content in the summer months in numerous states as a result of clean air restrictions (in order to address issues of smog). This was seen as a win for the corn ethanol industry, which has long sought to expand sales of the concentration above the 10% blend typically sold at gas stations in the US (see report). However, we remain sceptical that this will significantly impact volumes in the near term. Instead, a bigger issue for biofuels has been the administration's issuance of blend waivers to small refiners (exempting them from needing to comply with the RFS), which has reportedly caused the RIN credit prices to fall.

- **California**: On September 27, 2018 the California Air Resources Board (CARB) approved changes to the California Low Carbon Fuel Standard (LCFS), requiring a 20% reduction in carbon intensity by 2030. According to CARB, the new requirement is the most stringent in the US, and is aligned with California's overall 2030 target to reduce climate changing emissions by 40% below 1990 levels by 2030. Since 2011, the LCFS has resulted in more than 2 billion gallons of petroleum and natural gas being replaced with cleaner, renewable transportation fuels.

China: Biofuel policies in China have focused predominantly on ethanol production. As part of the E10 National Blending Mandate (the mandatory use of gasoline containing 10% ethanol), the country is building, or seeking approval to build new ethanol plants to meet requirements to triple its ethanol production capacity by 2020. This mandate implies the need to source 15 million tons of ethanol per year, nearly seven times the volume consumed today (source: IHS Markit). The central focus therefore is where this increase in capacity will come from. Currently, China imposes a 30% tariff on all ethanol imports, with the exception of the US (the world's largest ethanol producer), which is subject to a tariff of >45%. Our analysts suggest that this represents a material opportunity for Brazil and sugarcane in the medium term, and could have a material impact on the global corn balance and could potentially be even more relevant for sugar prices. For more details please refer to Because You Asked: Is 10% Ethanol Blend Mandate Feasible in China?.

India: In 2018 India launched its National Policy on Biofuels, which pledges fiscal and investment support for biofuels, with an indicative target of 20% blending of ethanol in petrol (up from 4% average at the start of the year) and 5% blending of biodiesel in diesel (up from less than 0.14% in 2018), which is proposed by 2030. The policy categorises biofuels as 'Basic Biofuels' or first generation, and 'Advanced Biofuels' which can be both second and third generation. This labelling exercise is intended to enable the extension of appropriate financial and fiscal incentives under each category. Given India's high sugarcane production and low sugar prices, the government's focus now is on expanding ethanol production. Most notably, it has introduced a road map for increasing the domestic production of biofuels via the commissioning of 12 2G ethanol bio-refineries across 11 states. While some projects have already been commissioned, with India's oil marketing companies having committed a capital expenditure of ~$1.42 bn, there is a Rs 5,000 crore viability funding gap (approximately $720 million), which the government has pledged to provide. This funding gap exists even with additional tax incentives in place. (Sources: Government of India Cabinet and Energy World.com).

Exhibit 85:

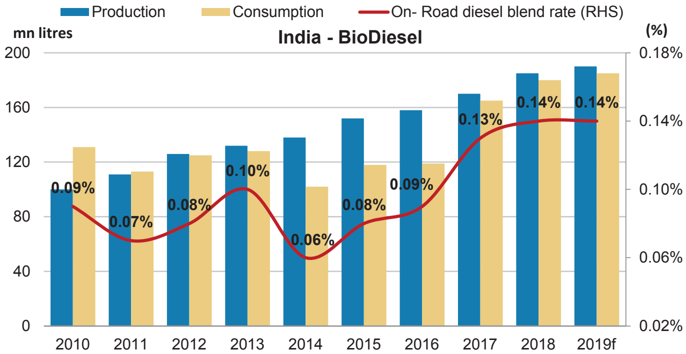
Proposed and finalised Renewable Fuel Standard (RFS)'s volume requirements in the US

	2017	2018	2019	Proposed 2020	2021
Cellulosic biofuel (billion gallons)	0.31	0.29	0.42	0.54	TBD
Biomass-based diesel (billion gallons)	2.0	2.1	2.1	TBD	2.43
Advanced biofuel (billion gallons)	4.3	4.3	4.9	5.0	TBD
Renewable fuel (billion gallons)	19.3	19.3	19.9	20.0	TBD
TOTAL	25.9	26.0	27.4	TBD	TBD

Source: EPA

Exhibit 86:

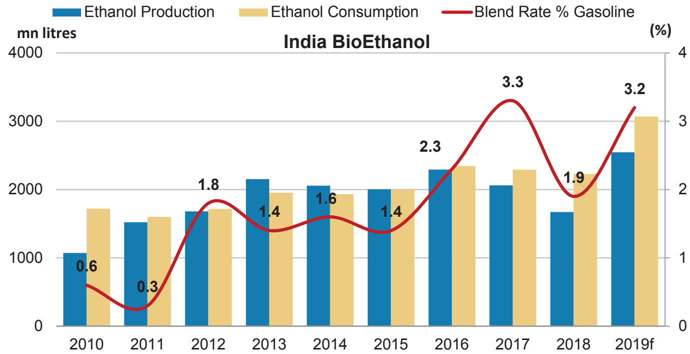
India's biodiesel blend rates are still well below their indicative 5% rate



Source: USDA

Exhibit 87:

While it is more positive in terms of ethanol, the country is still well below its 20% indicative blend rate



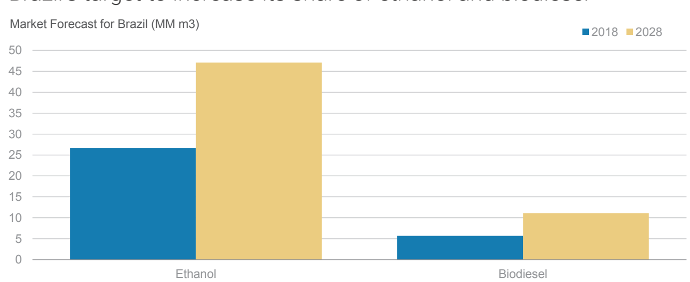
Source: USDA

Japan: Japan's FY2030 national target is that renewable energy should account for 13-14% of primary energy supply. Biofuels are part of a bigger renewable energy policy which incorporates the use of solar, wind, biomass and geothermal sources. In April 2018, the Government of Japan (GOJ) updated its mandate to use 500 million litres (crude oil equivalent) of biofuels a year up until 2022 and allow up to 44% of US corn-based ethanol in imported bio-Ethyl Tert-Butyl Ether (ETBE), whereas previously only Brazilian sugar cane ethanol was used. The ETBE source will be 91% reliant on imports. Given Japan's low food self-efficiency rate and its high sensitivity to rising food prices, from 2023 onwards the mandate will incentivise the use of second generation ethanol, which aims to increase the proportion of domestically produced biofuels.

Brazil: the country has a long-standing history in the production and usage of ethanol as a renewable fuel and is the second-largest producer of ethanol globally. Since 1976, the government has maintained a national mandate on ethanol blending of gasoline in the transport sector. The minimum blend is currently set at 27%. Ethanol production in Brazil uses sugar cane as a feedstock, making use of its advanced agri technology in the area. In 2010, the US EPA designated Brazilian sugarcane ethanol as an advanced biofuel (because it deemed that it reduced green-house gases by at least 61% compared to gasoline). Brazil's **Renovabio Policy** sets decarbonisation targets for fuel distributors and is likely to come into force in 2020. As part of its Nationally Determined Contributions (NDCs), Brazil committed to reducing its greenhouse gas emissions by 43% below 2005 levels by 2030. As part of this, the country pledged to increase the share of sustainable biofuels in Brazil's energy mix to 18% by expanding biofuel consumption (through increasing ethanol and biodiesel), and increasing the share of advanced biofuels. The Renovabio Policy therefore aims to contribute to Brazil's NDC by creating a market of certificated biofuel producers through the use of cbios (decarbonisation credit units), which are intended to be freely traded in financial markets. According to our LatAm Agribusiness team, feedback from the Brazilian Ministry of Mining suggests that it might take up to 5+ years for these carbon credits to be liquid enough to materially impact demand/supply of biofuels. Additionally, it may be challenging to get other geographies to participate in this market. The National Biofuel Policy is expected to inject US$20.21 bn into the Brazilian economy, although we see these targets as very ambitious given the difficulty in the profitability of the ethanol market as outlined on page 85, and taking into account disappointing past policy continuity. In addition to the Renovabio Policy, Brazil's **Rota 2030** could also offer considerable benefits to auto manufacturers that choose to invest in ethanol research by providing tax credits on industrial products.

Exhibit 88:

Brazil's target to increase its share of ethanol and biodiesel



Source: MME

Exhibit 89:

Brazil's future biofuel projects

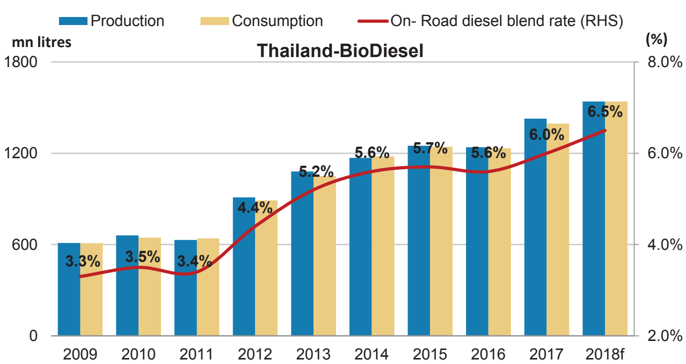
Category	Projects	USD $ (billion)
Ethanol Mills	• 19 New Units • 37 expansion • 9 new corn ethanol mills • 25 new second generation ethanol mills	14.07
Agriculture		1.03
Pipeline	• 1 Ethanol pipeline	1.02
Biodiesel	• 40 new units • 36 soybean oil extracting plants	4.09
Total		20.21

Source: EPE (2018)

Thailand: Government policy actions have been a key trigger for incentivising markets to deliver high biodiesel blends and consumption. For example, biodiesel consumption rose in Thailand post the implementation of B7 (up from B5) in 2014 (**Exhibit 90**). The outlook appears positive as efforts are being taken to transition over to B10 and phase out B7 over the next few years. In terms of ethanol, following the ban on unleaded gasoline 91, blend rates of ethanol have nearly doubled and are currently at 13% (**Exhibit 91**). Along with blending policy action, the government uses state oil funds to provide subsidies for using ethanol blended fuels, with discounts compared to premium gasoline ranging from 20-40%.

Exhibit 90:

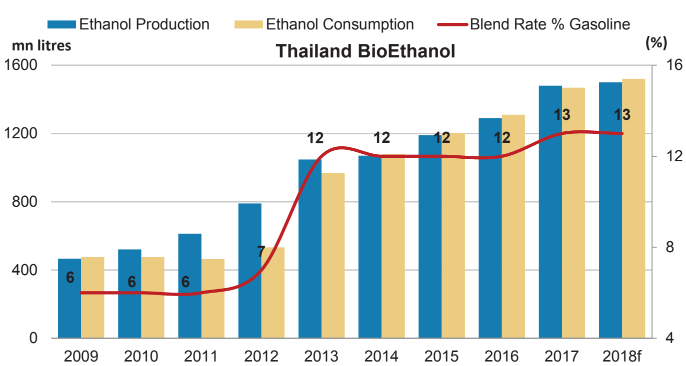
Government intervention has pushed up volumes significantly from 2014 onwards



Source: USDA

Exhibit 91:

A ban on unleaded gasoline caused ethanol blend rates to nearly double

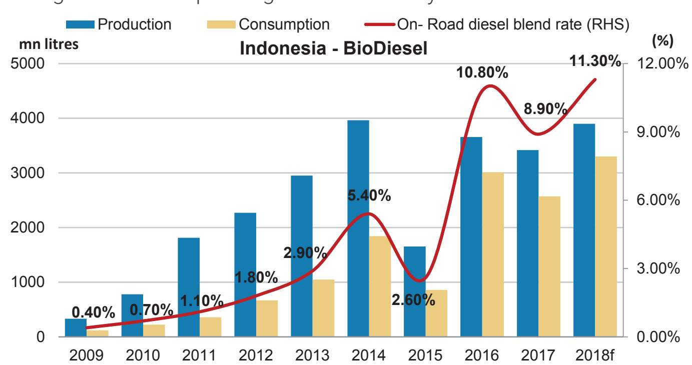


Source: USDA

Indonesia: As with Thailand, government policy in Indonesia has been a key driver in the uptake of higher biodiesel blends and consumption. The country is the largest producer of palm oil and thus benefits from the ready availability of feedstock, which allowed it to implement its B20 (20% biodiesel) mandate in September 2018. The Indonesian government is planning to implement B30 by 2020 to further push consumption of cleaner fuel. Ethanol consumption, on the other hand, has been poor due to lower ethanol feedstock availability. Feedstock availability could be improved if the price gap between molasses, ethanol and gasoline is reduced. Most of the bioethanol is currently used by industrials.

Exhibit 92:

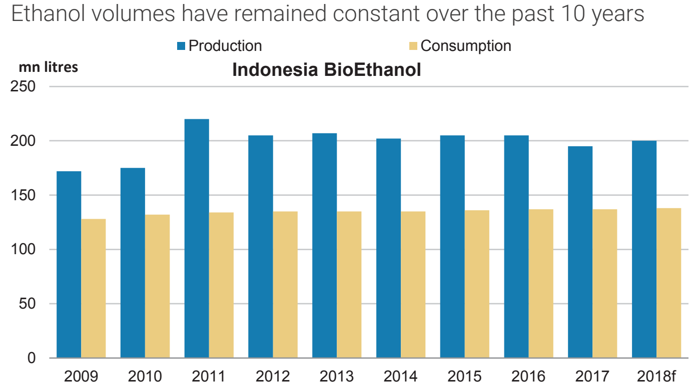
The government is pushing for a move away from B7 and towards B10



Source: USDA

Exhibit 93:

Ethanol volumes have remained constant over the past 10 years



Source: USDA

Biofuels

Risks

Cost of production. As outlined on page 89, the cost of feedstock for both ethanol and biodiesel currently acts as a barrier. For ethanol, this has affected the ability for producers to turn a profit. For biodiesel, we have seen margins tightening and the demand for the premium product acts as a barrier under current premiums. Moving forward, favourable government incentives (either subsidies or carbon taxes) need to be implemented to enable volumes to meet the IEA's SDS requirements.

Trade tensions: particularly relevant for ethanol, where the two largest producers (US and Brazil) produce 80% of the total ethanol market. For example, Brazil currently has a 20% tariff on ethanol imports from the US, and last year China raised its tariff on US ethanol to 70%, closing off a market that is expected to boom in China ahead of its E10 mandate (source).

Blending mandates from governments: blending mandates significantly impact the demand for biofuels, especially in countries such as Brazil, Thailand and Indonesia. **Exhibit 94** demonstrates the impact of regulatory changes and their corresponding impacts on demand volumes in Brazil.

Government support: while many corporations have been willing to invest in biofuel technology (as demonstrated in **Exhibit 75**), in order to achieve the aggressive targets that have been outlined by governmental policy, further support will be needed either through subsidising more sustainable fuels or taxing traditional fuels with a high carbon footprint. For example, India's commissioning of 12 2G ethanol bio-refineries (outlined on page 83) comes at a viability funding gap of approximately $720 million, even with an additional tax incentive in place.

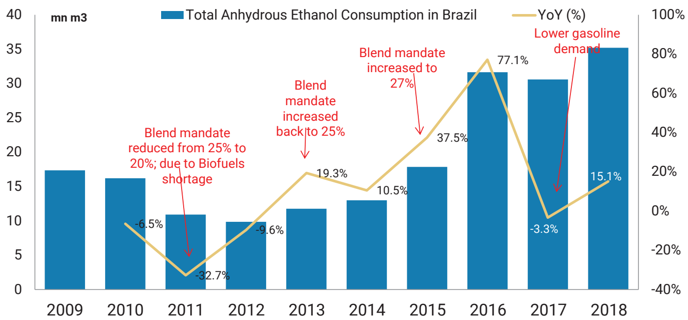
Environmental impact: While the IEA's SDS target of 280 Mtoe by 2030 refers to biofuels generally, it is emphasised that significant growth in advanced biofuels is required. As demonstrated by **Exhibit 70** and **Exhibit 71** on page 82, different types of feedstock significantly impact the carbon emissions of biofuels, particularly when we take into account indirect land use change (ILUC), which measures the land being cleared to grow new agricultural crops for feedstock. In order to achieve the aggressive decarbonisation targets set by governments through the ramp-up in biofuels, there must be a focus on transitioning away from carbon intensive first generation feedstocks towards second and third generation, which are considered to be advanced.

Food security: first generation biofuels use only edible crops, which has led to biofuel crops displacing food sources in certain regions and subsequent spikes in food prices. Subsidies for these crops only amplifies this issue.

Water: increased agriculture to create feedstocks for biofuels leads to increased water consumption.

Exhibit 94:

Anhydrous ethanol consumption in Brazil (mn m3)



Source: Morgan Stanley Research

Stock Implications

Adecoagro is broken into three main lines of business: farming, land transformation, and sugar, ethanol and energy. The latter lines of business consist of cultivating sugarcane, which is processed in owned sugar mills and consequently transformed into ethanol, sugar and electricity and is then marketed. The company owns and operates three sugar and ethanol mills with a total crushing capacity of approximately 10.2 million tons of sugarcane per year. MS' forecast for EBITDA exposed to ethanol is between 43.4% and 19.5% depending on market conditions.

Andritz designs and builds feed and biomass plants, including engineering, installation, start-up, service, and commissioning. 25% of EBITA is related to utility fuel switching.

Attis Industries (not covered) is a diversified company with a biofuels division within its Attis Innovations business. It uses waste fats and oils to produce biodiesel, renewable diesel, renewable gasoline and renewable jet fuel.

Cosan SA is a subsidiary of Cosan Ltd and is engaged primarily in the production of ethanol, sugar and energy. The company is also one of the largest producers of electricity from biomass, with a capacity to supply a city of up to 10 million. MS' forecast for EBITDA exposed to ethanol is between 3.5% and 2.8% depending on market conditions.

Darling Ingredients (not covered) is a Texas-based global developer and producer of sustainable natural ingredients from bio-nutrients. Its fuel segment, primarily made up of Diamond Green Diesel, represented ~9% of net sales and had an EBITDA margin of 20% in 2018.

Neste Corporation is the world's largest producer of renewable fuels from waste and residues and currently has nameplate capacity to produce 2.9 Mt of renewable diesel globally (representing 57% of the HVO biodiesel market). The company will increase its capacity to 4.5 Mtpa of biofuels by 2022, following a €1.4 billion investment in its 1.3 Mtpa per year biodiesel facility in Singapore. In addition, the company has indicated its ambition to increase the capacity further to ~8 Mtpa by 2030. The company produces HVO bio-diesel, or renewable diesel from a range of renewable feedstocks including animal fats from industry waste, used cooking oils and a range of vegetable oil products. For example, the company's Neste MY Renewable Diesel™ product helps reduce greenhouse gas emissions by 50-90% over the full life cycle as compared to fossil diesel. 70% of its EBIT was exposed to renewable diesel in 2018 rising to 80% in 2025, based on our European Energy team's estimates.

NewEnergyBlue (not listed) is a clean energy producer which plans to develop, build, own and operate a biomass refinery. The refinery targets to produce 16 million gallons of cellulosic ethanol and 109,000 tons of lignin pellets from 230,000 tons of crop residue annually. It will convert locally harvested wheat straw, barley straw and corn stover into sugars and ferment the sugars into cellulosic ethanol for renewable automotive fuel.

NEXT Renewable Fuels, Inc (not listed) has entered into a multi-year feedstock supply agreement with BP Products North America Inc agreeing to purchase ~2 million metric tons (13.2 million barrels) per year of renewable feedstocks for NEXT's upcoming Oregon-based second-generation advanced biofuel facility. The biodiesel will be made from 100% renewable feedstock including used cooking oils, animal tallows and selected virgin seed and vegetable oils, which BP will supply from its global feedstock aggregation and sourcing network. The plant is expected to have an annual processing capacity of 12.3 million barrels (600 million gallons) with a capex of over USD $1 billion. Shell Trading Co. has signed an agreement to purchase renewable diesel from NEXT's facility due to open in 2021.

POET biorefinning LLC (not covered) produces corn-based ethanol across 28 locations in N. America (and is also the fifth largest merchant of CO2 in America). The company has also been researching and developing cellulosic ethanol technology since 2001. Project LIBERTY (a partnership with Royal DSM of the Netherlands) uses corn crop residue (cobs, leaves, husk and some stalk) as a feedstock for ethanol. They intend to build further cellulosic ethanol plants co-located with their bio-refineries.

Raízen Energia (not listed) is a joint venture between Cosan and Royal Dutch Shell. Raízen is the leading sugarcane ethanol manufacturer in Brazil and Brazil's second-largest fuel distribution company, with the infrastructure to distribute 5 billion liters of fuel per month. In 2017/18 the company produced just under 2.1 billion liters of ethanol, 12 million liters of second generation (E2G - Etanol de segunda geração) and traded 4.3 billion liters of ethanol. MS' forecast for EBITDA exposed to ethanol is between 4.1% and 3.4% depending on market conditions.

Renewable Energy Group (not covered) is partnering with Phillips 66 to construct a large-scale renewable diesel plant on the US West Coast. The facility will utilize REGI's proprietary BioSynfining® technology for the production of renewable diesel fuel, which uses a mix waste of fats, oil and grease including regionally-sources vegetable oils, animal fats and used cooking oil as planned feedstock. The company expects the plant to be ready for production in 2022.

Ryze Renewable (not listed) has entered into a long-term supply and offtake agreement with Phillips 66 for two renewable diesel production facilities in Nevada. According to Phillips 66, once operational these plants will manufacture high-cetane (80+) renewable diesel fuel from agricultural oil and animal fats feedstock using a patented catalytic hydrogenation technology. Combined, the facilities are expected to produce 11 MBD of 100% renewable diesel. PSX will provide both facilities with feedstock and will move the products from the plants to customers in the West Coast.

São Martinho SA plants sugarcane and other sugarcane byproducts in Brazil. Of its raw sugar products, hydrous ethanol (used as a fuel by ethanol-driven vehicles) and anhydrous ethanol (used as an additive in gasoline-driven vehicles) are used in the transport sector. MS' forecast for EBITDA exposed to ethanol is between 59.8% and 32.7% depending on market conditions.

Valmet Oyj provides services and technologies for a range of industries including second generation ethanol. MS analysts estimate that approximately 5% of sales are exposed to biofuels.

Velocys (not covered) produces advanced biofuels from household waste, forest residues and other sustainable carbon sources.

Oil and Gas companies investing in Biofuels

Bharat Petroleum Corp announced plans in October 2018 to build a biofuel plant. This second generation ethanol bio refinery will have the capacity to produce 30 million litres of fuel grade ethanol per year. The plant will use around 200,000 metric tons of rice straw as feedstock annually and uses a zero-liquid discharge technology which recycles all water back into the production processes. Ethanol will then be blended with petroleum to be used as a biofuel. In addition to this facility, BCPL is also planning in the short term to set up two other bio fuel plants.

BP started its biofuels operations in 2008 through a joint venture with Tropical Bioenergia in Brazil. It now has three ethanol plants (Tropical, Itumbiara and Ituiutaba) with capacity for processing 10 million tonnes of sugar cane per year. In 2018 BP formed a venture with Brazil's Copersucar, a leading global ethanol seller, to jointly operate one of the largest fuel terminals in the country. BP has also agreed to form a 50:50 joint venture with Bunge – a leader in agriculture, food and ingredients – which will create a leading bioenergy company in one of the world's largest fast-growing markets for biofuels. Finally, BP Products North America Inc has entered into a multi-year feedstock supply agreement to sell ~2 million metric tons (13.2 million barrels) per year of renewable feedstocks for NEXT's upcoming Oregon-based second-generation advanced biofuel facility.

China Petroleum & Chemical Corp (Sinopec) has invested in fuel ethanol technology, biodiesel, micro algae biodiesel technology, researching cellulose ethanol technology and biological fuel technology. The company also built a B5 biodiesel plant in Shanghai to repurpose gutter oil and supply fuel to 200 petrol stations across the city. This plant gives the capacity to produce between 400,000 and 600,000 tons of B5 every year and use up all of Shanghai's gutter oil (cooking oil which has been recycled from waste oil collected from sources such as restaurants, fryers and sewers).

Hindustan Petroleum announced in 2017 plans for a 100,00 litres a day (8 million gallons a year) second generation ethanol plant at a cost of $92.4 million. This facility will use 400,000 metric tons of sugarcane bagasse and other crop waste as a feedstock.

Indian Oil Corp is planning a biomass-based second generation ethanol production facility at its flagship Panipat refinery. The proposed plant will utilise non-food biomass, mainly rice straw and other ligno-cellulosic feedstock, requiring around 473 tonnes of raw material every day.

Philips 66 has begun expanding its renewable diesel production capacity and has over 650 million gallons of annual capacity. Feedstocks include used cooking oil, bean oil, corn oil, canola, beef tallow, poultry fat, as well as a few others. It will be a drop-in fuel and so won't need to be blended with traditional diesel. Its upcoming project at its Humber refinery processes used cooking oil and will have the capacity for 6 million barrels per day (MBD). Its partnerships with Ryze Renewable and REGI (above) will allow for further renewable production capacity.

Shell is one of the largest producers of low-carbon biofuels made from sugar cane. Through its JV with Raizen (above) it blends biofuels into its fuels globally. Shell is also active in the development of advanced biofuels made from sustainable feedstocks such as waste and cellulosic biomass, or the non-edible parts of plants. The company has signed an agreement to purchase renewable diesel from NEXT's (above) facility due to open in 2021.

Valero Energy Corporation has a 50/50 JV with Darling Ingredients called Diamond Green Diesel (DGD). The JV converts animal fats, used cooking oils and other feedstocks into 275 million gallons of renewable diesel every year. Diamond Green Diesel makes up just ~4-5% of total corporate EBITDA currently, but the partners are currently expanding capacity by almost 150%.

Further reading on Biofuels

Agribusiness: Sugar & Ethanol: Sugar Recovery May Take Longer, but Is Coming (September 20, 2019)

Because You Asked: Is 10% Ethanol Blend Mandate Feasible in China? (August 9, 2019)

Neste Corporation: Volume Led Growth - Stay Overweight (July 25, 2019)

Refining & Marketing: Texas Tour Takeaways (April 8, 2019)

The Economic Consequences of Climate Change

By Derrick Kam, Economist

The economic losses associated with climate change

$10-20 trillion GDP could be lost by 2100. Various academic studies on the effects of climate change have tried to quantify the impact that climate change can have on economies. These studies have utilized multiple approaches, and a survey of the recent literature suggests that the economic losses due to climate change can affect anywhere between 3-7% of global GDP over the long term (most of these estimates run out to 2100).

These studies have tended to look at the issue of climate change on growth via a top-down approach of looking at the effects that climate change can have on productivity (the key sustainable driver of long-term growth) or via a bottom-up approach by assessing the at-risk (coastal) areas or impacted sectors (such as agriculture) due to changes in rainfall patterns.

Both developed and developing economies are at risk. While earlier research pointed towards a varied impact on countries, with more developed economies seemingly less exposed to the impact of climate change and less developed economies more exposed, recent research has found that this is no longer the case. Moreover, these estimates on economic growth are based on the current estimates of either temperature change or rise in sea levels. In turn, this could lead to an understatement of the economic losses given that the estimates of temperature change and / or rise in sea levels have also increasingly moved up over time. A recent UN climate report highlighted that the increase in the global temperature means the sea level is rising and that extreme and rare sea level events could become more commonplace by 2100, with low lying cities and coastal areas particularly at risk.

Past studies have focused on the short-term growth implications but recent research has pointed towards a long-lasting impact on economic growth. Climate change and its effects will therefore likely be another structural drag on global growth, considering that the global economy is already dealing with structurally lower potential growth due to weakening demographic trends and slower productivity growth.

Exhibit 95:

Academic research on climate change impact

Authors of Study	Methodology	Growth Impact	Assumption on climate change
Kahn, et al., 2019	Modelling impact of climate change on labour productivity.	GDP per capita to be lower by 7% by 2100 in absence of mitigation policies and to be lower by 1.07% by 2100 on abiding by the Paris agreement.	Assumes that temperatures rise by 0.04 degrees celsius annually in absence of mitigation policies and by 0.01 degree celsius under Paris agreement.
IMF, 2019	Estimating likely impact on emissions, fiscal revenues, local air pollution mortality, and economic welfare impacts of a range of instruments including comprehensive carbon taxes, emissions trading systems, taxes on individual fuels, and incentives for energy efficiency.	Warming of 4 degrees Celsius would permanently lower global GDP by around 3.5 percent below GDP levels with no climate change (Nordhaus, 2018).	Global average temperatures projected to rise 4 degree celsius above pre-industrial levels over the 21st century.
Desmet, et al., 2018	Estimating consequences of probabilistic projections of local sea-level changes under different emissions scenario.	Permanent flooding estimated to reduce global real GDP by an average of 0.19% in present value terms and welfare declining by 0.24%.	Mean sea level is likely to increase by 0.4 to 0.7 meters compared to the period 1986-2005 under the RCP 4.5 pathway. RCP 4.5 is a moderate-emissions pathway, leading to CO2 concentrations of 487 ppm in 2050, rising to 538 ppm in 2100 and then stabilizing at 543 ppm.
Tom Kompas, Van Ha Pham, Tuong Nhu Che, 2018	Estimate the effects of global warming (e.g., loss in agricultural productivity, sea level rise, and health effects) on Gross Domestic Product (GDP) growth and levels for 139 countries, by decade and over the long term.	Using the 2017 IMF GDP value, estimated loss of US$9,593.71 billion or roughly 3% of the 2100 world GDP.	Global warming of 3 degrees celsius by 2100.
Ciscar, et al., 2011	Estimating consequences of climate change in Europe in four market impact categories (agriculture, river floods, coastal areas, and tourism) and one non-market impact (human health).	European GDP loss is estimated to be between €20 billion for the 2.5 °C scenario and €65 billion for the 5.4 °C scenario. EU annual welfare loss between 0.2% for the 2.5 °C scenario and 1% for the 5.4 °C scenario.	Assuming 2080s climate in today's economy. The scenarios considered lead to an average temperature increase in Europe between 2.5 °C and 5.4 °C.

Source: Various academic papers as seen above, Morgan Stanley Research

But mitigating measures can be put in place

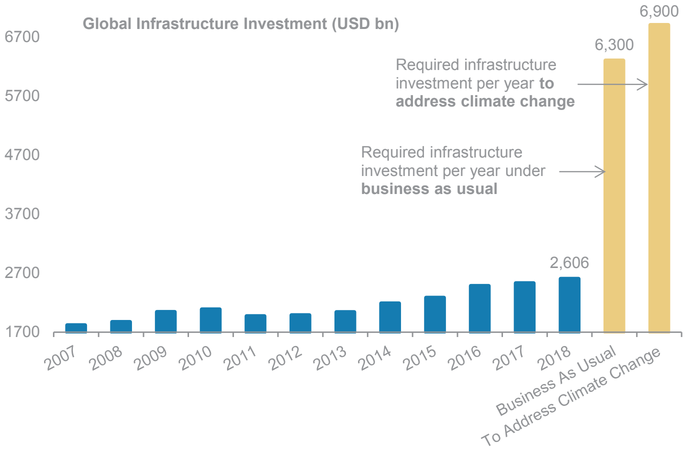
Just as the economic losses associated with climate change are becoming more apparent, action too has been taken to invest in technologies to either adapt or mitigate the impact of climate change. Empirical work has also suggested that investing in climate change technologies (either mitigation or adaptation) can help to offset the negative impact of climate change on growth. Indeed, a recent OECD report suggests that investing in climate change technologies and pursuing the objective of sustaining longer term growth can actually be compatible goals. The OECD report points out that G20 economies that invest in the right technologies can expect to get a boost to growth of 2.8% points on average, which would help at least partially to offset the impact of climate change.

The OECD estimates that existing (or business as usual) infrastructure needs amount to US$6.3 trillion per year (from 2016 to 2030). Adding the need to make infrastructure climate proof leads to a total required infrastructure need of US$6.9 trillion per year over the same time period (a 10% increase).

However, the same report points out that currently economies are already facing challenges in meeting the projected infrastructure needs for continued economic development as economies are only investing US$3.4 trillion in infrastructure as compared to the need for US$6.3 trillion.

Exhibit 96:

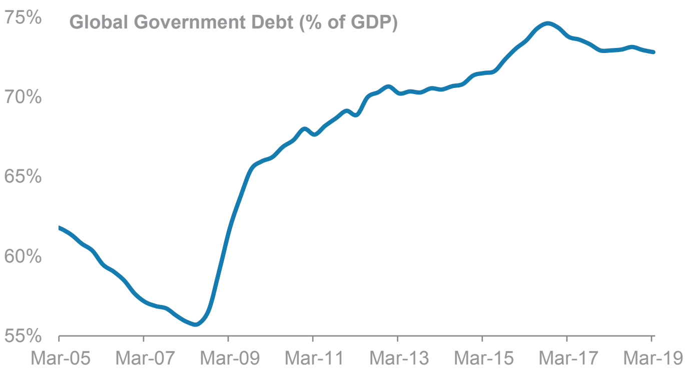
Global infrastructure investment trend



Source: Global Infrastructure Outlook, OECD, Morgan Stanley Research; The "Business As Usual" case of US$6300bn is the OECD estimated infrastructure investments required per year to sustain growth and meet the basic needs generated by rapid population growth and urbanisation in developing countries without taking into account climate concerns. The "To Address Climate Change" case of US$6900bn is the same estimate which takes into account the goal of achieving 2 degree Celsius rise in temperature with a 66% probability. Please refer to this OECD report for more details.

Exhibit 97:

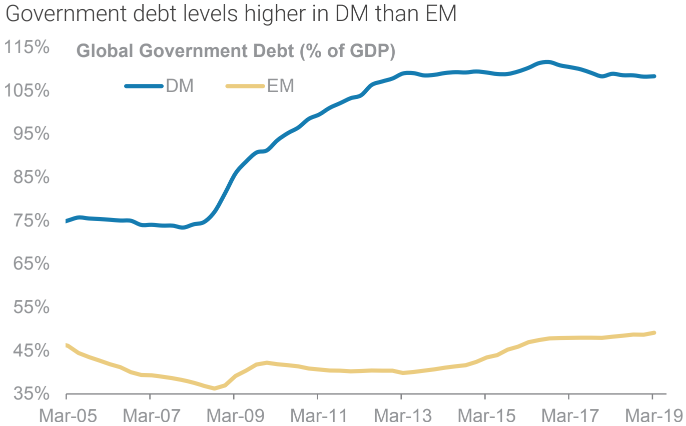
Global government debt remains elevated



Source: BIS, CEIC, Haver Analytics, IMF, national sources, Morgan Stanley Research

Exhibit 98:

Government debt levels higher in DM than EM



Source: BIS, CEIC, Haver Analytics, IMF, national sources, Morgan Stanley Research

Challenges to achieving the required investments in climate change

However, we see a couple of key macro challenges that policy makers could face in achieving the requisite investment for climate change:

1) Climate change as a global public good: To an extent, mitigating the rise of temperatures and / or sea levels can be viewed as a public good. In particular, the positive externalities could therefore lead to a situation in which it could be under-provided if left to market forces.

A parallel example would be infrastructure, where the benefits of good infrastructure networks are often underestimated, leading to a less than optimal supply.

In that vein, the benefits or positive externalities associated with successfully mitigating or adapting to climate change could also be underestimated by existing academic studies, as they have tended to look at it more from the perspective of potential economic losses.

Moreover, considering the global dimension of climate change, countries would need to cooperate in a multi-lateral fashion. This further complicates the issues given the need to address competing needs between developed market and emerging market economies as well as the need for trust among countries for coordinated multi-lateral action.

2) Intertemporal choice: Investing in climate change technologies would require a diversion of resources from elsewhere. This could mean having to prioritise investment in climate change technologies over other pressing needs for government investment or forgoing consumption today. This gives rise to the potential for procrastination.

3) Elevated levels of public debt: Global public debt levels are currently at 73% of GDP, close to the peak of 75% of GDP. This issue is more acute for DM economies as their average public debt levels are at 108% of GDP, as compared to the EM average of 49%. Elevated levels of public debt will likely be a constraint for governments to lift public investment to deal with climate change, over and above the cyclical challenge of managing the cycle.

Policy action is key

The economic costs associated with climate change are significant, but at the same time, investment in the right technologies to either adapt or mitigate the effects of climate change can also help to offset that impact. However, it requires policy makers to ensure that there is a quick reallocation of resources as well as faster technology diffusion in order to provide a timely offset.

However, challenges in the form of the public policy choice of prioritizing competing needs, as well as current elevated levels of public debt, could constrain policy makers in achieving these goals. Moreover, the recent increase in trade tensions has given rise to the notion that globalization could be in retreat, which further complicates the issue, as national governments might not be as willing to cooperate in jointly investing in climate change technologies.

Implications for Oil, Gas and Coal

Contributing equity analysts: Sasikanth Chilukuru, Mayank Maheshwari, Devin McDermott, Akash Mehta, Martijn Rats, Lillian Starke. Contributing commodity strategists: Susan Bates, Marius van Straaten

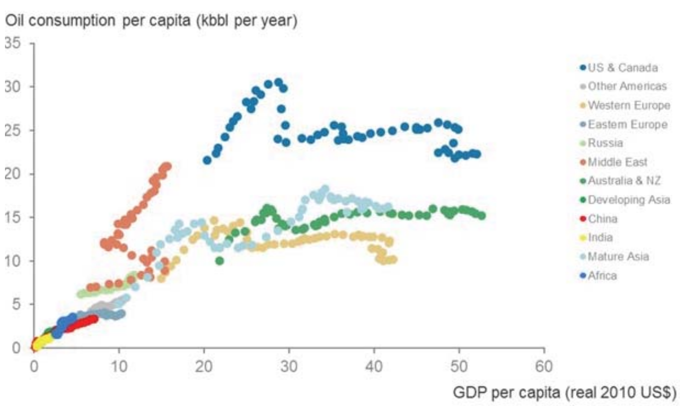
The world's need for energy will continue to rise. Over the next 30 years, the world population will rise by 2 billion people[25]. As GDP per capita increases so generally does energy consumption. Thus, even with an expectation for energy efficiency, we are likely to see higher demand for energy in the future compared to today.

25 Source: United Nations

Renewables will become a more important source of energy. Between 2017 and 2040, renewables are expected to increase from 14% to 20% of the total primary energy demand globally, based on the IEA's New Policies scenario (for more details on this please see the Appendix). Together, wind, solar, hydro and other renewables will account for ~45% of incremental growth in energy demand over that period.

Exhibit 99:

Oil consumption vs GDP per capita

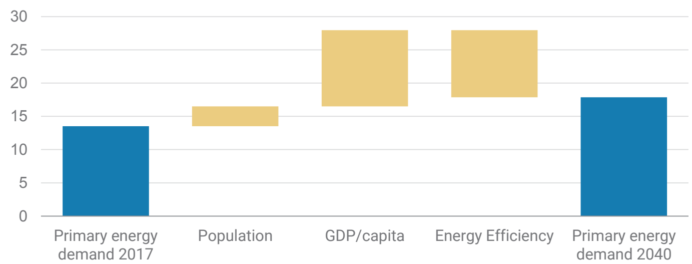


Source: World Bank, IMF, BP Statistical Review, IEA, Morgan Stanley Research

Exhibit 100:

Population growth and economic expansion will more than offset energy efficiency over the next 20 years

Primary energy demand 2017-2040 (billion toe)

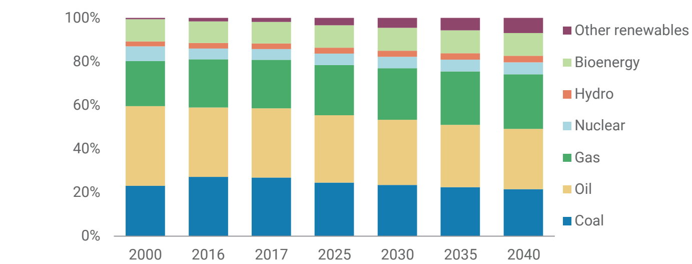


Source: BP World Energy Outlook 2019

Exhibit 101:

Renewables will represent 45% of incremental energy demand between 2017-40, taking renewable penetration to 20% of total primary energy demand

% of Total Primary Energy Demand



Source: IEA

But this requires electrification of some energy sources... As our Energy analyst Martijn Rats discussed previously in From Molecules to Electrons - What Energy Transition Means for Oil & Gas Investors, renewables only deliver electricity, and just 18% of total energy is consumed in this form. The remaining 82% still requires the burning of an oil, gas or coal molecule. Electricity's share is growing but at a low and stubbornly stable rate – up just 2 percentage points in each of the last four decades. Accelerating this will ultimately not just be a matter of producing more renewable power. Instead, technologies are needed that shift our consumption towards electricity.

… which will take time… The electric vehicle is the best example of energy supply moving from an oil molecule to an electron. However, this will take time. As discussed in **Electric Vehicles** , we expect the combustion engine to remain the dominant type of passenger vehicle globally until 2044. On optimistic forecasts, it would still take until 2027 before EVs offset more than 1 mb/d of oil demand.

...and some uses of fossil fuels cannot easily be replaced. Let's take oil: currently around 86mb/d of oil is consumed annually (source: 2016 IEA). Around two-thirds of this is used for light road vehicles and power generation, for which there are 'clean' options available whether it be through direct renewable power generation or the use of green electricity to power the car. But for the remaining two-thirds of current oil demand, it's not so clear that there is a commercial low-carbon alternative at present.

Petrochemicals currently account for 14% and 8% of total primary demand for oil and gas, respectively. But with consumption of plastics and fertilisers expected to continue to grow quickly worldwide, over the next decade to 2030 petrochemicals are expected to account for a third of the growth in oil demand and c 7% of the growth in gas demand. [26]

Alternative feedstocks and recycling plastic are two possible options that would reduce oil and gas demand. But CCS and switching from coal to natural gas feedstock are the two main options for decarbonising the petrochemical sector – both of which would still require significant amounts of oil and gas to be extracted and consumed.

26 Source: IEA: The Future of Petrochemicals, October 2018

Exhibit 102:

Finding alternatives to oil, gas and coal will be difficult in some end markets

Oil	% of end use	Transition from fossil fuels	Progress tracker	Reduction of emissions from fossil fuels	Progress tracker
Cars	28%	EVs, FCEVs, biofuels	MSe 8.5% park penetration by 2030	Efficiency improvements	Fuel economy standards cover ~ 85% light vehicles
Freight	19%	FCEVs	Early stage	Efficiency improvements	Fuel economy standards cover ~50% heavy duty vehicles
Aviation	7%	Low carbon fuels including biofuels hydrogen; Rail	Minimal at present	Efficiency improvements	Ongoing
Marine bunker	6%	Low carbon fuels e.g. ammonia, hydrogen or advanced bidiesel	IEA expects 3% penetration of low carbon fuel by 2040 vs 25% in SDS	Efficiency improvements	IMO targeting 40% reduction in carbon intensity by 2030 and 70% by 2050.
Other transportation	1%				
Petrochemical feedstock	12%	Bioplastic; recycling	~9% of plastic recycled; ~1% plastic is biobased	CCS	Minimal
Steam and process heat	7%	Hydrogen in combination with heat pumps			
Other	1%				
Power generation	6%	Renewables	-2% global capacity CAGR (2019-30 MSe)	CCS	Minimal
Buildings	9%	Hydrogen in combination with heat pumps	c 3% of heat in buildings globally		
Agriculture Fishing	3%				
Other	3%				
Gas	**% of end use**	**Transition from fossil fuels**	**Progress tracker**	**Reduction of emissions from fossil fuels**	**Progress tracker**
Industry	32%	Hydrogen	Early stage development	CCS	Minimal
Buildings	21%	Hydrogen in combination with heat pumps	c 3% of heat in buildings globally		
Non combusted	6%				
Transport	1%				
Power	39%	Renewables	+1% global capacity CAGR (2019-30 MSe)	CCS	Minimal
Coal	**% of end use**	**Transition from fossil fuels**	**Progress tracker**	**Reduction of emissions from fossil fuels**	**Progress tracker**
Power	62%	Renewables	0% global capacity CAGR (2019-30 MSe)	CCS	Minimal
Steel	14%	EAF, Hydrogen	Insufficient scrap; excess steel capacity	CCS	Minimal
Cement	4%	Electrification of process; reduce clinker to cement ratio	Ongoing	CCS	Minimal
Non power	2%				
Other, non power	18%				

Source: IEA, Morgan Stanley Research

Will we hit peak oil and gas demand? Achieving a 2DS requires demand for oil and gas to plateau at some point. However, there is much debate over when this will be, as demonstrated in **Exhibit 103** from BP, which outlines a range of views on the subject. The IEA's Sustainable Development Scenario – which is aligned with a two degree scenario – assumes peak oil will be just 6 years away in 2025.

Investment in new energies. There is an opportunity for the Oil and Gas sector to participate in the energy transition. Indeed, over the last few years we have seen a step up in the number of commitments being made to invest in technologies such as renewable power, electric vehicles and biofuels. A summary is below in **Exhibit 120** .

Decarbonising the legacy business. Integrated Oil and Gas companies (IOCs) have already started laying out the groundwork for the energy transition, setting near-term targets as well as providing further detail on the strategies for the mid to long term. Most IOCs have already set targets to reduce scope 1 and scope 2 emissions. Reaching these targets will require incorporating zero-emission businesses into their legacy oil and gas businesses, such as renewables, biofuels and hydrogen. However, near term we think decarbonising oil and gas production will also play an important role in reaching environmental targets.

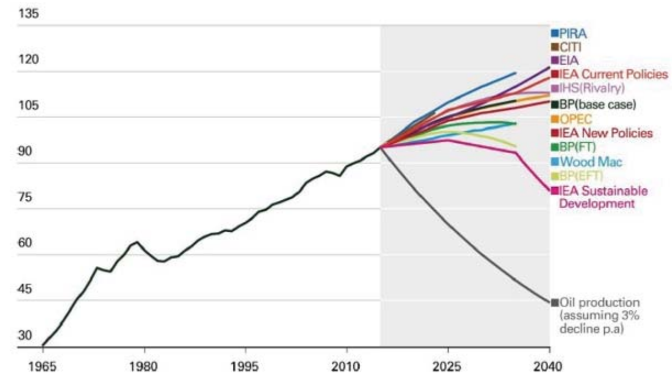
Currently, global CO2 emissions per barrel of equivalent oil stand at ~18 CO2 kg/boe, yet markets like Norway stand at the lower end of the carbon curve at 8-9 CO2 kg/boe, with some Norwegian operators at ~7 CO2 kg/boe. Not all geographies will be able to lower carbon intensity to that level, as some geologies are naturally higher in CO2 emissions given their complexity to extract hydrocarbons. However, several companies are already considering carbon intensity as part of their decision to move forward with projects.

How can oil and gas production be decarbonised? We highlight some of the efforts already taking place to reduce the carbon intensity of hydrocarbon production. We see the pipeline of new technologies delivering not only cost reductions as highlighted in previous reports (see note), but also enabling a reduction in carbon emissions. We detail some of these initiatives, yet recognise the effort to decarbonise may go beyond this list.

- Carbon Capture, Use and Storage (CCUS): As detailed in **this chapter** , CCUS has the potential to significantly reduce emissions from power and industrial processes. In the IEA Sustainable Development Scenario, CCUS accounts for 7% of the cumulative emissions reduction needed globally to 2040.

Exhibit 103:

Various scenarios for the trajectory of world oil demand (Mb/d)

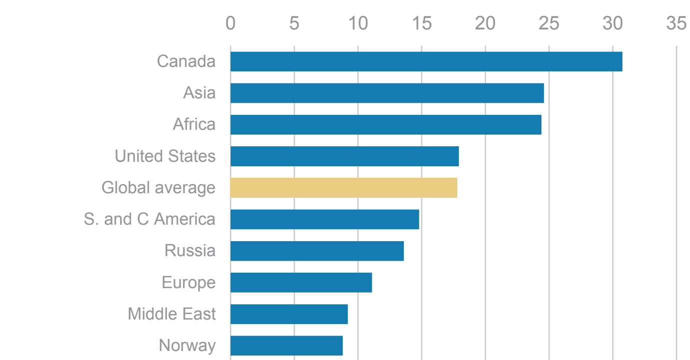


Source: BP

Exhibit 104:

Global carbon intensity stands at ~18 CO2kg/boe, yet some geographies are operating at around half

CO2 emissions intensity, kg CO2 per boe (2017)

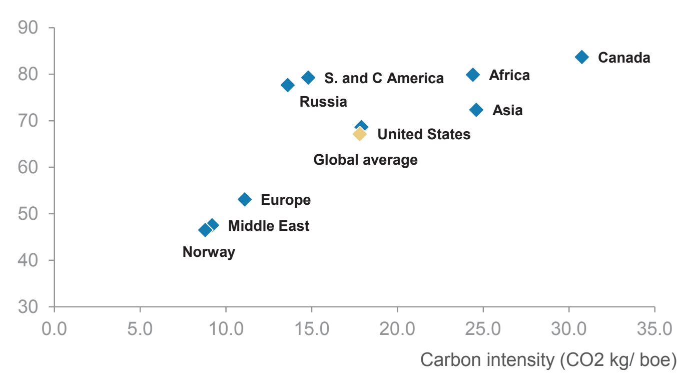


Source: Bloomberg, BP Statistical Review, Rystad Energy, Aker BP with information from IOGP data series, Morgan Stanley Research

Exhibit 105:

In general, geographies with lower breakevens also have lower CO2 emissions

Breakeven, $/bbl



Source: Bloomberg, BP Statistical Review, Rystad Energy, Aker BP with information from IOGP data series, Morgan Stanley Research

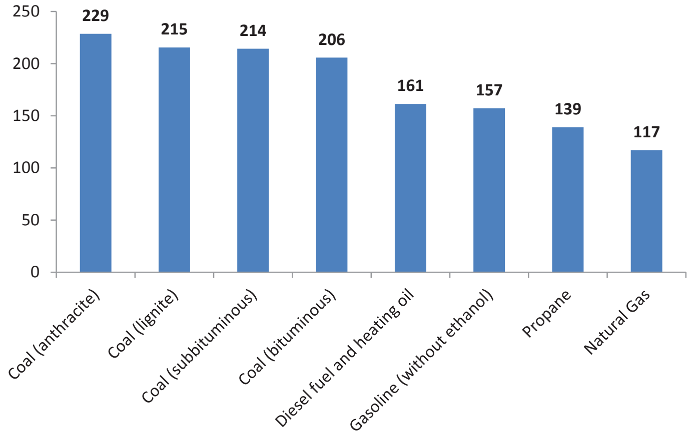
For oil companies, this technology has been used widely for enhanced oil recovery (EOR) from mature fields. As more regions/ geographies become mature productive areas, the efforts to pursue the EOR with CCUS could become relevant.

- Electrification: We see the move from molecules to electrons also impacting oil and gas production. Companies are already incorporating plans to power oil and gas facilities offshore with electricity rather than through combustion of fossil fuels. Equinor has highlighted that the electrification of three platforms in 2018 with onshore power supply will result in a reduction of CO2 emissions by 600k tpa. Equinor is also considering possibilities to supply fields with power from offshore floating wind farms, while Exxon has signed agreements to purchase wind and solar power for its operations in the Permian Basin. Further, in US Shale E&P companies are also exploring electrification with technologies such as electric fracking (e-frac), which should provide cost reductions as well as lower carbon emissions and gas flaring.
- Flare gas reduction: 32 governments, 36 companies and 15 development institutions have expressed support for the Word Bank and UN's Zero Routine Flaring by 2030 initiative. The initiative aims for operators to maintain new fields without routine flaring and to eliminate flaring – when economically viable – as soon as possible and no later than 2030 for existing fields. We see companies also incorporating gas flaring reduction among their sustainability targets.

Natural gas (and LNG) can be an effective tool for reducing carbon emissions. Coal is still a widely used source of energy globally, and natural gas offers a much cleaner alternative by emitting 50-60% less CO2. Perhaps one of the best success stories for reducing carbon emissions has been the US over the past decade, where innovation has transformed shale from an uneconomic resource into an abundant low-cost form of energy. The results have been profound: in the past 10 years, domestic naturalgas prices have fallen by 80% and coal consumption has collapsed by nearly 50%, with66 GW (20% of installed capacity) shutting permanently. Domestic energy costs for consumers have fallen, allowing the utility sector to invest $800 billion into infrastructure without *any* increase in average inflation-adjusted electric & gas rates, while power sector carbon emissions have fallen by 25%.

Exhibit 106:

Pounds of CO2 mitted per Btu



Source: EIA, Morgan Stanley Research

Exhibit 107:

Shale has transformed the North American energy industry, helping drive an 80% decline in natural gas prices over the past decade...

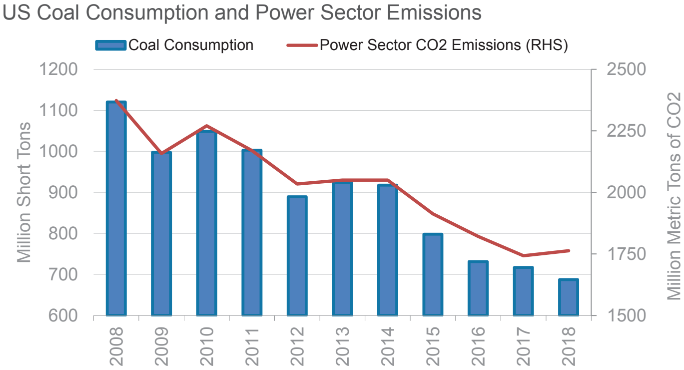
US Natural Gas Prices (Henry Hub) ($/mmbtu)

Source: Eikon, Morgan Stanley Research

Exhibit 108:

...reducing consumer energy costs while driving a 50% decline in coal consumption and a ~25% reduction in power sector carbon emissions.

US Coal Consumption and Power Sector Emissions



Source: EIA, Morgan Stanley Research

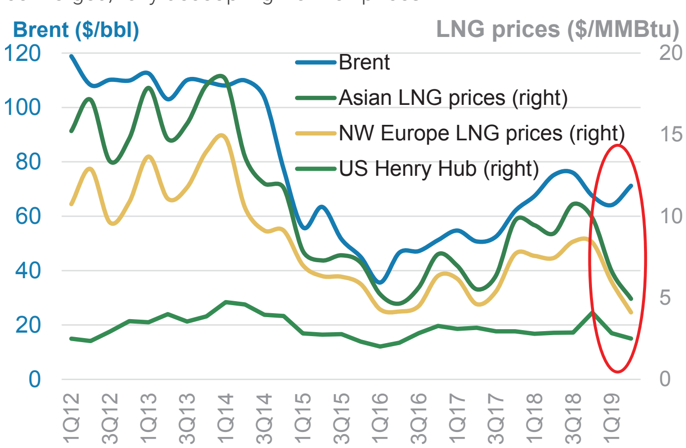
Natural gas has remained a very regional commodity so far... Fragmented markets globally have limited trade between them, driving highly variable natural gas pricing across the globe – often well in excess of transport costs. While there have been substantial discoveries of low-cost gas resources, outside of the US, many of these discoveries are not geographically close to demand. In the US, lack of infrastructure has constrained exports. However, this disconnect between regional prices and supply-demand is driving substantial investments in liquefied natural gas (LNG), which can be transported globally. While it is still early, this LNG trade has begun to grow substantially – a trend we expect will continue over at least the next decade.

...while LNG growth is globalising natural gas, and it has the potential to become an effective emissions reduction tool. We expect LNG to continue to become more liquid, with growing global trade eliminating the regional arbs that have existed historically. As the US transitions from a net importer of LNG to one of the largest global exporters by the end of 2020, low-cost shale gas will permanently alter global gas markets — likely driving prices lower in Europe and Asia and causing global gas and oil prices to decouple permanently. As global natural gas (and LNG) prices fall, it becomes a more competitive fuel source relative to coal.

India, for example,is entering into a multi decade energy transition where cheap gas is expected to disrupt oil/coal(Exhibit 113) and support electrification. Over $140bn of investments are committed in order to expand the gas infrastructure, also supported by favourable government initiatives for making gas accessible to more than 70% of India's population. Overall, gas will nearly double in India's energy mix – saving ~US$4.5bn in annual energy costs until 2025 and lowering energy costs by up to ~25% for gas consumers (see here). For more details please see India Gas: Fueling The Energy Transition (October 9, 2019).

Exhibit 109:

Within the last few months, regional gas prices across the globe have converged, fully decoupling from oil prices

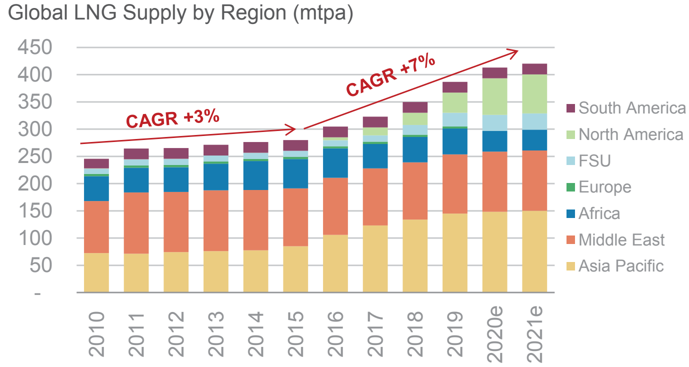


Source: Eikon, Platts, Morgan Stanley Research

Exhibit 110:

This change is driven by growing LNG trade, primarily the result of US LNG investments beginning to enter service

Global LNG Supply by Region (mtpa)

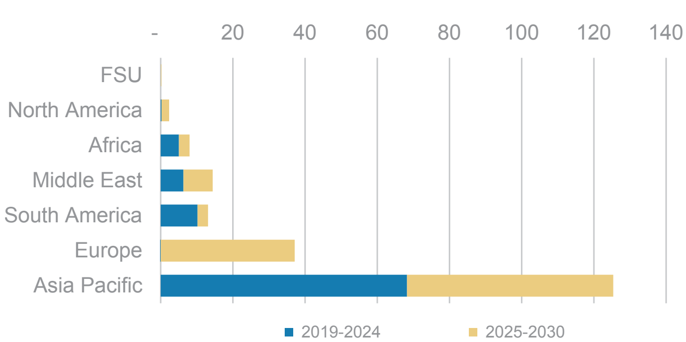


Source: Morgan Stanley Research estimates

Exhibit 111:

Asia drives the majority of incremental LNG demand, followed by Europe

Incremental Demand by Region (mtpa)



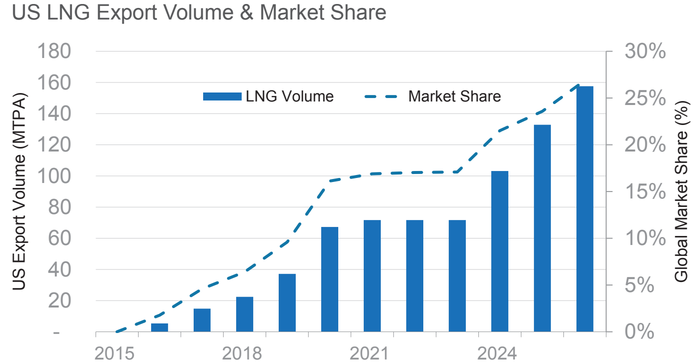
Note: Europe Demand excludes coal-to-gas switching

Source: Morgan Stanley Research estimates

Exhibit 112:

We expect North America to transition from a net importer of gas in 2015 to the largest exporter globally by 2026, with >25% global market share

US LNG Export Volume & Market Share



Source: Morgan Stanley Research estimates

Exhibit 113:

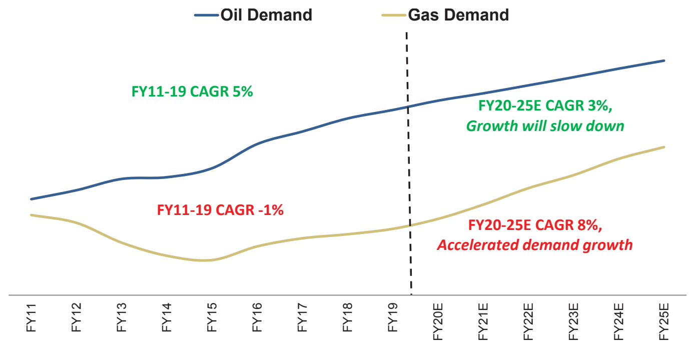
How gas is lowering energy costs and enabling India's energy transition

Sector/Economy	Benefits from Gas	Energy cost Decline
Oil/Coal Dependence	Lowered by 2023	100-150bps
Current Account Deficit	Lowered	4-6%
Transportation	Lower Energy Costs	47-59%
Electricity	Lower Tariffs and Pollution	
Industries	Shift from FO to gas	12-18%
Petrochemicals	Partial shift from naphtha to gas	30-35%
Cooking Fuels	Easier Access and Cleaner	15-20%

Source: Morgan Stanley Research estimates. Energy cost decline forecast, 2018-2025.

Exhibit 114:

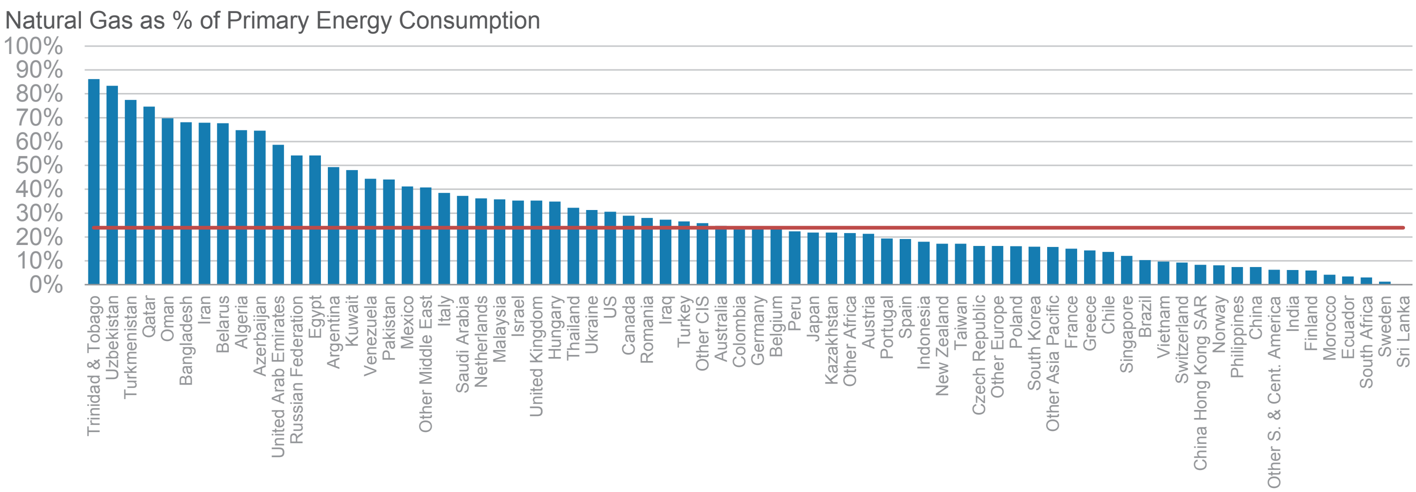
India gas demand to grow at more than 2x the rate of oil demand growth, as consumers shift to the cheaper energy source



Source: PPAC, Morgan Stanley Research estimates

Exhibit 115:

Many countries in the Caribbean, LatAm and Asia are well below the global average on natural gas energy consumption, creating opportunities for new gas infrastructure and integrated gas-to-power



Source: BP Statistical Review of World Energy, Morgan Stanley Research

However, concerns are rising that methane leakage throughout the natural gas ecosystem could be mitigating the environmental benefits of switching. Unburned methane that leaks into the air is believed to be 86x stronger than CO2 in terms of its ability to trap heat in the atmosphere over a 20-year period. Over a 100-year period, methane is ~34x stronger than CO2. As a result, only modest levels of methane leakage throughout the natural gas and LNG supply chain can have a sizeable impact on the net environmental impact of switching away from coal. The Environmental Protection Agency (EPA) has estimated that methane leakage of onshore natural gas was ~1.4%. However, a recent study by the Environmental Defense Fund (EDF) suggests that methane leakage is at least 60% higher than the EPA estimates, at 2.3%.

In an effort to better understand the emissions implications of LNG, we've built a bottom-up model looking at emissions from each stage of the LNG process. The biggest takeaway from this exercise is that the environmental impact of switching from coal to gas/LNG can vary quite substantially, depending on plant technology, the type of coal being burned, the transport distance, and the amount of methane leakage in the supply chain. Our assumptions include:

- We assume 10% feedgas loss during the liquefaction process and assume a base case CO2 efficiency of 69kg/MMBtu.
- We assume a boil off rate of 0.085% during the shipping process, and calculate the emissions implications for different geographies depending on estimated shipping times.
- Finally, once the LNG has reached its destination, we calculate the CO2 emissions from the power generation process based on the previously mentioned power plant efficiency metrics.

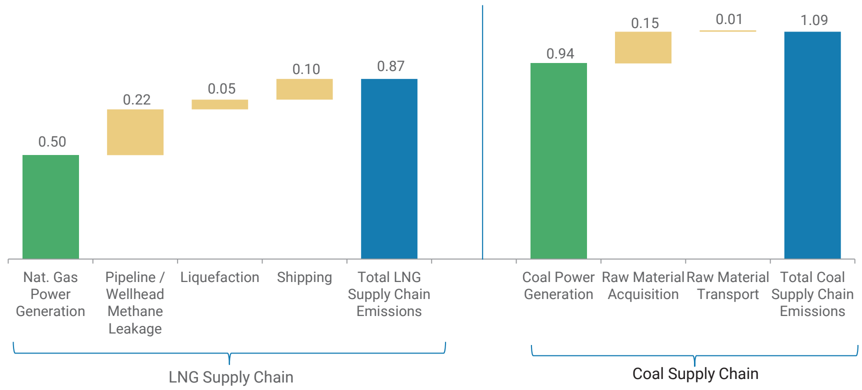
Our model suggests that the relative benefits of LNG vs. traditional coal can vary meaningfully by region. We analysed a 20-year scenario for both (assuming 86x intensity factor for methane leakage as described above). Given the number of variables in calculating a specific emissions impact, we use a sensitivity analysis to gauge the emissions impact of LNG relative to coal against various levels of methane leakage and power plant efficiency.

The emissions implications for China and India are starkly different:

- **China.** Based on analysis from the Center for American Progress, we assume that Chinese coal-fired power plants are ~24% more efficient than comparable US plants. This limits potential environmental benefits of switching. In most scenarios, LNG is actually a net negative on emissions.
- **India.** We assume that India coal plants are relatively on par with the US in terms of efficiency, but also assume that heating values are 50-60% lower given reduced coal quality, resulting in significantly more coal being burned per MWh of production. Because of this, we estimate that switching to LNG would produce less than half of the emissions of Indian coal plants, and be environmentally positive across virtually all of the leakage and efficiency scenarios laid out below.

Exhibit 116:

CO_2e emissions for LNG and European coal supply chain



Source: Morgan Stanley Research. Assumes 2.0% methane leakage.

Exhibit 117:

Coal to LNG emissions reduction sensitivity analysis for Europe

CO2e Emissions (20yr): LNG vs. Europe Coal						
		MMBtu to MWh				
		6.00	7.00	8.00	9.00	10.00
	1.00%	-31%	-27%	-23%	-19%	-15%
	1.50%	-26%	-21%	-16%	-11%	-6%
	2.00%	-20%	-15%	-9%	-3%	2%
Methane Leakage %	2.50%	-15%	-9%	-2%	4%	11%
	3.00%	-10%	-3%	5%	12%	19%
	3.50%	-5%	3%	12%	20%	28%

Source: Morgan Stanley Research

Exhibit 118:

Coal to LNG emissions reduction sensitivity analysis for China and India

CO2e Emissions (20yr): LNG vs. China Coal						
		MMBtu to MWh				
		6.00	7.00	8.00	9.00	10.00
	1.00%	-9%	7%	22%	37%	52%
	1.50%	-2%	14%	30%	47%	63%
	2.00%	4%	22%	39%	57%	74%
	2.50%	11%	30%	48%	67%	85%
Methane Leakage %	3.00%	18%	37%	57%	77%	96%
	3.50%	25%	45%	66%	87%	108%

CO2e Emissions (20yr): LNG vs. India Coal						
		MMBtu to MWh				
		6.00	7.00	8.00	9.00	10.00
	1.00%	-56%	-49%	-42%	-34%	-27%
	1.50%	-53%	-45%	-37%	-29%	-22%
	2.00%	-50%	-41%	-33%	-25%	-16%
Methane Leakage %	2.50%	-47%	-38%	-29%	-20%	-11%
	3.00%	-43%	-34%	-25%	-15%	-6%
	3.50%	-40%	-30%	-20%	-10%	0%

Source: Morgan Stanley Research

Shareholder engagement efforts around methane are increasing. Shareholders have become increasingly engaged in demanding solutions for energy companies to reduce the environmental impact of methane. As a result, companies have begun proactively to set methane emissions targets. For example, ExxonMobil has set aggressive targets — reducing emissions and flaring by 15% and 25% by 2020 — stating that "methane emissions do not negate the substantial climate change benefits of natural gas versus coal, but mitigating emissions can further enhance those benefits" (details here). Working with its subsidiary XTO Energy, Exxon has established a methane management program which involves switching out 1,000 high-bleed pneumatic devices for lower or no-bleed devices and enhancing leak detection and repair. Chevron has also been a leader on this front, targeting a 20-25% reduction in methane intensity by 2023 from 2016 levels.

In addition to these initiatives, we believe other technologies in early stages of development, such as unmanned platforms or autonomous inspection vehicles, could also be promising in terms of lowering emissions, reducing health and safety risks and driving cost efficiencies.

Exhibit 119:

Corporate methane emissions targets and commitments

Company	Ticker	Methane Reduction Goal
Marathon Oil Corporation	MRO	In 2016, Oklahoma asset set a goal to reduce 2015 methane intensity of the asset by >50% by 2020. Surpassed that goal by the end of 2017, reducing methane intensity by >54%
Devon Energy Corp	DVN	By 2025, Devon will achieve a methane-intensity rate of 0.28% or lower. In 2018, Devon's methane-intensity rate was estimated at 0.32%
Occidental Petroleum Corp	OXY	Methane intensity below 0.25% by 2025 with ambition of 0.20% compared to baseline 2017
Apache Corp.	APA	Reduce methane losses to less than 1% of total methane production from the wellhead to the ultimate point of use, and reduce methane emissions to 0.36% by 2025 (vs. 0.43% in 2017)
Chevron Corporation	CVX	20-25% methane intensity reductions and 25-30% flaring intensity reductions by 2023 from 2016 baseline
Exxon Mobil Corporation	XOM	Reduce methane emissions by 15% and flaring by 25% by 2020 compared to 2016 baseline
Southwestern Energy Co	SWN	Exceeded methane emissions target of 0.36% nearly 10 years ahead of schedule
Range Resources Corp.	RRC	Pledged zero emissions
Repsol	REP.MC	Reduce methane emissions in operated assets by 25% by 2025
TOTAL	TOTF.PA	Reduce methane intensity of the Exploration Production segment's operated facilities to .2% by 2025. Reduce routine flaring by 80% between 2010 and 2020 in order to eliminate it by 2030
Royal Dutch Shell	RDSa.L	Target methane emissions below 0.2% by 2025 in operated assets
Eni SpA	ENI.MI	80% reduction in upstream fugitive methane emissions by 2025 vs 2014

Source: Company Data, Morgan Stanley Research

Exhibit 120:

Investment by integrated oil and gas companies in new energy

Company	EVs	Biofuels	Renewables	Hydrogen
ExxonMobil		Invested more than $300m in biofuel research in the past decade.	Aera Energy, a JV between Shell and ExxonMobil, is to partner with GlassPoint Solar to build California's largest solar energy project.	Added a hydrogen plant to the Fawley Refinery in 2019.
Royal Dutch Shell	Joined IONITY, a JV of automotive manufacturers aiming to offer 500 charging points in Europe; launched Shell Recharge (EV charging service using 100% renewable electricity); acquired a number of EV charging companies including New Motion (2017) and Greenlots (2019).	Number of plants invested into biofuels; agreement with SBI Bioenergy for its renewable drop-in biofuels; 50% stake in Raizen (cellulosic ethanol).	US onshore wind projects; Europe offshore wind projects; 43.8% interest in Silicon Ranch Corporation, a US solar energy company; 49% interest in Cleantech Solar; 50/50 JVs with EDF Renewables and EDP Renewables to build offshore wind farms in the US.	Member of the Hydrogen Council; opened hydrogen fuelling sites in Europe and NA; H2 Mobility JV in Germany since 2018.
Chevron Corporation	Started offering EV charging points at some Californian gasoline stations; investments include ChargePoint (one of the largest operators of EV charging networks) and Natron Energy (a developer of battery technology).	JV (called Catchlight) with Weyerhaeuser to commercialise cellulosic biofuels; distribute diesel fuel containing 6-20% of renewable diesel; invested in Ensyn, a company which converts wood residues and other non-food cellulosic biomass to liquid biofuels.	Various geothermal, solar and wind facilities.	Hydrogen plant in its Richmond refinery.
Total	Installing EV charging facilities; acquired G2Mobility, a French EV charging company.	Invested more than €500m on advanced biofuel R&D over the last ten years; opens its La Mede biorefinery in 2019.	1.9GWp in renewable power generation capacity; invested in SunPower Corporation, EREN Renewable Energy and Direct Energie; consortium with Orsted and Elicio to bid for offshore wind farm project.	Involved in the H2 Mobility JV in Germany; acquired PitPoint (involved in biogas, hydrogen and EV charging points).
BP	Installing ultra-fast chargers; acquired Chargemaster (EV charging network), Freewire (mobile EV charging) and Storedot (ultra-fast charging battery technology). Invested in PowerShare (an EV charging network). MoU with NIO Capital, a Chinese fund manager, to look into investment opportunities in the EV space.	Operates three sugarcane ethanol plants in Brazil; 50/50 JV with DuPont on Butamax; 50/50 JV with Bunge; plans to explore and develop the supply chain for delivering renewable fuel to airports and airlines; invested in Fulcrum, a biojet fuel producer.	U.S. Wind Energy business; solar capacity; acquired stake in Lightsource. In 2019, divested 3 wind energy operations in Texas to Ares management on grounds of restructuring its wind portfolio.	Member of the Hydrogen Council; MoU with Nouryon to study the feasibility of a water electrolysis facility; piloted the use of green hydrogen at the Lingen refinery.
Equinor	Investments include ChargePoint and Volta Energy Technologies.	Developed a new hydrotreated vegetable oil called Eco-1 in 2015.	Invested more than $2.3bn in offshore wind projects; invested in Oxford Photovoltaics and Scatec Solar.	Member of the Hydrogen Council; MoU with Vattenfall and Gasunie to evaluate the possibility of converting Vattenfall's gas power plant into a hydrogen-powered plant.
Eni	Framework agreement with IONITY to install EV chargers for Eni service station in 2018.	Implementing biofuels at service stations; has a number of plants invested in biofuels; collaboration agreement with Cassa Depositi e Prestiti to identify and jointly promote biofuel initiatives in Italy.	Involved in a number of renewable energy projects in Italy, Tunisia, Algeria, Kazakhstan, Angola and Australia.	Collaborations with Toyota and Nextchem.
Repsol	50% stake in IBIL, which offers renewable energy charging service; invested in the EV charging start-up Ample and Spanish battery start-up Ampere Energy.	Aims to have 8.5% of its energy content as biofuel by 2020; research on biofuels includes SynBioGas project and the Repsol Technology Centre.	Goal of generating 4.5GW in low-carbon energy by 2025; acquired the low-carbon business and gas and electricity retail clients from Viesgo; acquired a solar company Valdesolar Hive; working on the WindFloat Atlantic Project; developing three renewable energy projects across Italy (wind and solar).	In 2018, announced plans to develop hydrogen using solar energy as a primary source in a joint project with Enagas.
Galp	Installing EV chargers in Portugal with plans to reach 55 rapid-charging stations.	Enerfuel - the first plant in Portugal which was producing 2nd generation biofuels using food waste and used oils.	50% stake in Ventiveste; acquired licences for solar power generation in the Iberian Peninsula.	Opened Enerfuel in 2013, which is able to produce hydrogen on top of biofuel.

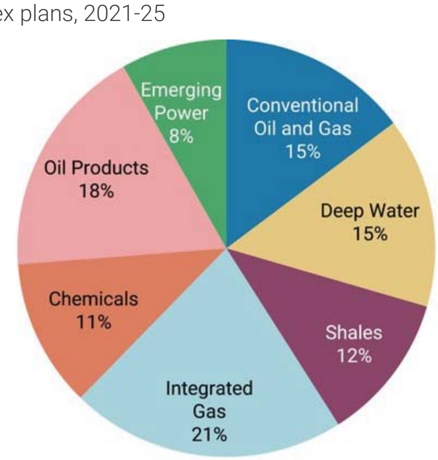
Source: Company data, Morgan Stanley Research

CCS will also be a key area for the energy sector. The oil and gas sector is already using CCS technology for Enhanced Oil Recovery, and companies such as Occidental Petroleum lead in this area. However, the major integrated oil and gas companies are also investing in early stage CCS projects and technologies.

- **BP:** Invested in several companies including C-Capture, Carbonfree Chemicals and Solidia Technologies. Also a member of the CO2 Capture Project and the Clean Gas Project, which is the UK's first commercial full-chain CCS project in Teesside.
- **Chevron:** Invested in Inventys and Carbon Engineering, plus has stakes in the Gorgon CCS Project and the Quest CCS Project. A member of the CO2 Capture Project.
- **Eni:** A member of the CO2 Capture Project, plus has launched an experimental plant which captures ~ 80 tonnes of CO2 per year. Participating in a feasibility study with Corepl on hydrogen production and carbon capture through a high temperature gasification plant.
- **Equinor:** Has had a stake in the Sleipner CCS project since 1996 plus involved in the Northern Lights project in Norway and has established carbon storage facilities on the Snohvit field in Norway. A member of the CO2 Capture Project.
- **ExxonMobil:** Has a stake in the Sleipner and Gorgon CCS projects. Also working with FuelCell Energy and Global Thermostat on carbon capture technology.
- **Galp:** Has implemented seven CCUS projects.
- **Shell:** Involved in the Clean Gas Project and Northern Lights Project. Has stakes in the Gorgon Project and Quest CCS project. Launched various pilot projects to test CCS technology.
- **Total:** Industrial partner to CO2 Solutions, a carbon capture company, has invested in Inventys, a carbon technology company, and involved with the Northern Lights Project in Norway.

Exhibit 121:

Shell: Capex plans, 2021-25



Source: Company data, Morgan Stanley Research

At the moment, investment levels are relatively small... While there are signs of diversification into new energy, the scale of the investment into renewables, biofuels and EVs is still dwarfed by capital investment in the traditional oil and gas assets. Shell has been the most explicitly ambitious in its decarbonisation strategy, but even its assumptions for capex on 'emerging power' are only equivalent to ~8% of total capex.

...but could this accelerate? Pressure on oil and gas companies' social licence to operate could conceivably begin to influence their decisions around investing in decarbonisation technologies. Over the last five years there has been an increase in the number of investors with some form of commitment to divesting from fossil fuel companies. According to non-profit organisation 350.org, over 1110 institutions have announced policies that include some approach to stepping away from coal, oil and gas investments. Together, these institutions account for over $11 trillion of assets – although it's important to be clear that this is now the value of assets with a fossil fuel free mandate. As illustration, Shell's annual report introduced in 2017 the following as one of its risk factors: *"Some groups are pressuring certain investors to divest their investments in fossil fuel companies. If this were to continue, it could have a material adverse effect on the price of our securities and our ability to access equity capital markets."*

Coal

We would argue that the outlook for coal is less attractive than for oil and gas, particularly given our house view that the globalisation of cheap natural gas will accelerate coal to gas switching. As such, we see continued headwinds for the $360 billion global coal industry.

Our base case assumes that from a domestic perspective, US domestic coal production declines rapidly in line with reductions in US coal-fired power generation. However, we do expect coal production in China to rise over the next 5 years, while we see India's coal output rising for at least the next decade to keep up with continued growth of its coal-fired power generation.

International thermal coal prices are set by supply-demand fundamentals in the seaborne market. We estimate the size of the seaborne market at c. 1,050Mt in 2018, which accounts for c.16% of global steam coal and lignite production, although seaborne demand is often a function of domestic supply shortages. We consider the seaborne traded coal market to be ex-growth going forward, with demand declining marginally from 1,070Mt in 2018 to 1,020Mt by 2022, after which it will stabilise.

The seaborne coal market is typically split in two basins: the Atlantic and Pacific.

Europe is the main demand centre in the Atlantic, with key suppliers Russia, the US and Colombia. With coal being phased out in Western Europe and under pressure from cheap natural gas, demand in the Atlantic basin is likely to decline further. However, we don't want to overemphasise the focus on Europe's demand decline, as its imports were just 10% of the total seaborne market in 2018.

Demand in the Pacific basin is dominated by Japan, South Korea, Taiwan, China, India and South East Asia. Key suppliers in the Pacific market are Australia, Indonesia and Russia. In the Pacific basin, we see China's coal imports gradually declining over the next 5 years, as the Chinese government favours domestic coal supply over imports rather than a significant slowdown in coal-fired power generation. In India, coal is likely to remain key in the power mix as well, but we expect the domestic supply gap here to narrow also. Meanwhile, traditional Asian demand from the JKT-block (c.30% of total seaborne demand) is under pressure as governments actively look to move away from coal-fired power generation.

The switch from coal to gas (and LNG) is typically viewed as an environmentally beneficial change, but there are several variables that will influence the net environmental impact. On the surface, natural gas is a relatively cleaner fuel to burn, emitting 50-60% less CO_2 emissions than coal. According to estimates from the EIA, natural gas typically emits 117 pounds of CO_2 per Btu, compared to coal which ranges from 214 to 229 pounds per Btu.

However, concerns are rising that methane leakage throughout the natural gas ecosystem could be mitigating the environmental benefits of switching. Unburned methane that leaks into the air is believed to be 86x stronger than CO_2 in terms of its ability to trap heat in the atmosphere over a 20-year period. Over a 100-year period, methane is ~34x stronger than CO_2. As a result, only modest levels of methane leakage throughout the natural gas and LNG supply chain can have a sizeable impact on the net environmental impact of switching away from coal. The Environmental Protection Agency (EPA) came out with an estimate that methane leakage of onshore natural gas was ~1.4%. However, a recent study by the Environmental Defense Fund (EDF) suggests that methane leakage is at least 60% higher than the EPA estimate, at 2.3%.

Should we transition to a pathway aligned with the Paris Agreement, we would expect more rapid declines in coal production. Under the IEA's Paris-aligned Sustainable Development Scenario that we explore in this report, electricity generation from coal power stations falls by 80% over the next 20 years.

Green Financing

Decarbonising the global energy system requires public and private financing to be directed towards key technologies.

Transitioning to a low carbon economy requires lenders and investors alike to direct capital towards certain sectors and technologies. The Principles for Responsible Investment were launched in 2006 and now ~2500 asset owners, asset managers and service providers are signatories globally. More recently, the Principles for Responsible Banking were launched at the UN General Assembly in September 2019. 130 banks that together account for more than $47 trillion of assets globally have signed these principles, which include the alignment of business strategies with the Paris Climate Agreement. At the same UN climate summit, a "Net Zero Asset Owner Alliance" was announced with insurers and pension funds, which together represent $2.3 trillion of assets, pledging to move investments away from carbon-heavy industries. [26]

Types of low carbon investments

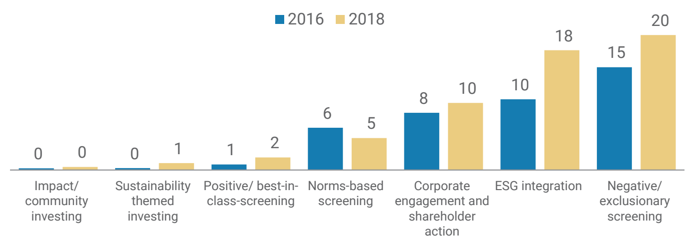
Sustainable finance has been growing rapidly and it's estimated that $31 trillion of AUM are now invested in sustainability funds (Exhibit 122). These assets are allocated to a broad range of investments but climate-focused funds have certainly increased in popularity. AUM in ESG funds with specific climate change attributes have nearly tripled since 2015 to now represent over $10 bn (source: Bloomberg data).

In this report we have identified 118 companies that are exposed to the decarbonisation technologies of renewable power, EVs, hydrogen, biofuels and CCS. Investing in such opportunities will direct capital towards green business models.

Exhibit 122:

Growth in Sustainable investing strategies globally

Global growth of sustainable investing strategies 2016-2018 (USD trillions)

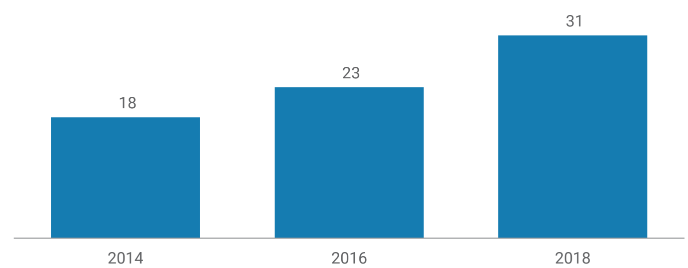


Source: GSIA

Exhibit 123:

Around $31 trillion of assets were managed with a Sustainability strategy at the end of 2018

Growth in Sustainable AUM (USD trillions)



Source: GSIA

Away from the equity markets, green bonds offer another way to finance the energy transition. Green bonds, also known as 'climate' bonds, are those whose proceeds are earmarked to finance eligible 'sustainability' projects or assets (for more information please refer to our green bond primer). They can be either asset-backed or asset-linked, but issuers must declare the types of eligible green assets or projects to be financed with the proceeds at issuance and commit to using the funds exclusively for that, as outlined by the Climate Bonds Initiative. Annual green bond issuance has grown rapidly over the last five years and YTD stands at ~$160 billion globally. Below are some examples of sustainable bond issuances linked to climate change.

26 Source: Reuters, September 23, 2019

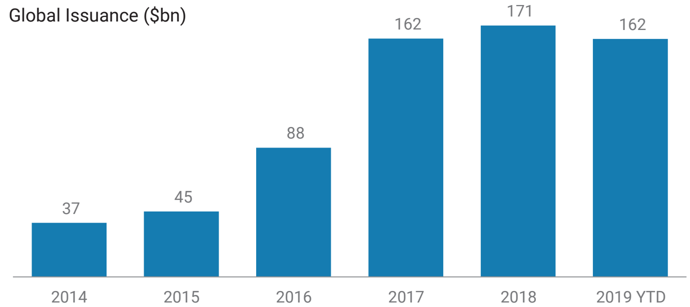
- **Enel SDG linked bond –** USD 1.5 billion sustainable bond which was nearly three times oversubscribed. The financing will not be used for a specific 'green' project (as is normally the case with green bonds) but will be part of the company's ordinary financing needs. However, it is unique in that the interest rate will be determined by the contribution of renewable assets to the total generation capacity of Enel. If a target of renewable capacity being 55% of the total capacity is not achieved the interest rate will increase. [27]

- **Marfrig Sustainable Transition bond** – USD 500 million bond with 6.625% coupon. The proceeds will be used to source cattle from the Amazon Biome with all cattle farmers needing to commit to certain criteria such as not using slave, forced or child labor, and not raising cattle in indigenous reserves, conservation units, blacklisted areas or deforestation areas.
- **Hannon Armstrong Green Bond**– USD 350 million bond with 5.25% coupon. The proceeds will be used to buy or refinance eligible green projects, which include assets that are neutral to negative on incremental carbon emissions.
- **Covivio Green Bond** – €500 million at 1.125% coupon with proceeds used to finance or refinance 190,000 m2 of offices under development in France and Italy.

27 Source: Enel press release, September 4, 2019

Exhibit 124:

Green bond issuance has increased significantly since 2014*



Source: Climate Bonds Initiative, Morgan Stanley Research *This data does not include other types of sustainable bonds

Public investment vehicles

As part of phase IV of the European Union's Emissions Trading Scheme, two new funds are to be launched to incentivise investment into a low carbon economy. The Innovation Fund will receive funding equivalent to the value of at least 450 million emission allowances to be used to support the development of innovative technologies. In addition, the Modernisation Fund will focus on investment into the modernisation of the power sector, the wider energy system as well as enabling a just transition for 10 lower-income member states.

Public sector incentives

The private sector will invest capital in those opportunities that offer attractive risk-adjusted returns. In order to increase the appeal of 'green investments' and specifically the decarbonisation technologies needed to achieve a 2DS, there needs to be a clear and stable regulatory approach. The public sector needs to create the right incentives for investing in low carbon opportunities either by taxing the high carbon activities or subsidising the low carbon alternatives.

Subsidising low carbon technologies is an option to finance decarbonisation. The overall cost of climate change would be equivalent to losing between 1% and 4% of global GDP each year, now and for the foreseeable future, according to the landmark 2006 Stern Review. As such, from a public sector funding perspective, the cost of mitigating climate change far outweighs the potential cost of dealing with climate disaster.

However, climate investments often require substantial up-front costs, with the benefits accruing only later; this is true for both adaptation interventions and mitigation investments (source). Prioritising the allocation of the necessary funding as part of national budgets and expenditure frameworks can therefore be a challenge, particularly in the face of short-term budgetary requirements.

Exhibit 125:

Examples of country policies committing to green finance initiatives

Country	Policy Name	Description
UK	Green Finance Strategy	Launched on July 02 2019, the Strategy supports the UK's economic policy for strong, sustainable and balanced growth whilst committing to a modern industrial strategy and addressing international commitments on climate change, the environment and sustainable development. The strategy is targeted at (a) greening finance (b) financing green and (c) capturing opportunity.
Japan	Joint Crediting Mechanism (JCM)	Japan aims to facilitate the diffusion of leading low-carbon technologies through the JCM in order to address climate change on a global scale. Japan will evaluate its contributions to GHG emission reductions or removals in a quantitative manner through the JCM and use them to achieve Japan's emission reduction target.
Germany	Green and Sustainable Finance Cluster (GSFC)	Developed in April 2018, it aims to establish forward thinking and efficient financial market structures based on the implementation of sustainable financing strategies, bringing together investor groups politicians and members of the public.
Australia	Australian Sustainable Finance Initiative (ASFI)	Due to be launched in 2020, the ASFI roadmap will recommend pathways, policies and frameworks. Objectives include: mobilising capital, enhancing the sustainability and resilience of the financial system, ensuring better informed financial decision making and delivering a financial system that meets community and consumer expectations around sustainability norms.
Brazil	Brazil Green Finance Initiative (BGFI)	The BGFI works to strengthen the development of a local green finance market and attract international capital flows to fund the development of Brazil's future economy.The current focus of the BGFI is the development of a green investment pipeline and investor engagement.
Sweden	Stockholm Sustainable Finance Centre	The centre aims to accelerate and promote the shift in capital investments required to deliver the Sustainable Development Goals (SDGs) and climate targets.

Source: Morgan Stanley Research

Therefore, we believe that a more effective market mechanism would be carbon pricing. Carbon pricing aims to capture the external costs of carbon emissions (i.e. the costs that the public pays in other ways, such as damage to health, crops, droughts etc) and tie them to their sources, therefore shifting the burden of the damage back to those who are responsible for it. Instead of dictating who should reduce emissions where and how, the carbon price should give an economic signal and encourage polluters to decide for themselves whether to discontinue polluting activities, reduce them, or to continue and simply pay for them. The two key forms of carbon pricing we see today are:

- **ETS / cap-and-trade system** – caps the total amount of greenhouse gas emissions and allows those emitters within the industry to trade emission permits, thus creating supply and demand for permits. With this carbon price, the emission reduction is pre-defined but the price is not. An example of this is the European ETS scheme.
- **Carbon tax** – this sets a price directly on carbon emissions by pre-defining a tax rate on the carbon content of fossil fuel. With this carbon price, the emission reduction is not pre-defined but the price is. An example of this is the recent federal carbon taxes that are being rolled out across various provinces in Canada.
- **Tax credit schemes** – an example of this is the 45Q federal tax credits in the US, which are aimed to incentivise investment in CCS. [28]

But, a 'green border' adjustment will be necessary to stop carbon leakage. Current carbon pricing is focused on taxing domestic emissions, which is not fit for purpose in today's global economy. As our previous report explores, Green Borders: Tax and Dividends for a Low Carbon Economy (April 25, 2019), for globally mobile industries, introducing local carbon taxes simply incentivises the production to move to countries with substantially lower environmental levies, causing net increases in carbon emissions.

As such, we argue that a 'green border' adjustment (which recognises the impact of consumption of carbon-heavy goods and services, and not just the domestic production) needs to be implemented in order to ensure market competitiveness remains. This idea of carbon-border adjustment has been put forward by the Climate Leadership Council in the US. It has proposed a four-point carbon dividends plan, which includes a $40 per ton carbon fee increasing every year at 5% above inflation, border adjustment to tax carbon-intensive imports, and carbon dividend payments for all Americans. [29]

28 Source: Clean Air Task Force

29 Source: Climate Leadership Council

A Just Transition?

A 'just transition' ***"provides and guarantees better and decent jobs, social protection, more training opportunities and greater job security for all workers affected by global warming and climate change policies."*** International Trade Union Confederation (ITUC).

Transitioning to a low carbon economy must be done in a sensitive way to minimise the potentially negative implications for society. The just transition explores the potential for stranded workers and stranded communities resulting from the move away from a carbon-intensive economy. It is an economy-wide, comprehensive process which produces the plans, policies and investments that build resilient economies and communities. Some jobs will be in industries that still exist but shift towards low-carbon models (e.g. gas-fired power switching to incorporate the use of hydrogen and CCS technologies). But other forms of employment will be eliminated – either phased out, or dramatically reduced in numbers (for example, French President Macron has announced that all coal-fired power station will be shut down by 2021 in France). The International Labour Organization (ILO) highlights 10 key guidelines (**Exhibit 126**) for a successful and just transition.

Exhibit 126:

Guidelines for a just transition – 10 key policy areas

Policy area	Example
1. Macroeconomic and growth policies	Undertake collaborative efforts to incorporate the just transition framework into macroeconomic policies (including tax reforms).
2. Industrial and sectoral policies	Pay special attention to the industries, regions, communities and workers whose livelihoods might experience the hardest impacts.
3. Enterprise policies	Enhance the resilience of businesses, in particular micro, small and medium-sized enterprises (MSMEs), to avoid disruption to economic activity and loss of assets, jobs and incomes.
4. Skills development	Give high priority and allocate resources to identifying and anticipating evolving skills needs and the alignment of training programmes.
5. Occupational health and safety	Assess occupational safety and health risks from climate change, resource scarcity or other risks linked to the environment.
6. Social protection	Promote adequate social protection systems, including healthcare, income security and social services.
7. Active labour market policies	Encourage policies that help enterprises and workers anticipate changing labour markets (especially workers affected by climate change).
8. Rights at work	Implement international labour standards: freedom of association, the right to collective bargaining; prohibition of forced labour and child labour; equal remuneration; non-discrimination.
9. Social dialogue	Actively promote social dialogue to forge consensus on pathways towards environmental sustainability with decent work.
10. Policy coherence	Integrate provisions for a just transition into national plans and policies for the Sustainable Development Goals and national climate plans.

Source: ILO (2016)

Globally, 1.5 billion workers are directly employed in sectors critical to climate stability, according to the United Nations Framework Convention on Climate Change (UNFCCC). These industries will face huge disruption in the coming years, with the transition necessitating either a move away from these highly emitting sectors, or a shift to a low-carbon alternative. Combined, these sectors represent about half of the global workforce, and therefore managing this transition has very material implications. Below, we highlight some of the key industries affected by the transition:

- **Energy**: moving towards a 100% renewable energy system by 2050 could create 52 million full-time jobs but cause the loss of 27 million jobs within the traditional energy sector, therefore implying a net gain of 25 million jobs (Source: Grantham Research Institute on Climate Change and the Environment). Coal mining represents about ⅓ of the overall energy sector employment.
- **Transport**: energy is linked to transport sectors on land, sea and air, which combined have employment levels three times higher than the energy sector. For example, one key theme to affect this sector is the transition to 'transport as a service' (TaaS), which could mean 70% fewer passenger vehicles and trucks being manufactured every year (according to a report from independent think tank RethinkX) – also meaning jobs in driving, fuelling and maintenance becoming obsolete.

Overall, the energy transition could result in a net increase in employment. While it is widely acknowledged that a transition away from a carbon intensive society will result in significant job loss, according to the New Climate Economy's (NCE) 2018 report a successful just transition could also create a net employment gain of 37 million jobs across the global economy by 2030 and a direct economic gain of US$26 trillion. Exhibit 127 presents examples of new job creation expected in the UK in the coming years as a result of a growing low-carbon economy.

Producing and delivering renewable energy products, infrastructure and services tends to be more labour intensive than providing the traditional equivalents. For example, the same amount of electric power produced by 1 worker in the coal industry would require 3 workers in the wind sector and 26 workers in the solar industry. Therefore, the expansion of a greener economy will translate into higher labour demand across many sectors of the economy and associated jobs.

However, greener jobs require higher skilled 'green collar' workers. The transition to a low carbon economy may result in a skills gap, due to the novel skills often required to implement low carbon technologies (source: Centre for Climate Change Economics and Policy). As such, if we are to achieve the net zero scenario by 2050 with minimal impact on society, there needs to be an emphasis on anticipating and implementing training programmes for future generations of workers, but also on equipping existing workforce with the right skills to transfer to a low carbon economy.

Exhibit 127:

Examples of certain jobs expected to be created as a result of a growing low-carbon economy in the UK

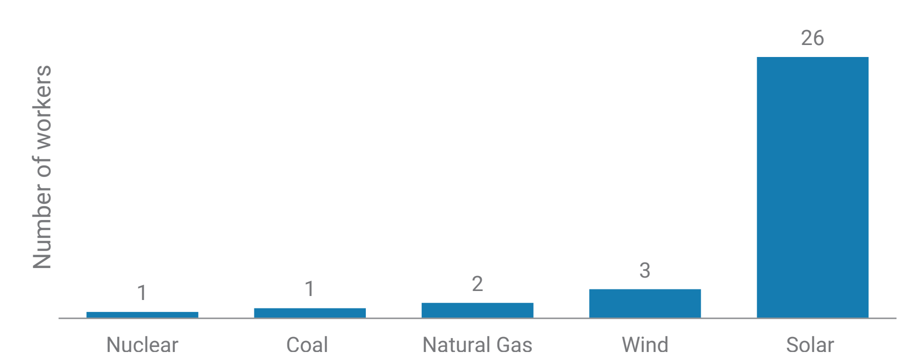
Sector	Job Estimate	Year	Publisher
Offshore wind	70,000	By 2023	RenewableUK
Heat networks	Up to 81,000	By 2030	IPPR
Energy efficiency	108,000	By 2035	Cedefop
Smart meters	12,000	By 2020	Energy Utilities Skills Partnership
Nuclear	34,000	By 2021	Cogent Skills

Source: Institute for Public Policy Research (IPPR), sources cited: Cedefop 2018; Energy & Utilities Skills Partnership 2017; Emden et al 2017; Cogent Skills 2017', Morgan Stanley Research

Exhibit 128:

In the US, 26 solar workers are required to produce the same amount of energy (MWh) as 1 worker in the coal industry

Workers in the US required to Produce ~7,000 MWh of Electric Power (2018)



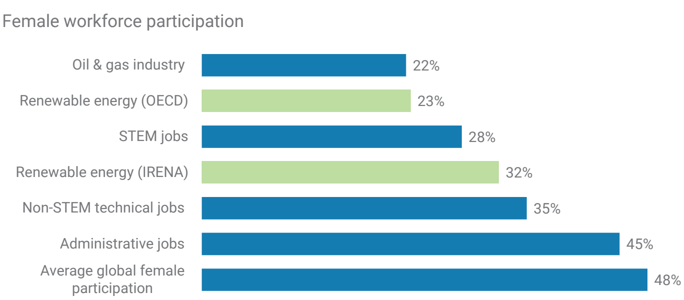
Source: IEA and United States Department of Energy, Morgan Stanley Research

Many of these skills are driven by the growth in digital technologies. While skills required vary hugely between different green sectors, a general trend of decarbonisation is digitalisation. Based on surveys conducted in 2017 by the Institution of Engineering and Technology (IET), 42% of respondents in the energy sector said they planned to implement new, or extend existing digital technologies in their line of work over the following three years. However, in the same survey only 18% reported that they are fully prepared for skills challenges ahead caused by trends such as automation and digitisation. [30]

We note that women are more represented in the clean energy sector than in the traditional energy sector. A recent study by the International Renewable Energy Agency (IRENA) found that women represent 32% of the renewable energy workforce. While this compares favourably to the conventional energy sector, it is worth noting that other estimates are more conservative, estimating that 20-25% of employees in this growth sector are female in countries such as Canada, Germany, Italy, Spain and the US (source: OECD). These are higher than the average in the traditional oil & gas industry, where only around ~22% of the workforce is female. Having said that, there are still significant imbalances when compared to the whole economy (Exhibit 129). Moving forward, specific policies should be considered to further promote gender balance within the sector.

Exhibit 129:

Female participation in the renewable energy sector is lagging behind the average



Source: IRENA, World Bank Data, OECD

While achieving a just transition is a global challenge, the impacts on workers and communities are inherently local. The impacts of the transition to a low-carbon economy tend to be highly local due to the localised nature of the types of employment affected. Many cities, for example, only exist in their modern form due to their high-carbon jobs. For example, in Aberdeen over 10% of the population are directly employed in oil & gas, with much more of the population dependent on the industry indirectly. In 2016 following the oil price crash, Aberdeen's population fell by 15,000 people (c. 7% of its population). [31]

Case study: Germany's coal phase out

While Germany's plan has yet to be fully approved, the final report (for more details, please refer to Coal Commission Report: Let the negotiations begin (28 Jan 2019)) from the Coal Commission includes a full phase-out of coal by 2038. In the lead up to the draft law due to be published in autumn 2019, discussions have begun regarding the creation of an effective transition pathway to compensate affected communities.

At present, coal and lignite still represent around 21% of the country's power generation installed capacity (2018). With 12.5GW to close by 2022 according to the commission's final report, it would represent only 16% by then and likely less than 10% by 2030.

From the outset, the economic future of the lignite mining regions has been highlighted as a key task of the coal exit commission. The government has been clear that its ambition is for coal regions to "use the coal exit as an opportunity" to turn into "modern energy and economic regions" (Peter Altmaier, Economy Minister, 30 August 2019 – source: Clean Energy Wire). The first key points are as follows:

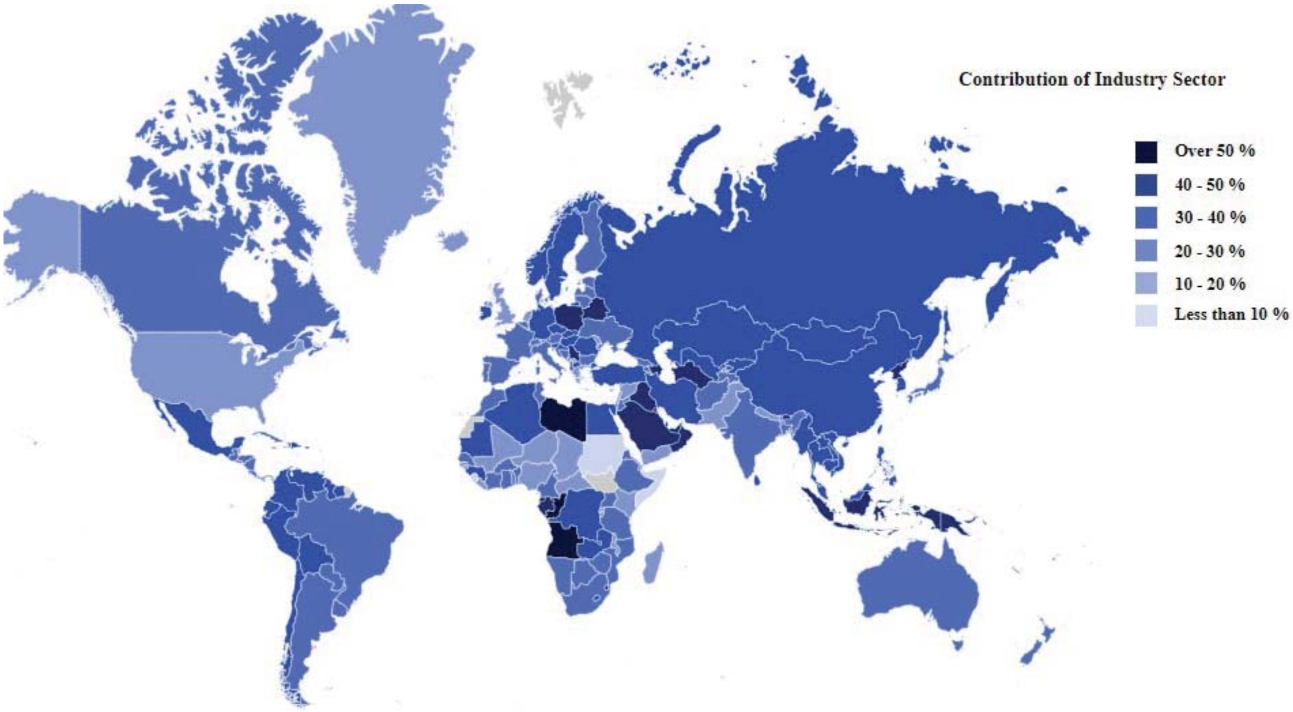
- Up to €40 billion pledged in support payments by 2038 to strengthen local infrastructure and provide training projects for affected workers.
- An emphasis on creating thousands of jobs through locating research institutions in former coal regions and incentivising private companies to invest there.

That said, those economies that are heavily reliant on industry are most exposed to this transition. Exhibit 130 represents the exposure of certain geographies' GDP to the industrial sector, the darker shaded countries are therefore those most highly exposed to the energy transition. Out of the world's top 20 largest economies, we highlight Saudi Arabia (44.2%), Indonesia (40.3%), China (39.5%), South Korea (39.3%) and Russia (32.4%) as having the highest GDP exposure to the industrial sector.

30Source: Skills & Development in Industry 2017 IET Survey

31Source: New Economics Foundation, Working Together For A Just Transition

Exhibit 130:
Darker shaded countries are more heavily reliant on industry for their GDP



Source: StatisticsTimes

Why should investors be looking at a Just Transition? Not only was a just transition declaration signed by 53 governments at the COP24 climate conference in 2018, but an investor statement backed by over 100 institutions worldwide with more than US$6 trillion in assets combined has also been launched by the PRI. Investors are urged to engage with the just transition in order to broaden their understanding of systemic risks such as social exclusion and increasing inequality, re-assessing fiduciary duty and recognising the importance of a social licence to operate from a corporate perspective.

Further Reading on Decarbonisation: Morgan Stanley Reports

Renewables

Sustainability & Utilities: A Deep Dive into Decarbonization (September 24, 2019)

China Clean Energy: What if a new subsidy payment system is implemented? (August 9, 2019)

Utilities & Materials: Renewables – From Big Government to Big Business (June 5, 2019)

Regulated Utilities: Energy Storage: Disruptor or Enabler? (April, 8, 2019)

Sustainability & European Utilities: ESG Face Off: Oersted & RWE - Is RWE the new Energy Transition stock in Europe? (February 25, 2019)

Clean Tech & Yieldcos: Refreshing our Thoughts on Key Themes & Debates (November 30, 2018)

Regulated Utilities: The Intersection of EVs, Solar, Fuel Cells, Hydrogen and Energy Storage (October 18, 2018)

Renewable Energy: What Cheap, Clean Energy Means for Global Utilities (July 5, 2017)

Electric Vehicles

Autos & Shared Mobility: BEV inflection point coming forward? (September 26, 2019)

Autos & Shared Mobility: The Climate Opportunity of Auto 2.0: How Big Tech Drives Faster EV Adoption (September 5, 2019)

European Automotive Sector: Cyclical – Recession or not? Structural – Electrification “Emission Troubles” part 2 (August 16, 2019)

Lithium: New Technologies, Same Oversupply (July 12, 2019)

EV Batteries: Better Anode, Safer Batteries (June 26, 2019)

EV Batteries: Cathode Evolution: Are Volume and Price mutually exclusive? (June 7, 2019)

Autos and Shared Mobility: Introducing the Morgan Stanley Global Electric Vehicle Market Monitor (April 12, 2019)

EV Battery Materials: Initiating on EV Battery Material Suppliers: Be Selective (February 20, 2019)

Investor Presentation: Disruption Decoded: Global Autos 2.0 (November 22, 2018)

The Next India: India’s Transport EVolution (May 31, 2018)

Electric Vehicles: On the Charge (August 31, 2017)

CCS

Sustainable and Responsible: Carbon Capture and Storage: A degree of progress? (May 27, 2015)

Sustainable and Responsible: Carbon Capture and Storage - A Realistic Solution? (August 28, 2014)

Hydrogen

Chemicals: Hydrogen: Bridging The Gap (June 17, 2019)

Clean Tech & Yieldcos: Refreshing our Thoughts on Key Themes & Debates (November 30, 2018).

Regulated Utilities: The Intersection of EVs, Solar, Fuel Cells, Hydrogen and Energy Storage (October 18, 2018)

Utilities: Hydrogen: new projects and push back (October 15, 2018)

Global Hydrogen: A US$2.5 trillion industry? (July 22, 2018)

Biofuels

Agribusiness: Sugar & Ethanol: Sugar Recovery May Take Longer, but Is Coming (September 20, 2019)

Because You Asked: Is 10% Ethanol Blend Mandate Feasible in China? (August 9, 2019)

Neste Corporation: Volume Led Growth - Stay Overweight (July 25, 2019)

Refining & Marketing: Texas Tour Takeaways (April 8, 2019)

Oil & Gas

India Gas: Fueling The Energy Transition (October 9, 2019)

Natural Gas: Fueling Global Disruption (July 22, 2019)

Integrated Oil & Refining: CERA Week - Day #1: Energy Transition and Digitalisation Stand Out (March 12, 2019)

Sustainability: Further Signs of a Low Carbon Future in Oil & Gas? (January 29, 2018)

From Molecules to Electrons - What Energy Transition Means for Oil & Gas Investors (February 5, 2017)

Green Financing

Green Borders: Tax and Dividends for a Low Carbon Economy (April 25, 2019)

Cross-Asset Strategy and Sustainability: Why We Think Green Bonds Will Continue to Grow: A Primer (September 21, 2017)

Appendix

IEA energy scenarios

The IEA's World Energy Outlook presents three scenarios for future energy consumption and thus carbon emissions.

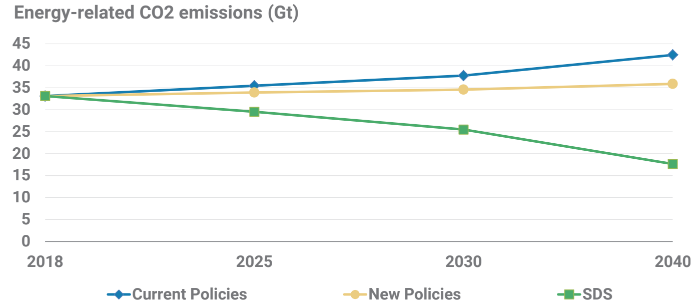
Current Policies assumes no policy change from today, driving a 30% increase in energy demand and 28% rise in carbon emissions over 2017-40.

New Policies includes measures and targets that governments have announced but not yet implemented. In this scenario, energy demand increases by 27% and carbon emissions by 10%.

Sustainable Development is aligned with the Paris Agreement's objective of "holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C". This scenario also includes the three energy-focused Sustainable Development Goals: SDG 7 (ensure access to affordable, reliable, sustainable and modern energy), SDG 3 (reduce the number of deaths and illness from air pollution) and SDG 13 (combat climate change and its impacts). CO_2 emissions fall by 46% between 2018 and 2040 with overall energy demand roughly flat

Exhibit 131:

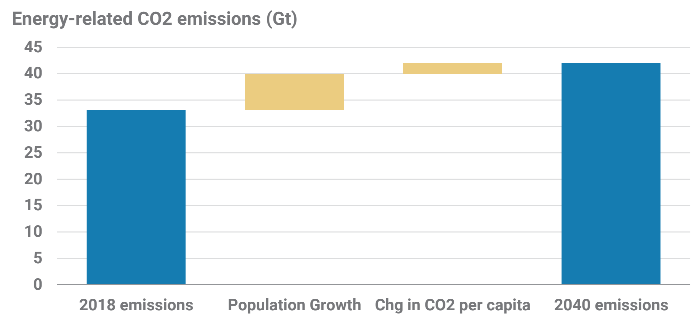
IEA's three scenarios for carbon emissions



Source: IEA

Exhibit 132:

IEA's current policies scenario implies population growth and higher carbon intensity



Source: IEA

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(as of September 30, 2019)

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	Coverage Universe		Investment Banking Clients (IBC)			Other Material Investment Services Clients (MISC)	
Stock Rating Category	Count	% of Total	Count	% of Total IBC	% of Rating Category	Count	% of Total Other MISC
Overweight/Buy	1155	37%	281	42%	24%	532	37%
Equal-weight/Hold	1432	46%	319	47%	22%	678	47%
Not-Rated/Hold	1	0%	0	0%	0%	1	0%
Underweight/Sell	558	18%	76	11%	14%	224	16%
Total	3,146		676			1435	

Data include common stock and ADRs currently assigned ratings. Investment Banking Clients are companies from whom Morgan Stanley received investment banking compensation in the last 12 months. Due to rounding off of decimals, the percentages provided in the "% of total" column may not add up to exactly 100 percent.

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Stock Price, Price Target and Rating History (See Rating Definitions)

Ecopro Co Ltd (086520.KQ) - As of 10/20/19 in KRW
Industry : S. Korea Energy & Materials

Stock Rating History: 2/21/19 : E

Price Target History: 2/21/19 : 34000; 4/10/19 : 27000; 7/4/19 : 26000; 10/21/19 : 20000

Source: Morgan Stanley Research Date Format : MM/DD/YY Price Target -- No Price Target Assigned (NA)
Stock Price (Not Covered by Current Analyst) — Stock Price (Covered by Current Analyst) ▬
Stock and Industry Ratings (abbreviations below) appear as ◆ Stock Rating/Industry View
Stock Ratings: Overweight (O) Equal-weight (E) Underweight (U) Not-Rated (NR) No Rating Available (NA)
Industry View: Attractive (A) In-line (I) Cautious (C) No Rating (NR)

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Iljin Materials (020150.KS) - As of 10/20/19 in KRW
Industry : S. Korea Energy & Materials

Stock Rating History: 2/21/19 : O

Price Target History: 2/21/19 : 56000; 4/10/19 : 51000; 8/21/19 : 57000

Source: Morgan Stanley Research Date Format : MM/DD/YY Price Target -- No Price Target Assigned (NA)
Stock Price (Not Covered by Current Analyst) — Stock Price (Covered by Current Analyst) ▬
Stock and Industry Ratings (abbreviations below) appear as ◆ Stock Rating/Industry View
Stock Ratings: Overweight (O) Equal-weight (E) Underweight (U) Not-Rated (NR) No Rating Available (NA)
Industry View: Attractive (A) In-line (I) Cautious (C) No Rating (NR)

Effective January 13, 2014, the stocks covered by Morgan Stanley Asia Pacific will be rated relative to the analyst's industry (or industry team's) coverage.

Effective January 13, 2014, the industry view benchmarks for Morgan Stanley Asia Pacific are as follows: relevant MSCI country index or MSCI sub-regional index or MSCI AC Asia Pacific ex Japan Index.

L&F Co Ltd (066970.KQ) - As of 10/20/19 in KRW
Industry : S. Korea Energy & Materials

Stock Rating History: 2/21/19 : U

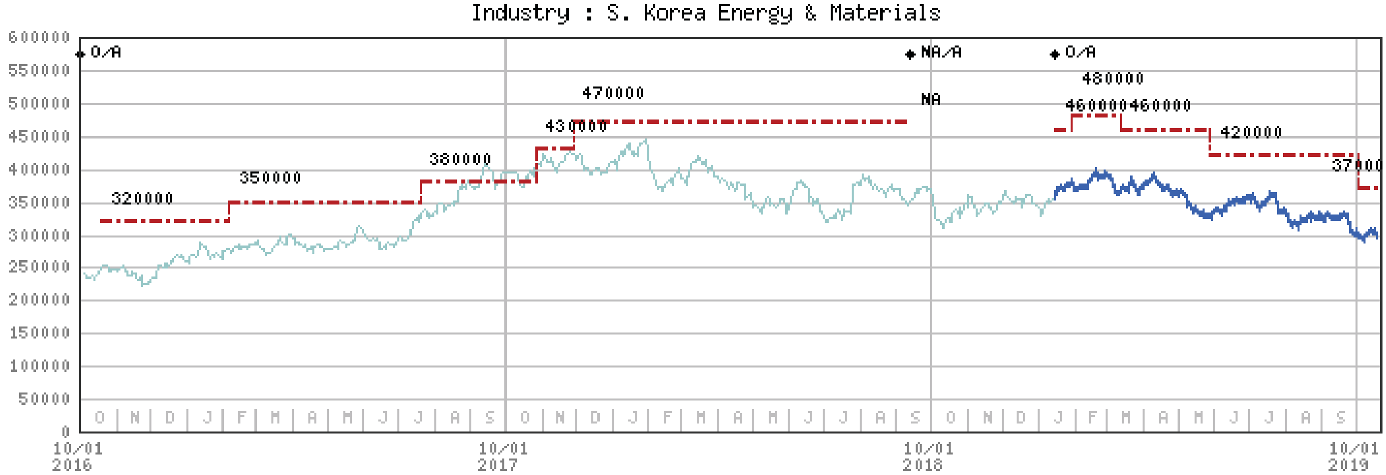
Price Target History: 2/21/19 : 28000; 4/10/19 : 23000; 7/4/19 : 22000

Source: Morgan Stanley Research   Date Format : MM/DD/YY   Price Target --   No Price Target Assigned (NA)
Stock Price (Not Covered by Current Analyst) —   Stock Price (Covered by Current Analyst) ■
Stock and Industry Ratings (abbreviations below) appear as ◆ Stock Rating/Industry View
Stock Ratings: Overweight (O) Equal-weight (E) Underweight (U) Not-Rated (NR) No Rating Available (NA)
Industry View: Attractive (A) In-line (I) Cautious (C) No Rating (NR)

Effective January 13, 2014, the stocks covered by Morgan Stanley Asia Pacific will be rated relative to the analyst's industry (or industry team's) coverage.

Effective January 13, 2014, the industry view benchmarks for Morgan Stanley Asia Pacific are as follows: relevant MSCI country index or MSCI sub-regional index or MSCI AC Asia Pacific ex Japan Index.

LG Chem Ltd (051910.KS) - As of 10/20/19 in KRW
Industry : S. Korea Energy & Materials



Stock Rating History: 11/9/15 : NA; 6/2/16 : O; 10/1/16 : O; 9/13/18 : NA; 1/15/19 : O

Price Target History: 10/21/14 : 300000; 1/27/15 : 270000; 4/20/15 : 300000; 5/13/15 : 350000; 11/9/15 : NA; 6/2/16 : 350000; 10/19/16 : 320000; 2/6/17 : 350000; 7/20/17 : 380000; 10/27/17 : 430000; 11/28/17 : 470000; 9/13/18 : NA; 1/15/19 : 460000; 1/30/19 : 480000; 3/12/19 : 460000; 5/28/19 : 420000; 10/3/19 : 370000

Source: Morgan Stanley Research   Date Format : MM/DD/YY   Price Target --   No Price Target Assigned (NA)
Stock Price (Not Covered by Current Analyst) —   Stock Price (Covered by Current Analyst) ■
Stock and Industry Ratings (abbreviations below) appear as ◆ Stock Rating/Industry View
Stock Ratings: Overweight (O) Equal-weight (E) Underweight (U) Not-Rated (NR) No Rating Available (NA)
Industry View: Attractive (A) In-line (I) Cautious (C) No Rating (NR)

Effective January 13, 2014, the stocks covered by Morgan Stanley Asia Pacific will be rated relative to the analyst's industry (or industry team's) coverage.

Effective January 13, 2014, the industry view benchmarks for Morgan Stanley Asia Pacific are as follows: relevant MSCI country index or MSCI sub-regional index or MSCI AC Asia Pacific ex Japan Index.

Posco Chemical Co Ltd. (003670.KS) - As of 10/20/19 in KRW
Industry : S. Korea Energy & Materials

Stock Rating History: 2/21/19 : O

Price Target History: 2/21/19 : 95000; 4/10/19 : 76000; 7/4/19 : 66000

Source: Morgan Stanley Research Date Format : MM/DD/YY Price Target -- No Price Target Assigned (NA)
Stock Price (Not Covered by Current Analyst) — Stock Price (Covered by Current Analyst) ■
Stock and Industry Ratings (abbreviations below) appear as ♦ Stock Rating/Industry View
Stock Ratings: Overweight (O) Equal-weight (E) Underweight (U) Not-Rated (NR) No Rating Available (NA)
Industry View: Attractive (A) In-line (I) Cautious (C) No Rating (NR)

Effective January 13, 2014, the stocks covered by Morgan Stanley Asia Pacific will be rated relative to the analyst's industry (or industry team's) coverage.

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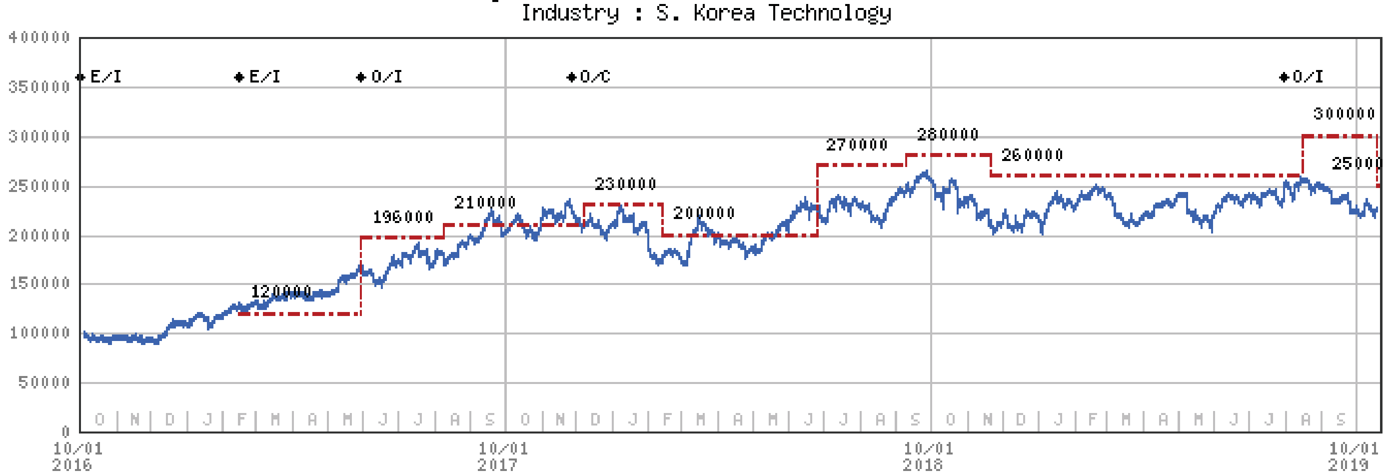
Samsung SDI (006400.KS) - As of 10/20/19 in KRW
Industry : S. Korea Technology



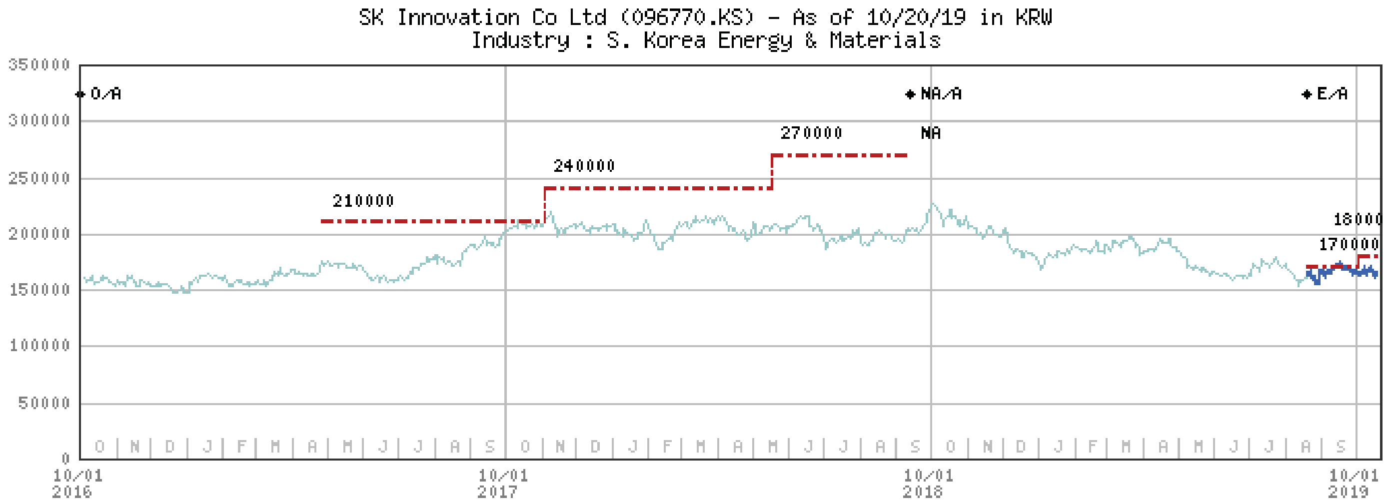
Stock Rating History: 6/2/16 : U; 10/1/16 : E; 2/15/17 : E; 5/30/17 : O

Price Target History: 2/3/14 : 150000; 11/25/14 : 144000; 1/16/15 : 130000; 8/20/15 : 85000; 10/19/15 : 114000; 1/26/16 : 100000; 6/2/16 : 86000; 2/15/17 : 120000; 5/30/17 : 196000; 8/9/17 : 210000; 12/7/17 : 230000; 2/13/18 : 200000; 6/25/18 : 270000; 9/10/18 : 280000; 11/21/18 : 260000; 8/16/19 : 300000; 10/18/19 : 250000

Source: Morgan Stanley Research Date Format : MM/DD/YY Price Target -- No Price Target Assigned (NA)
Stock Price (Not Covered by Current Analyst) — Stock Price (Covered by Current Analyst) ■
Stock and Industry Ratings (abbreviations below) appear as ♦ Stock Rating/Industry View
Stock Ratings: Overweight (O) Equal-weight (E) Underweight (U) Not-Rated (NR) No Rating Available (NA)
Industry View: Attractive (A) In-line (I) Cautious (C) No Rating (NR)

Effective January 13, 2014, the stocks covered by Morgan Stanley Asia Pacific will be rated relative to the analyst's industry (or industry team's) coverage.

Effective January 13, 2014, the industry view benchmarks for Morgan Stanley Asia Pacific are as follows: relevant MSCI country index or MSCI sub-regional index or MSCI AC Asia Pacific ex Japan Index.



Stock Rating History: 5/13/15 : E; 1/13/16 : O; 10/1/16 : O; 9/13/18 : NA; 8/20/19 : E

Price Target History: 10/16/14 : 110000; 5/13/15 : 130000; 7/24/15 : 115000; 1/13/16 : 150000; 4/1/16 : 200000; 4/26/17 : 210000; 11/3/17 : 240000; 5/17/18 : 270000; 9/13/18 : NA; 8/20/19 : 170000; 10/3/19 : 180000

Source: Morgan Stanley Research Date Format : MM/DD/YY Price Target -- No Price Target Assigned (NA)
Stock Price (Not Covered by Current Analyst) Stock Price (Covered by Current Analyst)
Stock and Industry Ratings (abbreviations below) appear as ◆ Stock Rating/Industry View
Stock Ratings: Overweight (O) Equal-weight (E) Underweight (U) Not-Rated (NR) No Rating Available (NA)
Industry View: Attractive (A) In-line (I) Cautious (C) No Rating (NR)

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