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Goldman Sachs

Carbonomics

10 key themes from the inaugural conference

We hosted our **inaugural Carbonomics conference** on November 12, with **30 CEOs and key policymakers** discussing their strategies to de-carbonize the economy and generate sustainable growth, in front of an audience of c.5,000 investors, corporates, regulators and industry experts. In our Carbonomics study, we argue that **Net Zero Carbon is becoming more affordable** as technological and financial innovation, supported by policy, is flattening the de-carbonization cost curve. Investors and corporates are driving this clean tech innovation through deep engagement across 10 key themes of de-carbonization and sustainable growth, which we analyze in depth in this report: **Sustainable Investing & Financing**, driving a seismic shift in capital allocation, with an implied carbon price of US$40-80/t; **Renewable power, Re-imagining Big Oils, The rise of Clean Hydrogen** and **Rethinking Mobility** overhauling the energy industry and driving US$16 tn of green infrastructure investments and 15-20 mn net new jobs worldwide by 2030; **Circular Economy and Farm to Fork** and **Assuring Sustainability**, as consumers demand visibility on their carbon footprint; **Flying Sustainably, Carbon Sequestration** and **De-carbonizing Basic Materials** to address the toughest to abate sectors.

Michele Della Vigna, CFA
+44 20 7552-9383
michele.dellavigna@gs.com
Goldman Sachs International

Zoe Stavrinou
+44 20 7051-2816
zoe.stavrinou@gs.com
Goldman Sachs International

Alberto Gandolfi
+44 20 7552-2539
alberto.gandolfi@gs.com
Goldman Sachs International

John Ennis, CFA
+44 20 7552-9608
john.ennis@gs.com
Goldman Sachs International

George Galliers
+44 20 7552-5784
george.galliers@gs.com
Goldman Sachs International

The Goldman Sachs Group, Inc.

For the full list of authors, see inside.




AUTHORS

Michele Della Vigna, CFA
+44 20 7552-9383
michele.dellavigna@gs.com
Goldman Sachs International

Zoe Stavrinou
+44 20 7051-2816
zoe.stavrinou@gs.com
Goldman Sachs International

Alberto Gandolfi
+44 20 7552-2539
alberto.gandolfi@gs.com
Goldman Sachs International

John Ennis, CFA
+44 20 7552-9608
john.ennis@gs.com
Goldman Sachs International

George Galliers
+44 20 7552-5784
george.galliers@gs.com
Goldman Sachs International

Daniela Costa
+44 20 7774-8354
daniela.costa@gs.com
Goldman Sachs International

Heather Bellini, CFA
+1 212 357-7710
heather.bellini@gs.com
Goldman Sachs & Co. LLC

Robert Koort, CFA
+1 713 654-8480
robert.koort@gs.com
Goldman Sachs & Co. LLC

Patrick Creuset
+44 20 7552-5960
patrick.creuset@gs.com
Goldman Sachs International

Venetia Baden-Powell
+44 20 7552-2139
venetia.baden-powell@gs.com
Goldman Sachs International

Chris Hallam
+44 20 7552-2958
chris.hallam@gs.com
Goldman Sachs International

Mark Delaney, CFA
+1 212 357-0535
mark.delaney@gs.com
Goldman Sachs & Co. LLC

Nikhil Bhandari
+65 6889-2867
nikhil.bhandari@gs.com
Goldman Sachs (Singapore) Pte

Suhasini Varanasi
+44 20 7774-3722
suhasini.varanasi@gs.com
Goldman Sachs International

Kota Yuzawa
+81 3 6437-9863
kota.yuzawa@gs.com
Goldman Sachs Japan Co., Ltd.

Theodora Lee Joseph, CFA
+44 20 7051-8362
theodoralee.joseph@gs.com
Goldman Sachs International

Georgina Iwamoto, Ph.D.
+44 20 7552-5984
georgina.iwamoto@gs.com
Goldman Sachs International

Neil Mehta
+1 212 357-4042
neil.mehta@gs.com
Goldman Sachs & Co. LLC

Geydar Mamedov
+7 495 645-4041
geydar.mamedov@gs.com
OOO Goldman Sachs Bank

Ajay Patel
+44 20 7552-1168
ajay.patel@gs.com
Goldman Sachs International

Keyur Parekh
+44 20 7552-9939
keyur.parekh@gs.com
Goldman Sachs International

Jack O'Brien
+44 20 7552-2998
jack.obrien@gs.com
Goldman Sachs International

Vinit Joshi
+91 22 6616-9158
vinit.joshi@gs.com
Goldman Sachs India SPL

Michael Lapides
+1 212 357-6307
michael.lapides@gs.com
Goldman Sachs & Co. LLC

Roberta De Luca
+44 20 7051-2264
roberta.deluca@gs.com
Goldman Sachs International

Jean-Francois Neuez
+44 20 7552-9362
jean-francois.neuez@gs.com
Goldman Sachs International

Jerry Revich, CFA
+1 212 902-4116
jerry.revich@gs.com
Goldman Sachs & Co. LLC

Derek R. Bingham
+1 415 249-7435
derek.bingham@gs.com
Goldman Sachs & Co. LLC

Sharmini Chetwode, Ph.D.
+852 2978-1123
sharmini.p.chetwode@gs.com
Goldman Sachs (Asia) L.L.C.

Evan Tylenda, CFA
+44 20 7774-1153
evan.tylenda@gs.com
Goldman Sachs International

Inaugural Carbonomics conference: 10 Key themes of sustainable growth

We hosted our first ever ***Carbonomics: The Green Engine of Economic Recovery Conference*** in London on November 12, with speakers including 30 CEOs of leading corporates and key policymakers, convening c.5,000 investors, company management, regulators and industry experts. Against a backdrop of intensified focus on de-carbonization and sustainable investing, with increasing shareholder engagement, the conference focused on the key themes surrounding the new de-carbonization trends and technologies currently transforming all major industries globally (power, mobility, buildings, agriculture and industry):

1. **Sustainable Investing & Financing:** Sustainable investing is gaining momentum, with U$103 tn AUM behind PRI signatories, and top ESG performers have generated 320 bp of alpha pa over bottom ESG performers since 2012, according to our GS SUSTAIN analysis. Mark Carney, United Nations Special Envoy on Climate Action & Finance, senior management from Amundi, Europe's largest asset manager, and Goldman Sachs' CEO David Solomon have laid out the business case for sustainable investing and the key role of private capital in the low-carbon transition. The UK Minister of State for Business, Energy, and Clean Growth laid out the important role of policy and regulatory frameworks, c.12 months before the UK hosts the landmark UN Climate Change Conference (COP26). We estimate that rising capital markets engagement in climate change is driving a seismic shift in capital allocation, with the market charging an implied carbon price of US$40-80/tonne for new hydrocarbon developments.
2. **Renewable power:** Renewable power has transformed the landscape of the energy industry and represents one of the most economically attractive opportunities in our de-carbonization cost curve. Our research suggests that renewable power will become the largest area of energy investment in 2021, surpassing upstream oil & gas for the first time in history, and that clean tech has the potential to drive US$16 tn of green infrastructure investments and create 15-20 mn jobs worldwide by 2030. The CEO of NextEra, the world's largest wind and solar developer, the CEOs of Iberdrola and EDP and the CFOs of RWE and Siemens Gamesa joined our conference to discuss growth and opportunities in the renewable power space.
3. **Circular Economy and Farm to Fork**: The circular economy is a critical pillar of global de-carbonization and improved resource and energy management, redefining current industrial and consumer practices. The CEOs of Unilever and Covestro joined our conference and discussed how they aim to accelerate the shift to a circular economy and make sustainable living commonplace. Enhanced agricultural efficiency and the food revolution have a key role to play in helping reduce carbon emissions, while feeding a growing global population, as the CEO of Danone and senior management from Bayer discussed.
4. **The rise of Clean Hydrogen:** Clean hydrogen is a key rising technology in the path towards net zero carbon, providing de-carbonization solutions in the most challenging parts of the Carbonomics cost curve, including long-haul transport, steel, chemicals, heating and long-term power storage. We discussed the value chain of

clean hydrogen with industry leaders in the manufacturing, distribution and use of clean hydrogen, including the CEOs of Air Products, SNAM and Ballard Power, and senior representatives of Air Liquide, Cummins and Linde.

5. **Re-imagining Big Oils:** Big Oils are re-imagining their businesses, consistent with the global ambition to contain global warming within 2°C, transforming themselves into broader, lower-carbon energy companies. The CEOs of BP, TOTAL, ENI, OMV and Lundin Energy laid out their visions for the transformation of their companies.
6. **Rethinking Mobility:** Road transport is at the start of its most significant technological change in a century, with electrification, autonomous driving and clean hydrogen at the core of the de-carbonization challenge. The CEOs of Daimler and Nikola Motor joined our conference to discuss the opportunities and challenges of this clean tech revolution.
7. **Flying Sustainably:** Aviation sits at the top of our Carbonomics cost curve, and is one of the toughest industries to de-carbonize. Biofuels, synthetic fuels and improved efficiency are key parts of the solution, as we discussed with the CEO of Neste, the world's biofuels leader, and senior management from Lufthansa, Airbus and Rolls Royce during our conference.
8. **Carbon Sequestration:** Carbon sequestration technologies are important to achieve Net Zero in a cost-efficient way. We discussed the topic with the CEOs of OGCI Climate Investments, the CCS Institute and Storegga Geotechnologies. The CEO of Carbon Engineering and the founders of Climeworks also laid out the case for Direct Air Carbon Capture, while Microsoft discussed its strategy to become carbon negative by 2030.
9. **Assuring Sustainability:** In a world where consumers are increasingly aware of the importance of climate change, and demand lower-carbon products and services, assuring the carbon content of different processes becomes an important business opportunity, as we discussed with Intertek's CEO, and with the CEOs of the leaders in voluntary carbon credit certifications: Verra and the Gold Standard Foundation.
10. **De-carbonizing Basic Materials:** De-carbonizing industry is one of the most complex and important areas of carbon abatement. Senior management from ArcelorMittal and LafargeHolcim shared their plans to de-carbonize steel and cement manufacturing.

Carbonomics Conference Agenda

Live Agenda: Thursday, 12 November 2020

UK times:

08.00-09.00	**Opening remarks** **Richard Gnodde,** CEO of Goldman Sachs International
	Opening Keynote **Mark Carney,** United Nations Special Envoy on Climate Action & Finance
09.00-09.30	**The Business Case for Sustainable Investing** **Amundi,** Jean-Jacques Barberis, Head of Institutional and Corporate Clients & Member of Executive Board Moderator: Sam Morgan, Co-Head of EMEA FICC Sales
09.30-10.00	**The Future of Energy** **Eni,** Claudio Descalzi, CEO Moderator: Michele della Vigna, Head EMEA Natural Resources Research
10.00-10.30	**Re-imagining Big Oils for a Low Carbon Future** **BP,** Bernard Looney, CEO Moderator: Anthony Gutman, Co-Head Investment Banking in EMEA
10.40-11.20	**The Dual Challenge: providing more energy with lower carbon emissions** **Lundin Energy,** Nick Walker, COO & incoming President & CEO **OMV,** Rainer Seele, CEO **Royal Dutch Shell,** Elisabeth Brinton, EVP New Energies Moderator: Sheila Patel, Chairman, GSAM
11.30-12.00	**Driving a Profitable Transition to a Broad Energy Company** **TOTAL,** Patrick Pouyanné, CEO Moderator: Pierre Hudry, Head of Paris Office
12.00-12.30	**Assuring Sustainability and Carbon Emissions** **Intertek,** André Lacroix, CEO Moderator: Anna Skoglund, Head EMEA Financial & Strategic Investor Grp
12.30-13.00	**Making Sustainable Living Commonplace** **Unilever,** Alan Jope, CEO Moderator: Gilberto Pozzi, Co-Chairman Global Mergers & Acquisitions
13.00-13.30	**Rethinking Mobility** **Daimler,** Ola Kallenius, CEO Moderator: Wolfgang Fink, CEO Germany and Austria

On-Demand Agenda: Pre-recorded sessions available from 6pm (UK) on 11 November

COP26 –12 months to the landmark UN Climate Change Conference
The Rt Hon Kwasi Kwarteng MP, UK Minister of State for Business, Energy, and Clean Growth
Moderator: Kathleen Hughes, Global Head of Liquidity Solutions, GSAM

Farm to Fork – De-carbonizing Agriculture
Bayer, Matthias Berninger, SVP Head of Public Affairs, Science & Sustainability
Moderator: Keyur Parekh, European Pharmaceutical Equity Research

Financing a Lower Carbon Future
BNP Paribas, Constance Chalchat, Global Head of Engagement, BNP Paribas Corporate and Institutional Banking
Moderator: Charlotte Keenan, Head of the Office of Corporate Engagement International

Making Direct Air Carbon Capture a reality
Carbon Engineering, Steve Oldham, CEO
Moderator: Edward Emerson, Head of Global Commodities Trading

DACS – Taking CO2 back from the Atmosphere
Climeworks, Dr. Christoph Gebald, Director, Founder and Member of the Board & Dr. Jan Wurzbacher, Director, Founder and Member of the Board
Moderator: Alberto Gandolfi, Head of European Utilities Research

Accelerating the shift to a Circular Economy
Covestro, Dr. Markus Steilemann, CEO
Moderator: Dr. Georgina Iwamoto, European Chemicals Equity Research

Accelerating the Food Revolution
Danone, Emmanuel Faber, CEO
Moderator: David Solomon, Chairman and Chief Executive Officer

Scaling up the Path towards Net Zero
EDP, Miguel Stilwell de Andrade, CFO and Interim CEO
Moderator: Alberto Gandolfi, Head of European Utilities Research

Continues to page 2 >

Goldman Sachs

Carbonomics

The Green Engine of Economic Recovery

Live Agenda: Thursday, 12 November 2020 - continued

UK times:

13.30-14.15 ***Flying Sustainably***

Airbus, *Jean-Brice Dumont , EVP Engineering*

Lufthansa, *Christina Foerster, Member Exec Board Customer, IT & CR*

Neste, *Peter Vanacker, Chief Executive Officer*

Rolls Royce, *Paul Stein, Chief Technology Officer*

Moderator: Kathryn Koch, Co-Head of Fundamental Equity GSAM

14.15-14.45 ***De-carbonizing Basic Materials***

ArcelorMittal, *Alan Knight, GM, Corporate Responsibility*

LafargeHolcim, *Géraldine Picaud, CFO*

Moderator: John Goldstein, Head of Sustainable Finance

14.50-15.45 ***The Rise of Clean Hydrogen***

Air Liquide*, Pierre-Etienne Franc, Head of Hydrogen Energy*

Ballard Power, *Randall MacEwen, President & CEO*

Cummins, *Amy Davis, President New Power*

Linde, *David Burns, VP Clean Hydrogen*

Snam, *Marco Alverà, CEO*

Moderator: Alison Mass, Chairman, Investment Banking Division

15.45-16.15 ***The Clean Hydrogen Opportunity***

Air Products, *Seifi Ghasemi, Chairman, President and CEO*

Moderator: Clare Scherrer, Global Co-Head, Industrials Group, IBD

16.20-16.50 ***Beyond Net Zero: Carbon Negative by 2030***

Microsoft*, Brian Janous, GM, Datacenter Energy & Sustainability*

Moderator: Heather Bellini, Co-Head of TMT Research

16.55-17.25 ***A New Era for Clean Energy***

NextEra Energy, *Jim Robo, Chairman and CEO*

Moderator: John Waldron, President and Chief Operating Officer

17.30-18.00 ***De-carbonizing Heavy Transport***

Nikola Motor, *Mark Russell, Chief Executive Officer*

Moderator: Daniela Costa, Head of European Industrials Research

18.00-18.30 ***Closing Keynote***

David Solomon*, Chairman & CEO of Goldman Sachs*

Moderator: Dina Powell, Partner, Investment Banking Division

On-Demand Agenda: Pre-recorded sessions available from 6pm (UK) on 11 November- continued

Accelerating the deployment of carbon capture and storage

Global CCS Institute, *Brad Page, CEO*

Moderator: Sharmini Chetwode, Head of ESG Research for Asia

The profitable path towards Green Electrification

Iberdrola, *Ignacio Galán, Chairman & CEO*

Moderator: Gonzalo Garcia, Co-Head Investment Banking Division in EMEA

Financing Carbon Innovation

OGCI Climate Investments, *Pratima Rangarajan, CEO*

Moderator: Kara Mangone, COO, Sustainable Finance Group

Our Energy for a Sustainable Life

RWE, *Markus Krebber, CFO*

Moderator: Alberto Gandolfi, Head of European Utilities Research

The Future of Wind Power

Siemens Gamesa*, Thomas Spannring, CFO*

Moderator: Ajay Patel, European Utilities Equity Research

Carbon Storage and Hydrogen technology solutions

Storegga Geotechnologies, *Nick Cooper, CEO*

Moderator: Chris Pilot, Head of EMEA Energy Services, IBD

Common practices to calculate de-carbonization

The Gold Standard Foundation, *Maggie Kim, CEO*

Moderator: Sharmini Chetwode, Head of ESG Research for Asia

Standards for a Sustainable Future

Verra, *David Antonioli, CEO*

Moderator: Sharmini Chetwode, Head of ESG Research for Asia

Goldman Sachs 10,000 Small Businesses and a Sustainable Future

Toast Ale, *Rob Wilson, Founder*

Forster Communications*, Amanda Powell-Smith, CEO*

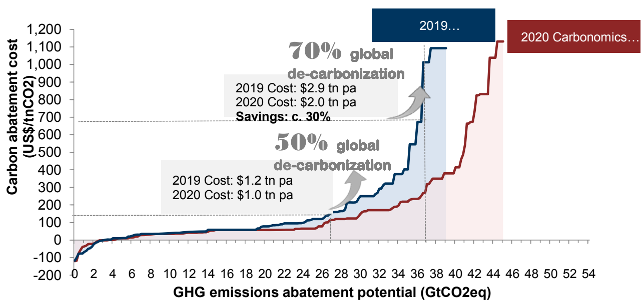
Walker-Miller Energy Services*, Carla Walker-Miller, Founder and CEO*

Moderator: Asahi Pompey, Global Head of Corporate Engagement

Updated: 11 November 2020. Subject to change.

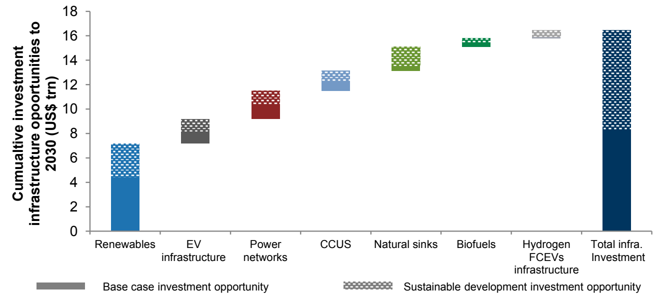
Carbonomics: Thesis in 12 charts

Exhibit 1: Technological and financial innovation are flattening the de-carbonization cost curve, shaving US$1 tn pa from the cost to Net Zero...
Conservation carbon abatement cost curve for anthropogenic GHG emissions and associated costs for different levels of de-carbonization



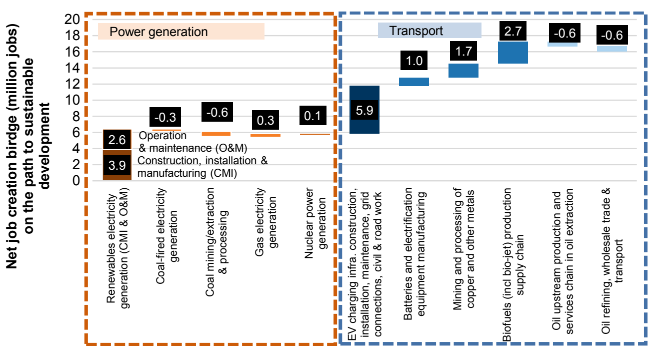
Source: Goldman Sachs Global Investment Research

Exhibit 2: ...driving economic recovery, with potential for US$16 tn of infrastructure investments by 2030...
Cumulative investment in clean energy transition to 2030 (US$ tn)



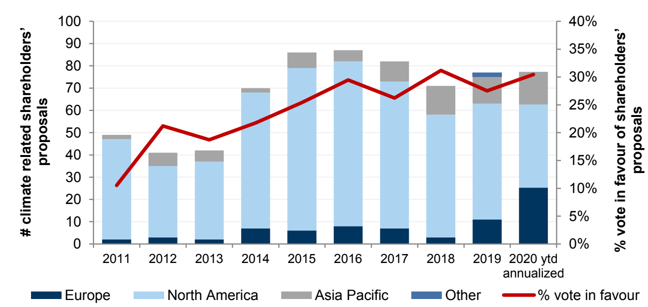
Source: IEA WEO (2019), Goldman Sachs Global Investment Research

Exhibit 3: ...and creating 15-20 mn net new jobs globally
Net job creation bridge (mn jobs) for a sustainable path across the energy supply chain



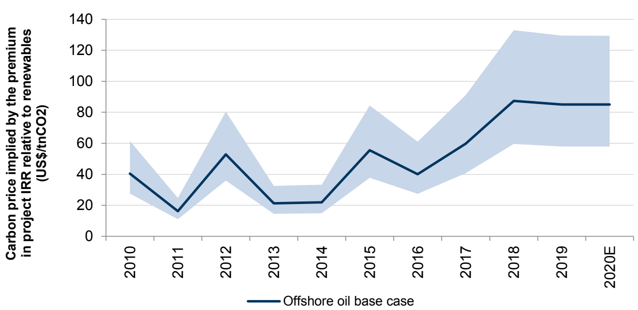
Source: IEA, IRENA, UNEP - ILO - IOE - ITUC, EuropeOn, Goldman Sachs Global Investment Research

Exhibit 4: Investors are driving the climate change debate through corporate engagement...
Number of climate-related shareholders' proposals vs. % vote in favour



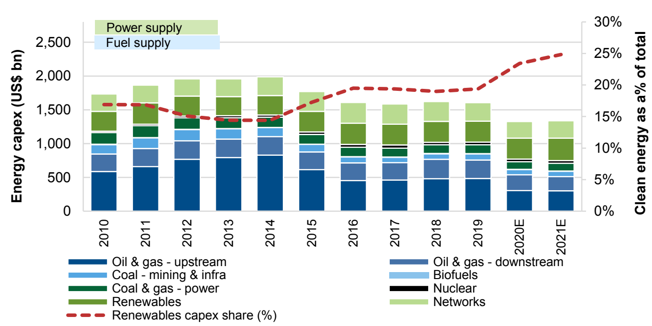
Source: ProxyInsight, Goldman Sachs Global Investment Research

Exhibit 5: ...and higher cost of capital for hydrocarbon developments – implying US$80/ton CO2 price...
Carbon price implied by the IRR premium for offshore oil projects compared with renewables (US$/tn CO2)



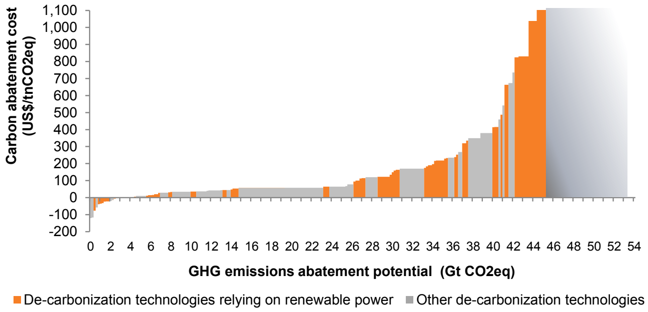
Source: Goldman Sachs Global Investment Research

Exhibit 6: ...leading to an unprecedented shift in capital allocation: renewable power investment becomes larger than oil & gas for the first time in history
Energy supply capex (US$bn - LHS), and clean energy (renewables, biofuels) as a % of total (% - RHS)



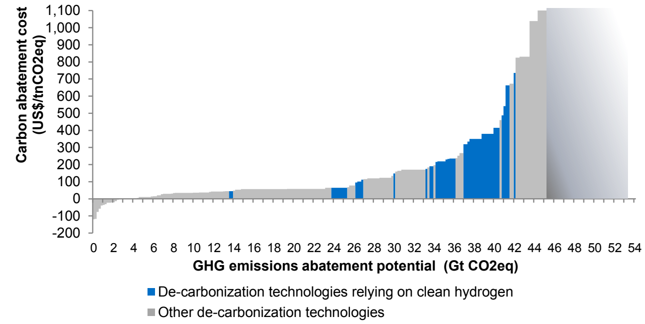
Source: IEA WEI (historicals), Goldman Sachs Global Investment Research

Exhibit 7: Renewable power is vital for the de-carbonization of c.35% of global emissions across sectors...
2020 conservation carbon abatement cost curve for anthropogenic GHG emissions, orange indicating renewable power-reliant technologies



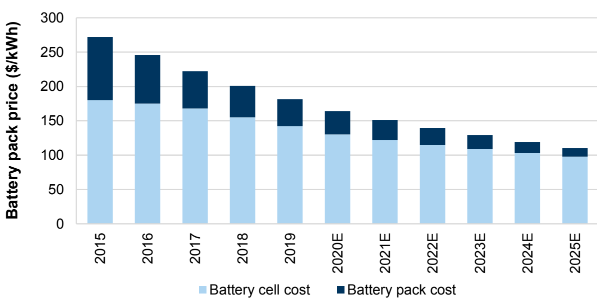
Source: Goldman Sachs Global Investment Research

Exhibit 8: ...complemented by clean hydrogen for another 20% of emissions, creating a de-carbonization ecosystem...
2020 conservation carbon abatement cost curve for anthropogenic GHG emissions, blue indicating clean hydrogen-reliant technologies



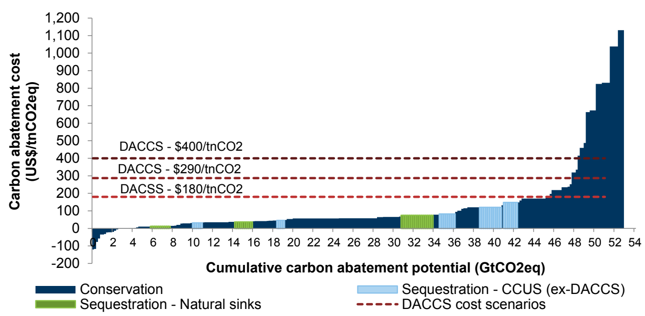
Source: Goldman Sachs Global Investment Research

Exhibit 9: ...that also leverages on battery technology improvements...
Battery pack and cell price (US$/kWh)



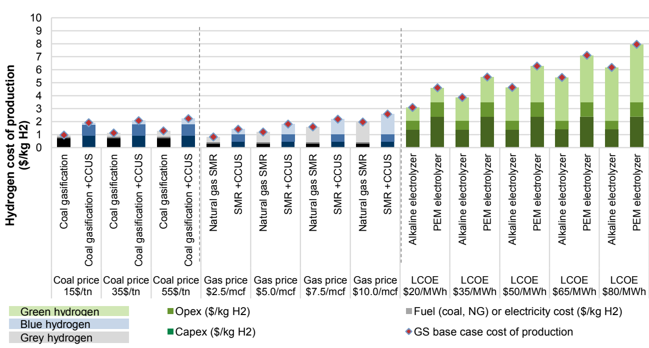
Source: Company data, Goldman Sachs Global Investment Research

Exhibit 10: ...and carbon sequestration technologies
Total conservation and sequestration abatement cost curve of de-carbonization for anthropogenic GHG emissions, based on current technologies and associated costs



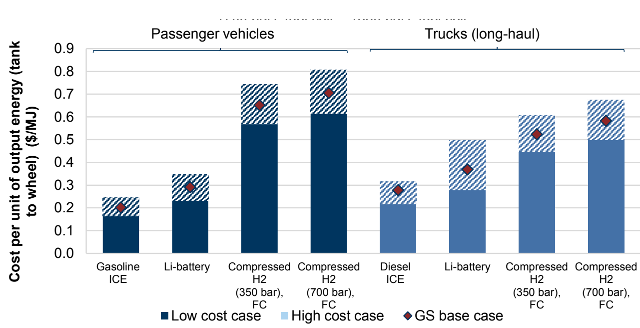
Source: Goldman Sachs Global Investment Research

Exhibit 11: Clean Hydrogen: we expect strong technological evolution in blue and green hydrogen...
LCOH for hydrogen split by method of production ($/kgH2)



Source: Company data, Goldman Sachs Global Investment Research

Exhibit 12: ...as a key driver of de-carbonization for industry, heating and long-haul transport
Cost per unit of output energy (tank-to-wheel, $/MJ)



Source: Company data, Goldman Sachs Global Investment Research

Carbonomics: The green engine of economic recovery

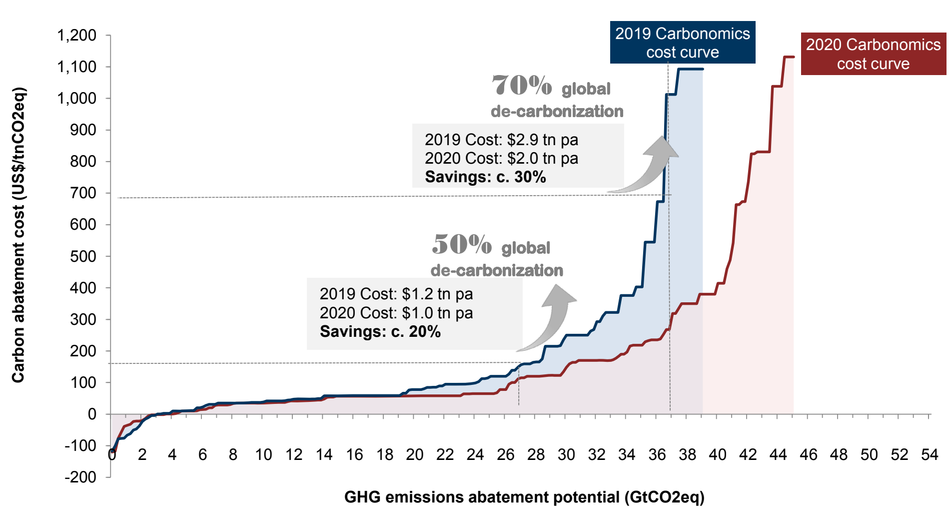
Climate change is reshaping the global investment framework through technological innovation and capital markets pressure. We launched our Carbonomics reports series last year, focusing on analyzing the key technologies, trends and themes that remain top of mind for investors in the age of climate change and de-carbonization. In our inaugural Carbonomics report, *Carbonomics: The Future of Energy in the Age of Climate Change*, we introduced our global **cost curve of de-carbonization.**

Technological and financial innovation are making de-carbonization more affordable: The evolution of the Carbonomics cost curve results, on our estimates, in a c.US$1 tn pa reduction in the global cost to reach 70% de-carbonization

The Carbonomics cost curve shows the reduction potential for anthropogenic GHG emissions relative to the latest reported global anthropogenic GHG emissions. It comprises **>100 applications of de-carbonization technologies** that are currently available at commercial scale (commercial operation & development), presenting the findings at the current costs associated with each technology's adoption. We include conservation technologies across all key emission-contributing industries globally: power generation, industry and industrial waste, transport, buildings and agriculture. In our latest report, *Carbonomics: Innovation, Deflation and Affordable De-carbonization*, we updated this cost curve across all key emitting sectors globally. **The evolution of the Carbonomics cost curve results, on our estimates, in a c.US$1 tn pa reduction in the global cost to reach 70% de-carbonization.**

Exhibit 13: The evolution of the Carbonomics cost curve results, on our estimates, in a c.US$1 tn pa reduction in the global cost to reach 70% de-carbonization

Conservation carbon abatement cost curve for anthropogenic GHG emissions and associated costs for different levels of de-carbonization



Source: Goldman Sachs Global Investment Research

As shown in Exhibit 13, **the wealth of relatively low-cost de-carbonization opportunities has increased even further with the transformation of the cost curve,** resulting in an overall higher proportion of abatable emissions under current technologies and a flattening of the cost curve**.** This is in line with our view, as we highlight in our report *Carbonomics: The green engine of economic recovery*, that **the recovery that is likely to follow the COVID-19 crisis** will see an **acceleration of low-cost opportunities for de-carbonization**. In fact, such areas of investment could act as a further catalyst for increased investment and employment, a key focus for governments in the coming months.

The transformation of the cost curve brings with it a **meaningful reduction in the global annual cost required to achieve de-carbonization** from existing, large-scale commercially available technologies. As shown in Exhibit 13, the initial c.50% of global anthropogenic GHG emissions, what we classify as **'low-cost de-carbonization'**, can be abated at an **annual cost that has decreased by c.20%**, from c.US$1.2 tn pa based on the initial 2019 cost curve of de-carbonization, to c.US$1.0 tn pa based on the latest updated 2020 cost curve. More importantly, as we move towards 70% de-carbonization, we enter into the **'high-cost de-carbonization'** spectrum, with the two curves – and subsequently the annual cost required to achieve de-carbonization – diverging significantly; we estimate **c.30% global annual cost reduction in the upper part of the cost curve,** from US$2.9 tn in our 2019 cost curve to US$2.0 tn in our updated 2020 cost curve. Overall, this implies **c.US$1 tn of annual savings as we approach net zero by 2050.** Moreover, for the same total global annual investment, the evolved cost curve results in c.85% de-carbonization vs c.75% de-carbonization achieved based on the 2019 de-carbonization cost curve, with this year's cost curve evolution effectively contributing an additional c.10% of de-carbonization potential.

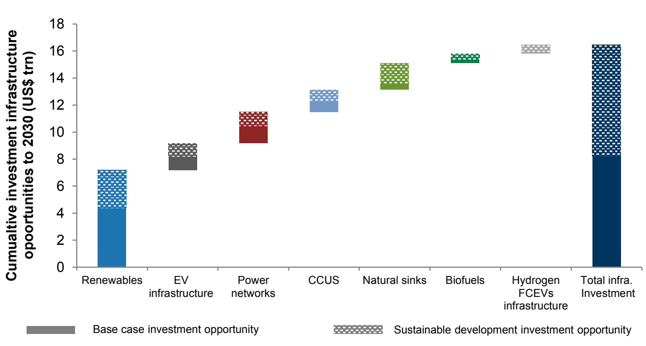
Moreover, we note that while in our original de-carbonization cost curve, an estimated c.25% of anthropogenic GHG emissions remained non-abatable (through carbon conservation) under the commercial technologies then available at large scale, this **proportion has decreased to c.15% on the updated de-carbonization cost curve**, as more technologies reach commercial scale and find their way into our cost curve analysis. A notable example of this is clean hydrogen, which, as we outlined in our deep-dive report *Carbonomics: The rise of clean hydrogen*, could unlock de-carbonization in some of the harder-to-abate sectors, including: long-haul heavy transport, seasonal storage that enables the full uptake of renewables in power generation, high-temperature heat for industrial combustion, other industrial applications (such as iron & steel and petrochemicals), and heating systems for buildings.

The green engine of economic recovery: A c.US$8-16 tn investment opportunity in clean energy infrastructure and the potential for 15-20 mn net job creation globally by 2030

Historically, times of macroeconomic downturns have been associated with a deceleration of global de-carbonization efforts, as affordability has taken precedence over sustainability. We believe this time will be different, especially for technologies that are now mature enough to be deployed at scale and can benefit from a falling cost of capital and an attractive regulatory framework, unlocking one of the largest infrastructure investment opportunities in history, on our estimates. Exhibit 14 below shows a wide range of investments associated with what we believe are the key technologies required to de-carbonize the energy value chain. These include an increasing uptake of renewables and biofuels, an increasing focus on infrastructure investments that will enable a new era of electrification, and a greater focus on natural sinks, clean hydrogen and carbon sequestration (carbon-dioxide capture, utilization and storage, CCUS). In aggregate, we see a **total investment opportunity of up to US$16 tn by 2030 in a scenario that would be consistent with the global ambition to contain global warming within 2°C**.

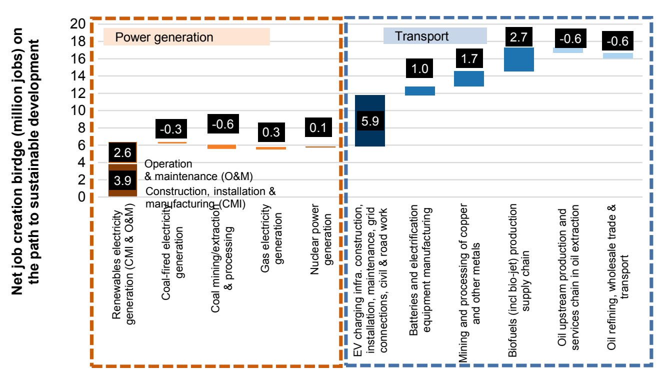
We estimate that an acceleration of the energy transition towards the goals laid out in the Paris Agreement could also **lead to net creation in the coming decade (to 2030) of 15-20 mn jobs globally,** when compared with current levels**.** We focus primarily on the low-carbon transition within the energy ecosystem, and we separate our analysis into two parts: (1) the shift of power generation to cleaner alternatives in a pathway consistent with containing global warming below 2°C (in line with the IEA's Sustainable Development Scenario), assessing the net job creation opportunities compared with current levels; and (2) the potential de-carbonization of transport. In both parts of the analysis, we focus primarily on the direct impact of employment across the supply chain, and do not account for indirect and induced employment effects. The Rt Hon Kwasi Kwarteng MP, UK Minister of State for Business, Energy, and Clean Growth, laid out the UK government's ambition to create 2 million green jobs by 2030, as part of its plan to build back greener and achieve net zero emissions by 2050.

Exhibit 14: We estimate there exists a c.US$8-16 tn investment opportunity for the de-carbonization of the energy industry...
Cumulative investment in clean energy transition to 2030 (US$ tn)



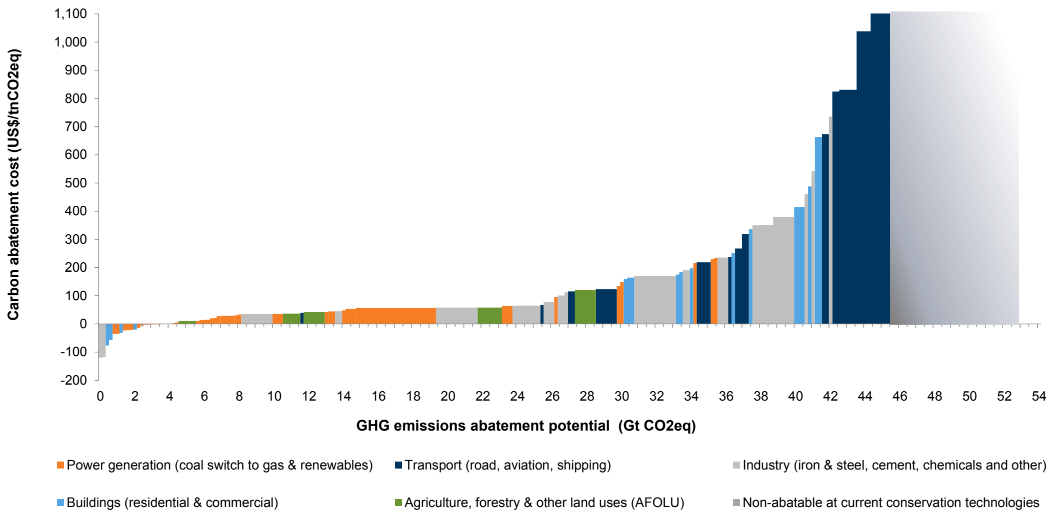
Source: IEA WEO (2019), Goldman Sachs Global Investment Research

Exhibit 15: ...having the potential to lead to net creation of 15-20 mn jobs globally by 2030E
Net job creation bridge (mn jobs) for a sustainable path across the energy supply chain



Source: IEA, IRENA, UNEP - ILO - IOE - ITUC, EuropeOn, Goldman Sachs Global Investment Research

Exhibit 16: The Carbonomics cost curve in more detail: Analyzing 100+ de-carbonization technologies across all key emitting sectors



TRANSPORTATION

De-carbonization technologies

- **Aviation:** The switch to a more efficient aircraft model is considered a viable option for partial de-carbonization in the near-term. Sustainable aviation fuels (SAFs, biojet) remain the sole commercially available de-carbonization route longer term.
- **Shipping/marine:** LNG ships a technological option for ships meeting a threshold size, marine biofuels another viable technology, with clean ammonia run ships the key de-carbonization technology longer-term.
- **Road short-haul transport:** EVs the key technology for road passenger transport, with a small proportion of de-carbonization achieved through road biofuels for places with constrained electrification infrastructure.
- **Road long-haul transport:** Electrification of short and medium haul trucks and buses a viable option. Hydrogen FCEVs the most promising de-carbonization option for long-haul heavy truck routes and forklifts.

2020 Cost curve technology additions

- Clean hydrogen FCEVs for long-haul trucks
- Switch to most efficient aircraft in aviation
- Clean ammonia-run ships

POWER GENERATION

De-carbonization technologies

- **Switch from coal to gas:** Natural gas a key transition fuel for the near term, particularly in heavily coal-reliant power generation systems globally. Biogas and clean hydrogen co-firing in power plants is another possible technology considered longer-term.
- **Switch to renewables:** The ultimate de-carbonization route for power generation, which could achieve full de-carbonization in the presence of energy storage.
- **Energy storage**: Batteries a key technology for intraday storage with clean hydrogen the ultimate solution for seasonal storage enabling the full uptake of renewables in the power generation system.

2020 Cost curve technology additions

- Clean hydrogen-based seasonal storage for full uptake of renewables
- Hydrogen and biogas based CGGTs (co-firing)

AGRICULTURE

De-carbonization technologies

- **Improved land management and livestock management practices**: Improved cropland, grazing land and livestock management practices can help to optimize resource use for the agriculture sector.
- **Precision agriculture**: the use of technology to optimize crop yields, minimize excess use of nutrients and pesticides could all potentially contribute to reduced raw material and energy needs for the sector.

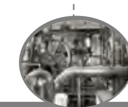
BUILDINGS

De-carbonization technologies

- **Heating**: Hydrogen and renewable electricity-run heat pumps are the two key technologies currently commercially available for de-carbonization of buildings. We consider both in our cost curve, both for new developments and retrofits, for commercial and residential buildings.
- **Efficiency**: Efficiency improvements can reduce the energy needs for heating and electricity and are thus viable options for de-carbonization. Switch to LED lighting, addition of cavity wall insulation, use of thermostats and highest efficiency HVAC systems can all contribute to efficiency improvements.

2020 Cost curve technology additions

- Clean hydrogen for heating (including switch from conventional gas boilers to hydrogen boilers)
- Heat pumps run on renewable electricity supported by hydrogen seasonal storage



INDUSTRY & WASTE

De-carbonization technologies

- **Industrial combustion/ heating:** Across major emitting industrisl sectors, c. 40% of emissions are associated with the use of energy, primarily through industrial combustion (heat) processes. Switch from coal, natural gas to biomass, biogas or hydrogen are the key technologies in de-carbonizing energy-related emissions in industry.
- **Cement**: Process emissions (c60%) associated with the materials involved such as clinker. Reducing the ratio of clinker to cement a key technology, along with CCUS.
- **Iron & Steel**: The switch from BF-BOF process to natural gas or hydrogen based DIR-EAF a possible near term de-carbonization option.
- **Petrochemicals:** Clean hydrogen (either blue or green) could aid the de-carbonization of process/raw material-related emissions.
- **Efficiency**: Across all industrial processes, improvements in efficiency & recycling have the potential to aid de-carbonization.

2020 Cost curve technology additions

- Hydrogen for full de-carbonization of iron & steel
- Clean hydrogen as a raw material for ammonia and petrochemicals production (ie. methanol)
- Hydrogen for high temperature heat/combustion

Source: Goldman Sachs Global Investment Research

Theme #1: Sustainable Investing & Financing: Unprecedented momentum

Sustainable investing is gaining momentum, potentially reaching ~US$50 tn AUM this year

Global AUM adopting ESG investing strategies continue to surge... As our GS SUSTAIN team outline in their *PM's Guide to the ESG Revolution 2*, ESG-linked investments continue to grow in both size and influence. **There are now 3,000+ signatories to the PRI** (Principles of Responsible Investment), **representing over US$103 tn in global AUM** (+20% yoy AUM growth) (Exhibit 17). Signatories are required to incorporate ESG considerations into at least 50% of their AUM by the end of 2020, suggesting that **at least US$50 tn should become 'ESG aware' this year**. While signatory AUM reflects growth across global markets, the team also see this corresponding with trends in **ESG fund flows which have consistently remained positive, adding US$135 bn in AUM ytd versus -US$422 bn in outflows for non-ESG funds** (Exhibit 18) – see *ESG Nifty Fifty Series: How have ESG fund favorites changed in 2020*.

...leading to calls for improved data and more investor-relevant ESG reporting. Despite the doubling of available ESG data points from companies over the last three years, disclosures remain dominated by vague and difficult-to-compare policy pronouncement (70% of total disclosures), while 54% of available numeric metrics still have disclosures below 20%. The lacking data quality creates challenges for assessing corporate ESG performance, and has influenced the increasing focus on ESG reporting frameworks such as SASB (Sustainability Accounting Standards Board) and TCFD (Task Force on Climate-related Financial Disclosures). Our SUSTAIN team's analysis of public filing for Global S&P 1,200 companies found the number of companies mentioning and discussing SASB has risen from 73 in 2016 to 268 as of June 2020 (+38% CAGR), while TCFD's adoption has accelerated from 12 company mentions in 2016 to over 515 as of June 2020 (Exhibit 19).

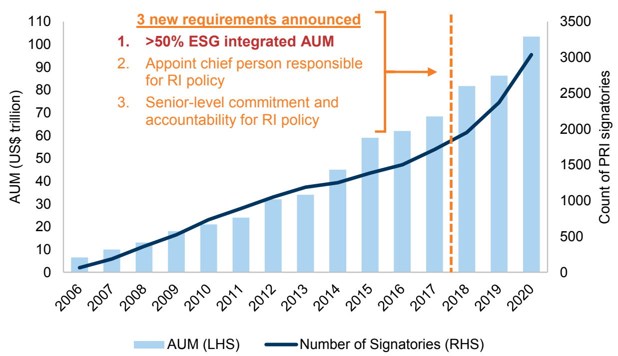
GS SUSTAIN Headline E&S Scores have generated 320 bp of outperformance between top (Q1) and bottom (Q5) performers since 2012

Is ESG is becoming its own factor? Almost 50% of the 136% total stock return for the top E&S quintile was driven by stock specific behavior, and cannot be explained by other common multi-factor inputs vs. 15% of the 84% total return of bottom quintile companies (2012-2020).

Our GS SUSTAIN team's E&S Scoring framework, focused on the material, measurable, and available metrics by sector, affirms alpha linkages at both the single metric and headline level. **Stocks with weak E&S scores have delivered significant underperformance and higher risk, while those with good E&S scores have started to outperform in more recent years.** Since 2012, the cumulative total return performance in USD for the bottom quintile (Q5 – i.e. stocks ranked least favorably from an E&S headline perspective) underperformed the top quintile (Q1) by 3.2% per annum (7.5% vs. 10.7% annualized return) and exhibited higher volatility than all other quintiles (Exhibit 20).

- **Carbon-related metrics that worked well:** Low relative levels of Total CO_2 Emissions (Scopes 1 & 2) performed well for Basic Resources and Manufacturing industries, linked to an average of 149 bp and 166 bp of excess returns annually, respectively, for top vs bottom quintile. Low relative Scope 1 Emissions worked well for Electric and Multi Utilities (128 bp and 715 bp of annual excess returns, respectively). In Oil & Gas, both Carbon Embedded Reserves (820 bp) and Gas Flaring (377 bp) metrics worked well.

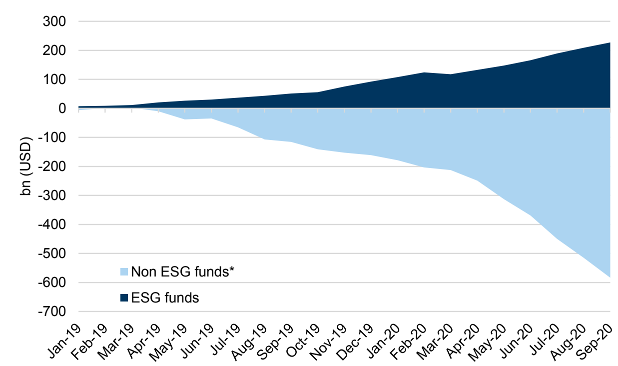
Exhibit 17: PRI signatory count and AUM growth is accelerating off an already large base...
PRI Signatory Growth and AUM, 2006 - 2020 YTD*



*as at June 2020

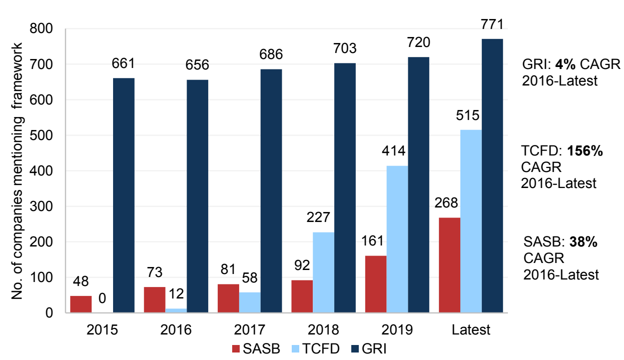
Source: PRI, Goldman Sachs Global Investment Research

Exhibit 18: ...helping fuel the consistently positive flow of AUM into ESG funds...
Cumulative monthly fund flows for ESG and non-ESG equity funds (1/2019-9/2020)



Source: Morningstar

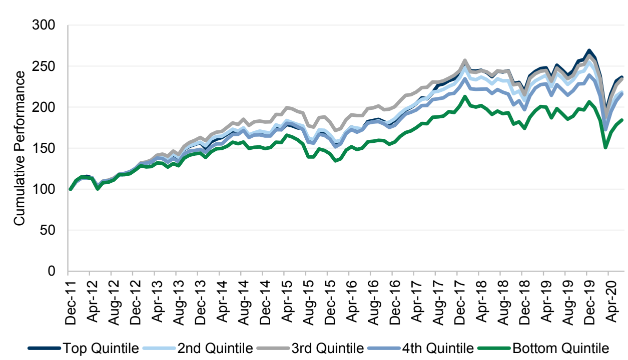
Exhibit 19: ...and is also putting pressure on companies to report ESG data in a more investor-relevant manner
Number of S&P Global 1,200 companies mentioning SASB, TCFD, and GRI in public filings from 2015 to latest*



*as at June 2020

Source: Bloomberg, Company data, Goldman Sachs Global Investment Research

Exhibit 20: Bottom-quintile headline E&S companies have significantly underperformed, with the top quintile outperforming in recent years
Cumulative performance of quintiles based on SUSTAIN E&S headline percentiles (January 2012 to June 2020)

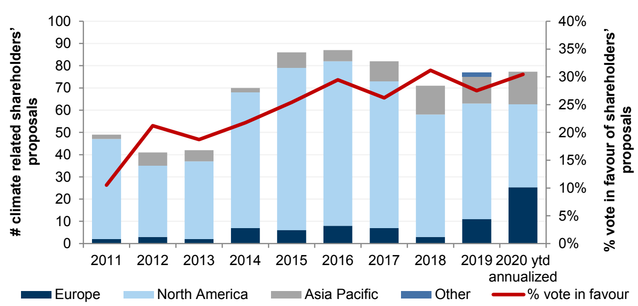


Source: Bloomberg, Refinitiv, FactSet, MSCI, Goldman Sachs Global Investment Research

Investors have emerged with a leading role in driving the climate change debate, through rising engagement and shareholder proposals

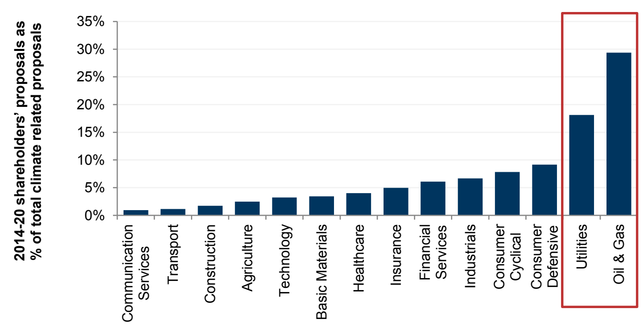
With global GHG emissions on a persistent upward trajectory over the past few years, investors have emerged with a leading role in driving the climate change debate, pushing corporate managements towards incorporating climate change into their business plans and strategies. The number of climate-related shareholder proposals (as shown by data from ProxyInsight) has almost doubled since 2011 and the percentage of investors voting in favour has tripled over the same period. So far, 2020 has been, despite the outbreak of COVID-19, another year of strong shareholder engagement on climate change, with the year-to-date climate-related shareholder resolutions exceeding last year's on an annualized basis (the most notable increase coming from Europe). Similarly, the percentage vote in favour has increased yoy, currently at c.30%. This investor pressure, however, is not uniformly distributed across sectors and shows a clear bias towards energy producers vs. energy consumers, with data since 2014 showing 50% of proposals targeting energy producers (oil & gas, utilities) while only 30% target the sectors that account for most of the final energy consumption.

Exhibit 21: The number of climate-related shareholder resolutions and % vote in favour continues to gain momentum so far in 2020...
Number of climate-related shareholders' proposals vs. % vote in favour



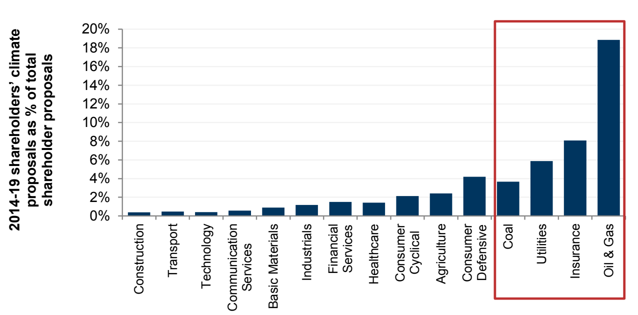
Source: ProxyInsight, Goldman Sachs Global Investment Research

Exhibit 22: ...with a targeted focus on energy producers (oil & gas, utilities)...
% of climate-related shareholder proposals, split by industry, 2014-20



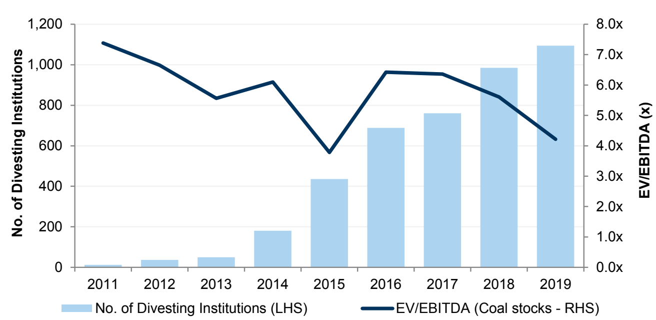
Source: ProxyInsight, Goldman Sachs Global Investment Research

Exhibit 23: ...which also have the largest proportion of climate-related proposals relative to total shareholder proposals
% of shareholder proposals that are climate-related, 2014-19



Source: ProxyInsight, Goldman Sachs Global Investment Research

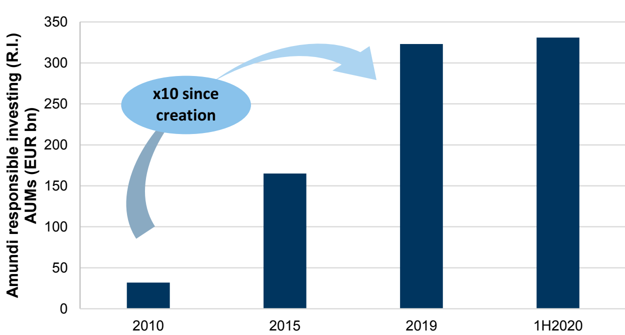
Exhibit 24: Investor divestments are already evident in the coal industry
Number of divesting institutions (LHS) vs. coal stocks EV/EBITDA (RHS)



Source: Thomson Reuters Datastream, DivestInvest, Goldman Sachs Global Investment Research

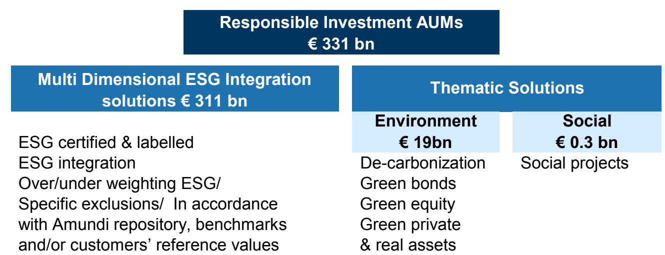
This increase in shareholder engagement and the unprecedented momentum in sustainable investing are evident across many examples, one of which is **Amundi**, a leading European asset management company whose Head of Institutional and Corporate Clients & Member of Executive Board, Jean-Jacques Barberis, attended our Carbonomics conference. In autumn 2018, Amundi announced a three-year plan, committing to incorporating ESG criteria into 100% of the assets managed by its actively managed open-ended funds, which will have to maintain an ESG score higher than that of their benchmark index (or investment universe). According to the company, in 1H2020, ESG inflows reached a high of €331 bn, growing >10x since 2010. Moreover, the company has actively been involved in the rise of coal asset divestment, as we show in Exhibit 24, excluding all companies with revenue from coal extraction and power generation from coal equal to or greater than 50% of their total revenue, as well as all power generation and coal extraction companies with a threshold between 25% and 50% that do not intend to reduce the percentage of their revenue derived from those activities.

Exhibit 25: Amundi's responsible investing (RI) assets under management (AUMs) have grown 10-fold since 2010...
Amundi responsible investing AUMs (EUR bn)



Source: Company data

Exhibit 26: ...most of which fall under the 'multi-dimensional ESG integrated solutions' approach of Amundi
Amundi responsible investment approaches



Source: Company data

Mark Carney, the UN Special Envoy for Climate Action and Finance and the Prime Minister's Finance Adviser for COP26, referenced the importance of building a private finance system for Net Zero, as part of the priorities for COP26. He highlighted the strong progress and positive momentum in the private sector's initiatives and clean tech innovation and laid out a framework to ensure that every financial decision takes climate change into account, built on the four pillars of Reporting, Risk management, Returns and Mobilization of private finance.

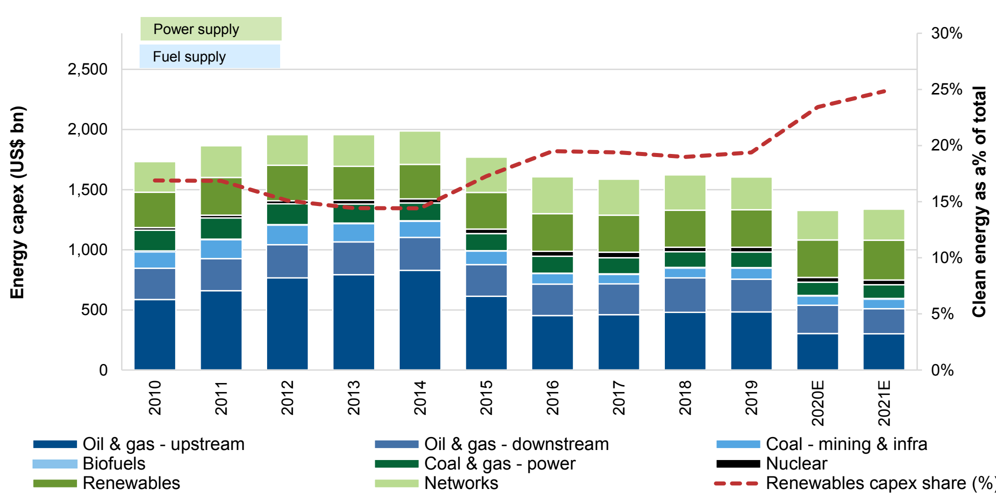
Theme #2: Renewable power: The low-carbon technology dominating 'low-cost de-carbonization'

For the first time in history, we expect capex in renewable power supply to overtake upstream oil & gas in 2021

Historically, times of macroeconomic downturns have been associated with a deceleration of global de-carbonization efforts, as affordability has taken precedence over sustainability. We believe this time will be different, especially for technologies that are now mature enough to be deployed at scale and can benefit from a falling cost of capital and an attractive regulatory framework, unlocking one of the largest infrastructure investment opportunities in history, on our estimates. As can be seen from our Carbonomics cost curve of de-carbonization, the low-cost end of the curve is primarily associated with power generation and building efficiency, which together have the triple advantage of generating local jobs, benefiting from low cost of capital and successful public-private partnerships, and adding limited costs to national budgets. While the growth in investment in clean energies moderated during previous economic downturns, the much more abrupt fall in investments in other parts of the energy system (particularly upstream oil & gas) should result in the **overall share of clean energies** (renewables including bioenergy) **in total energy supply capex increasing from 15% in 2014 to c.25% by 2021,** on our estimates, making **capex in renewable power supply larger than capex in upstream oil & gas for the first time in history by 2021E.**

Exhibit 27: Renewable energy will reach c.25% of global energy supply investments by 2021, on our estimates, surpassing upstream oil & gas for the first time in history

Energy supply capex split by fuel and power supply sources (US$bn - LHS), and clean energy (renewables, biofuels) as a % of total (% - RHS)

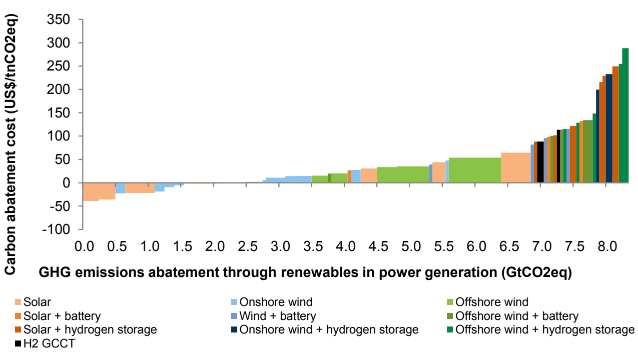


Source: IEA WEI (historicals), Goldman Sachs Global Investment Research

The power of renewable power: c.35% of the de-carbonization of global anthropogenic GHG emissions is reliant on access to clean power generation, on our estimates

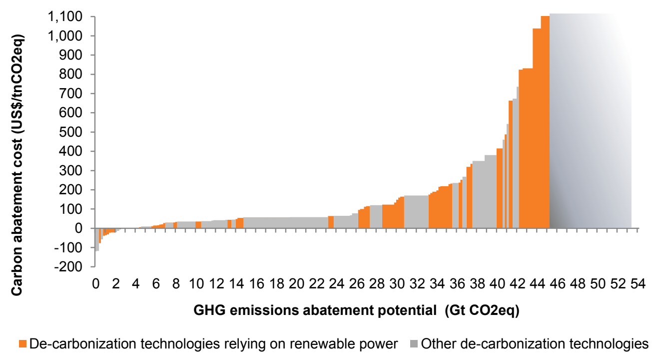
Renewable power has transformed the landscape of the energy industry and represents one of the most economically attractive opportunities in our de-carbonization cost curve on the back **of lower technology costs** as the industry benefits from economies of scale and **lower cost of capital.** We estimate that c.**35% of the de-carbonization of global anthropogenic GHG emissions is reliant on access to clean power generation** (as shown in Exhibit 29), including electrification of transport and various industrial processes, electricity used for heating and more.

Exhibit 28: De-carbonization through renewable power generation is among the lowest-cost technologies on our de-carbonization cost curve, even when energy storage (batteries and hydrogen) is needed...
Power generation switch from natural gas to renewables (and storage) de-carbonization cost curve



Source: Goldman Sachs Global Investment Research

Exhibit 29: ...while access to low-carbon power more broadly is vital for the de-carbonization of c.35% of the current global anthropogenic GHG emissions across sectors (such as electrification of transport, industry, buildings)
2020 conservation carbon abatement cost curve for anthropogenic GHG emissions, with orange indicating renewable power-reliant technologies

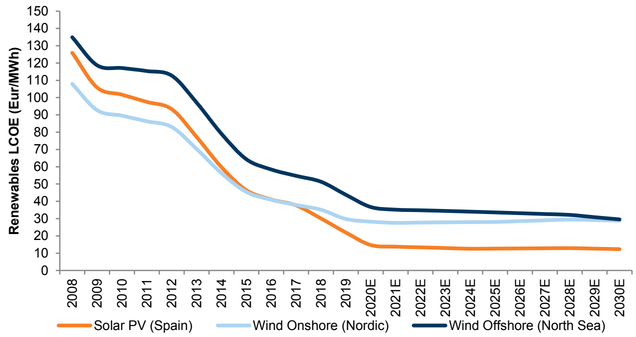


Source: Goldman Sachs Global Investment Research

The bifurcation in the cost of capital for high-carbon vs. low-carbon energy has contributed c.1/3 of the reduction in overall costs for renewable power...

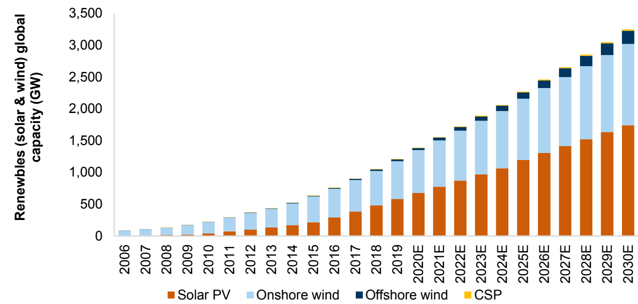
We note that along with the operational cost reduction that renewable energy has enjoyed over the past decade owing to economies of scale, the ongoing downward trajectory of the cost of capital for these low-carbon energy developments has also made a meaningful contribution to the overall affordability and competitiveness of clean energy. We show in Exhibit 32 how the **reduction in the cost of capital has contributed c.1/3 of the reduction in LCOEs of renewable technologies since 2010**. In contrast, financial conditions keep tightening for long-term hydrocarbon developments, creating higher barriers to entry, lower activity, and ultimately lower oil & gas supply, in our view. This has created an unprecedented divergence in the cost of capital for the supply of energy, as we show in Exhibit 33, with the continuing shift in allocation away from hydrocarbon investments leading to hurdle rates of 10-20% for long-cycle oil & gas developments compared with c.3-5% for the regulated investments in Europe.

Exhibit 30: Renewable power LCOEs have decreased by > 70% on aggregate across technologies...
LCOE for solar PV, wind onshore and wind offshore for select regions in Europe (EUR/MWh)



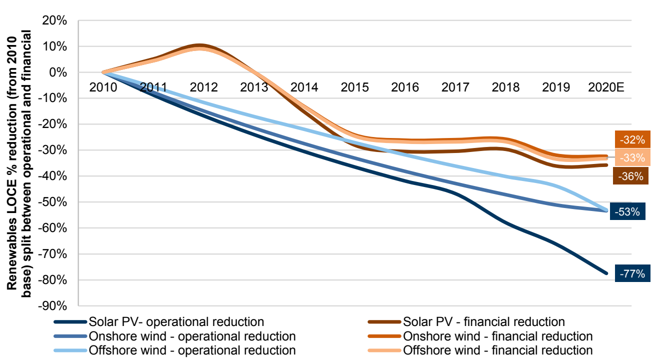
Source: Company data, Goldman Sachs Global Investment Research

Exhibit 31: ...on the back of ongoing operational cost reduction as the industry continues to grow and benefits from economies of scale...
Global renewables (solar & wind) installed capacity (GW)



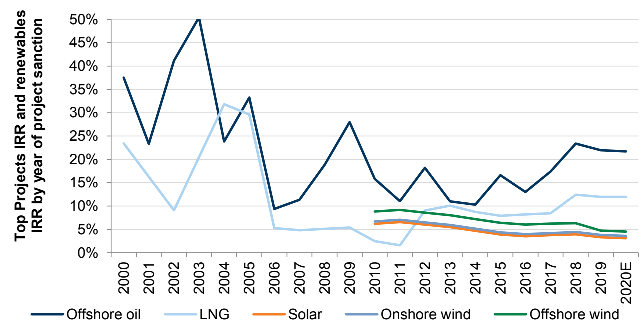
Source: IRENA, Goldman Sachs Global Investment Research

Exhibit 32: ...but also benefiting from a reduction in the cost of capital for these clean energy developments, contributing c.1/3 of the cost reduction since 2010
Renewables LCOE % reduction from 2010 base, split between operational and financial (cost of capital)



Source: Goldman Sachs Global Investment Research

Exhibit 33: The bifurcation in the cost of capital for hydrocarbon vs renewable energy developments is widening, on the back on investor pressure for de-carbonization
Top Projects IRR for oil & gas and renewable projects by year of project sanction

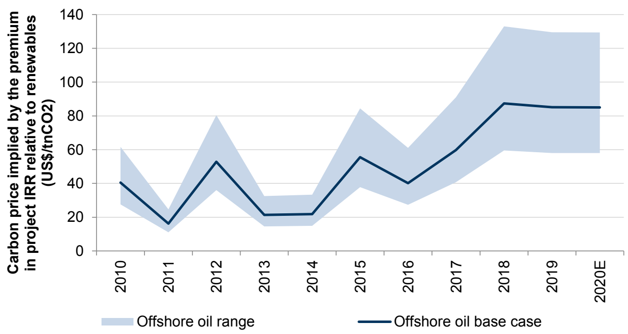


Source: Goldman Sachs Global Investment Research

...and on our estimates implies a carbon price of US$40-80/ton on hydrocarbon developments

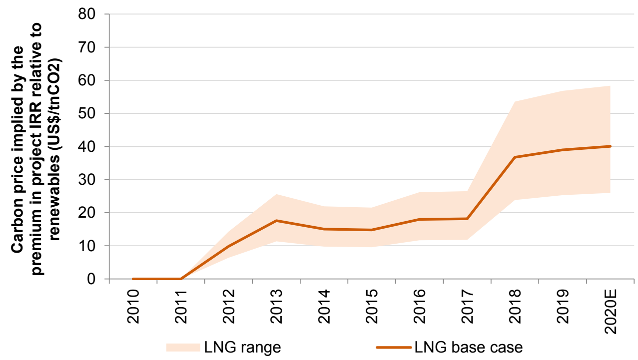
In the charts below, we present the carbon price implied by the IRR premium of long-life offshore oil (deepwater) and LNG projects compared with renewables. We calculate the implied carbon price by leveraging our Top Projects database of the most important oil & gas projects in the world. We estimate the projects' "well to wheel" carbon intensity (scope 1+2+3) and charge each project the cost of carbon in full (we assume the producer takes the full economic hit from carbon pricing, without passing on any of the cost to the consumer through higher oil and gas prices). We calculate the IRR sensitivity by oil & gas field to different CO_2 prices and work out the carbon price that would bring the IRR of the project in line with the IRR of low-carbon projects (renewables) that were developed in the same year. We estimate that the IRR sensitivity of oil and LNG projects is 14-32 bps for each US$1/ton of carbon pricing, with an average of 21 bps. We make two critical assumptions in this analysis: (1) we assume that the carbon cost associated with the use of the oil and gas produced (scope 3) is fully paid by the producers and not by the final consumer of those hydrocarbons; and (2) we consider the different risk profile of renewables vs. hydrocarbon developments given the implicit incentive for renewables provided by governments, and include its value in the implied carbon price.

Exhibit 34: The current IRR project premium for offshore oil developments compared with renewables implies a carbon price range of US$60-130/tn CO2...
Carbon price implied by the IRR premium for offshore oil projects compared with renewables (US$/tn CO2)



Source: Goldman Sachs Global Investment Research

Exhibit 35: ...and a range of US$30-60/tn CO2 for LNG projects
Carbon price implied by the IRR premium for LNG projects compared with renewables (US$/tn CO2)

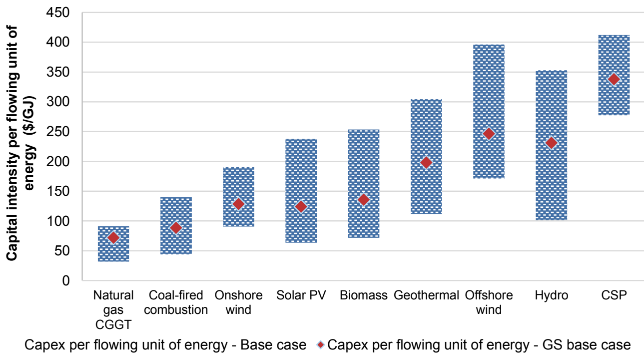


Source: Goldman Sachs Global Investment Research

Higher capital intensity and lower cost of capital can create jobs in a financially efficient way through public-private partnerships

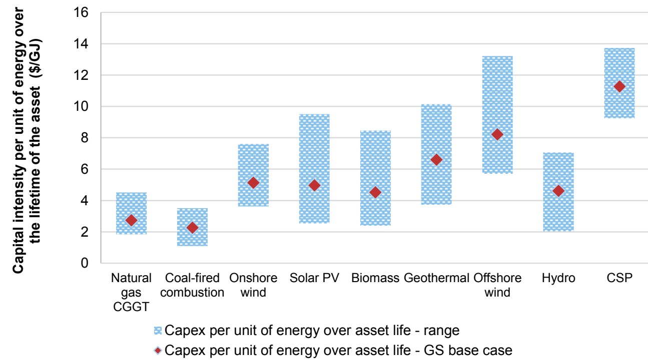
Economic policy following a recession is often driven by the desire to increase employment within the constraints of limited financial resources. We believe that green infrastructure could play a major role in this economic recovery, as it tends to be more capital- and job-intensive than traditional energy developments, but also benefits from a much lower cost of capital under the right regulatory framework, making it a strong example of a successful pro-growth pro-environment public-private partnership. In the exhibits that follow, we present the capital intensity (capex) per unit of output energy for each type of power generation and transport technologies. We present the results both in units of capex per flowing unit of energy (US$/GJ of peak energy capacity) and per unit of energy over the life of the asset (US$/GJ). This shows **higher capital intensity per unit of energy as we move to cleaner alternatives for power generation and transport**. This, however, does not necessarily translate into higher costs for the consumer, thanks to the availability of very cheap financing (under an attractive and stable long-term regulatory framework) and lower opex, compared with traditional hydrocarbon developments.

Exhibit 36: All renewable clean technologies in power generation have higher capital intensity compared with traditional fossil fuel sources based on per flowing unit of energy...
Capex per flowing unit of energy (US$/GJ)



Source: IRENA, EIA, Goldman Sachs Global Investment Research

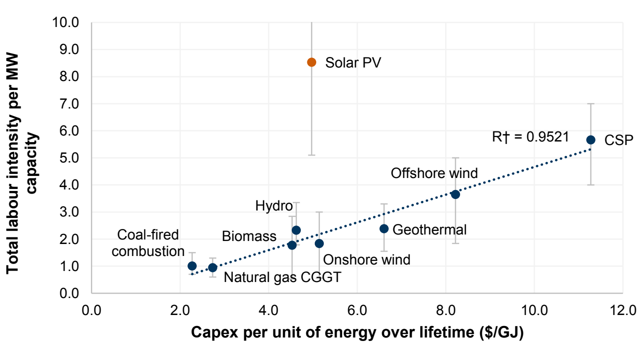
Exhibit 37: ...and over the lifetime of the asset
Capex per unit of energy over the life of the asset (US$/GJ) for each technology



Source: IRENA, EIA, Goldman Sachs Global Investment Research

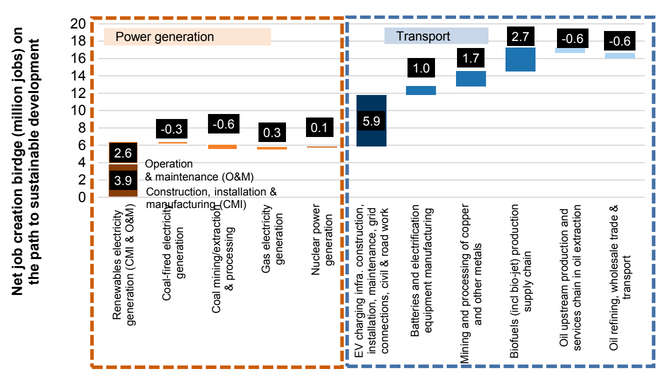
Across power generation, clean technologies have a notably higher capital intensity than hydrocarbons, based on both per unit of flowing output energy and per unit of energy over the asset/technology lifetime. With greater capital intensity comes the greater need for low cost of capital and revenue visibility. Furthermore, the low-carbon economy's **higher capital intensity is likely to foster employment creation, as indicated by the strong correlation between the capital intensity per unit of energy and its labour intensity** (jobs per unit of average capacity over asset life) presented in the exhibits below. Solar PV is, according to the International Labour Organization (ILO) and the International Renewable Energy Agency (IRENA), the most labour-intensive clean technology in power generation (including construction, manufacturing, installation, operating & maintenance), albeit there exists a wide range of labour intensity factors depending on utility scale vs. rooftop PV.

Exhibit 38: Clean energy technologies are more capital- and job-intensive and benefit the most from low cost of capital and attractive regulation...
Capex per unit of energy over asset life vs. labour intensity per MW average capacity



Source: Wet et al. - IRENA, UNEP-ILO-IOE-ITUC, Goldman Sachs Global Investment Research

Exhibit 39: ...while potentially supporting the creation of 15-20 mn jobs by 2030
Net job creation bridge (mn jobs) for a sustainable path across the energy supply chain



Source: IEA, IRENA, EuropeOn, UNEP-ILO-IOE-ITUC, Goldman Sachs Global Investment Research

The CEOs of NextEra, Iberdrola and EDP and the CFOs of RWE and Siemens Gamesa joined our conference discussing their investment opportunities in the fast growing renewables space. NextEra is the world's largest solar and wind energy developer, with c.45.5 GW of net generating capacity, and one of America's largest capital investors in infrastructure, with between US$50 bn and US$55 bn in new infrastructure investments planned through 2022. Iberdrola has a pipeline of >70GW and recently launched an ambitious €75 bn investment plan to 2025 as a firm commitment to de-carbonization and economic recovery. EDP and RWE have the potential to upgrade their net capacity additions over the medium term: our research suggests that both companies might double net annual additions over the coming five years. Finally, Siemens Gamesa, one of the leading companies in wind turbine manufacturing, is well positioned to benefit from the structural growth prospects that the offshore and onshore wind market present, as highlighted by our Utility team in their *Europe Wind Manufacturers* report.

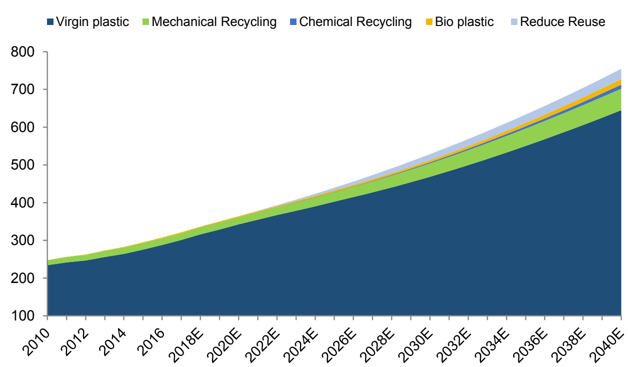
Theme #3: Circular Economy and Farm to Fork

Embracing an acceleration of the circular economy

The circular economy is a critical pillar of global de-carbonization and improved resource and energy management, redefining current industrial and consumer practices. The circular economy should be by design regenerative and restorative as materials move around a closed-loop system, a different approach to the traditional make-use-discard approach.

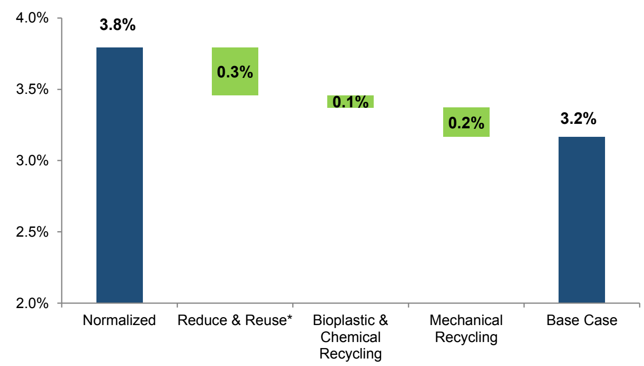
Plastics have played an integral role in the modernization of our society, offering substantial benefits vs. alternative materials, such as their lightweight and barrier properties, malleability and resource efficiency. In our Chemicals team's deep-dive report *The Plastics Paradox*, the team argue that one of plastic's greatest strengths is its greatest weakness – it is not degradable and a large volume is lost to landfill or the environment. Based on our Global Plastics Demand Model, our base case assumes a 60 bp impact on demand growth over the next decade.

Exhibit 40: Virgin plastics demand grows 3.2% over the next decade in our base case...
Demand for plastics (Mt tonnes)



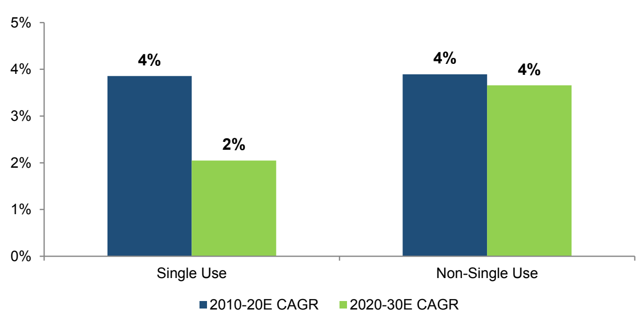
Source: IHS, Eurostat, US EPA, Euromonitor, Goldman Sachs Global Investment Research

Exhibit 41: ...and recycling and changing consumer behavior habits could lower demand growth by 60 bps in this period
Demand CAGR (%)



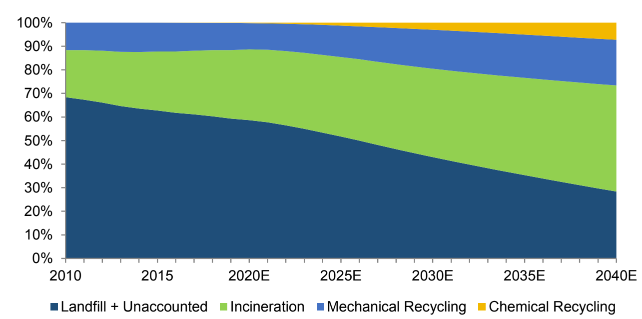
Source: IHS, Eurostat, US EPA, Euromonitor, Goldman Sachs Global Investment Research

Exhibit 42: We expect a slowdown in single-use plastic growth given targeted regulations
2010-20E and 2020-23E CAGR in single-use and non-single-use plastics



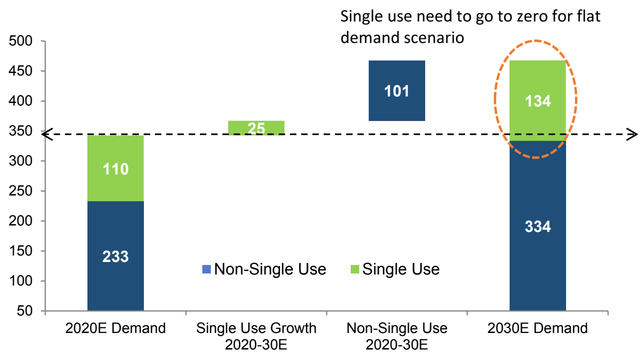
Source: IHS, Eurostat, US EPA, Euromonitor, Goldman Sachs Global Investment Research

Exhibit 43: We expect the decreasing role of landfill in plastic waste disposal to continue



Source: IHS, Eurostat, US EPA, Euromonitor, Goldman Sachs Global Investment Research

Exhibit 44: In a flat plastic demand scenario, single-use plastic demand needs to go to zero
Mtonnes plastic



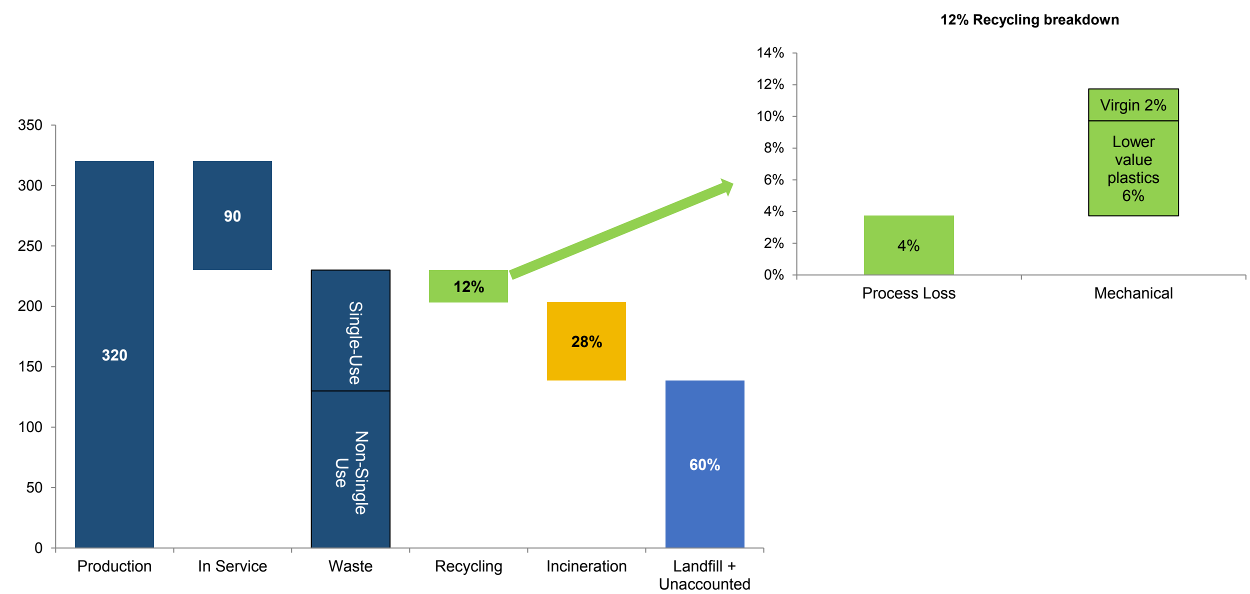
Source: IHS, Eurostat, US EPA, Euromonitor, Goldman Sachs Global Investment Research

Exhibit 45: The single-use plastic applications you need to give up to ensure flat demand

Packaging Applications	Market share in Single-Use Plastics	Unintended Consequences
Food	c.50%	Food wastage and GHG emissions increase
Beverage (PET)	c.20%	Cost and transport related emissions rise
Healthcare	NA	Compromise on hygiene
Cosmetics	NA	Transport related emissions rise due to higher weight
E-Commerce & Others	NA	Transport related emissions rise due to higher weight

Source: IHS, Eurostat, US EPA, Euromonitor, Goldman Sachs Global Investment Research

Exhibit 46: Most plastic waste is lost to landfill or is unaccounted for
Plastic life cycle, 2018



Source: IHS, Eurostat, US EPA, World Economic Forum, Goldman Sachs Global Investment Research

The challenges of plastics

Despite offering many environmental benefits while in use, plastic waste management has become a challenging issue manifesting into landfill, marine litter and open waste dumps, especially in EMs. Perception of plastic has continued to deteriorate, with many countries banning certain plastic items (carrier bags, straws, etc.).

1

Single use plastic: Single use plastics are mostly used in packaging applications. These plastics have an "in-service" life of less than one year and become waste thereafter. Single use plastics comprise ~32% of global plastic demand and ~42% of plastic waste generation every year. Almost one-third of single use plastics (~10% of total plastic demand) is a key target of government regulations and consumer perception, and face risk of phase-out over time.

2

Leakage to oceans: Plastics are featured most frequently among the top ten marine debris items. A lot of marine plastic waste is fed through river systems in Asia (10 rivers account for >90% of plastic waste in oceans, of which 8 rivers are in Asia.)

Source: https://pubs.acs.org/doi/10.1021/acs.est.7b02368.

3

Mismanaged waste: Almost 60% of the plastic waste generated in a year finds its way either to land fill or is unaccounted for especially in emerging economies.

4

Low recycling rates: Plastic recycling rates are very low (~12%) versus other single use applications (eg. aluminum). Lower recycling rate is a function of (1) low volume mass, (2) contamination of plastic waste with food and additives, (3) poor waste mgmt. infrastructure in EMs, (4) lack of adequate recycling facilities in DMs who export part of their plastic waste to Asia and (5) poor economics at lower oil prices.

Source: Goldman Sachs Global Investment Research

Solving the Plastics challenge

- **Reduce/Reuse:** Several countries are banning single-use plastics such as carrier bags, straws and cutlery. While these items are supplied in large numbers, they are low in weight and account for only ~3% of plastics demand (~9% of total single-use demand).
- **Alternatives:** Replacement of plastics with bioplastics and traditional alternatives (e.g. metal and glass) is top of mind. Bioplastics volumes are currently quite small, only ~42% are biodegradable, and they require specific environmental conditions to degrade. We consider traditional alternatives as most likely to replace PET bottles (~7% of plastic demand) due to accelerating consumer perception risk.
- **Mechanical Recycling:** Currently, 12% of plastic waste is collected for mechanical recycling and after yield loss, only 8% of plastics value is retained for reuse. Lower recycling rates are a function of low volume mass, multi-plastic packaging, use of additives, poor waste management in EMs, lack of sufficient recycling facilities in DMs, and poor returns at lower oil prices. Consumer education, packaging designing changes and government incentives are crucial for recycling rates to rise.
- **Chemical Recycling:** This method converts the plastic mixed waste stream back to monomers (chemical building blocks) or fuel (oil/refined products). The latter is called pyrolysis and is gaining traction with several new pilot projects. Technologies associated with pyrolysis have existed for a long time. The key challenge has been scale and economics. Economics are heavily dependent on (1) oil prices, (2) the ability to source sufficient waste regularly, and (3) government incentives.
- **Incineration (Waste to Energy):** This involves controlled burning and energy recovery from non-recyclable plastic waste. Government approved waste management hierarchies prefer incineration over landfill, but this raises carbon emissions. Further, it does not pay for itself, but rather has been supported by government incentives. DMs with advanced waste collection facilities have seen rising incineration rates (e.g. Japan, Europe, Singapore).

Exhibit 47: Overview of solutions for managing plastic waste

	Challenges	Notes
Reduce	Sticky consumer habits	Single use plastics like bags, straws, cutlery account for c.3% of global plastic demand
Reuse	Deterioration and limited life time	1% demand risk if 10% of bottles are re-used
Bio alternatives	Expensive, not always environment friendly	Biodegradation needs specific conditions
Traditional alternatives	Full cycle impact not carbon positive	Market share gains likely in Beverage bottles
Mechanical Recycling	Clean collection and sorting, contaminations, downcycling, volatile returns (oil linked)	Limited to PET, PE and PP plastics
Chemical Recycling	Clean collection, pilot stage	Limited to polyester
Pyrolysis (Waste to Fuel)	Scale, pilot stage, volatile returns (oil linked)	Feed is mixed plastic types ex of PET/PVC
Incineration (Waste to Energy)	Carbon emissions, capex intensive, needs government support	Incineration rates have picked up in DMs

Source: Goldman Sachs Global Investment Research

We hosted at our conference the CEOs of Unilever and Covestro, both of whom addressed the importance of the circular economy in aiding a global cost effective de-carbonization process, as well as the steps that each company is taking in helping achieve that goal. Unilever has committed to achieving net zero emissions from all its products by 2039 and also made four key commitments that will radically reshape its plastic use, all by 2025, namely: halving the amount of virgin plastic the company uses in its packaging, with an absolute reduction of >100,000 tonnes in plastic waste; helping collect and process more plastic packaging than it sells; ensuring that 100% of its plastic packaging is designed to be fully reusable, recyclable or compostable; and finally, increasing the use of post-consumer recycled plastic material in its packaging to at least 25%. Unilever's CEO outlined the company's commitments, highlighting how Unilever is continuing to help the acceleration to a circular economy.

Covestro is another company well positioned to contribute to the global circular economy transformation, as our colleagues highlight in their report *Covestro: Distinctly leveraged to volume recovery and green investment themes.* We hosted the company's CEO at our conference, discussing the importance of the theme and the steps the company is taking to accelerate this shift. Under its strategic program launched in 2019, the company aims to transition to a circular economy, with four key pillars to its program: alternative raw materials, recycling, renewable energy and partnerships. Covestro has already implemented steps to foster the use of alternative raw materials, e.g. using biomass to produce bio-based aniline, or using CO_2 as a source for carbon needed in the production of plastics. The company is also a founding member of the Alliance to End Plastic Waste, and is working on new recycling technologies (e.g. to reuse soft polyurethane foams), as well as driving efficiency gains (e.g. it has developed a new catalyst reducing CO_2 emissions from polyols production by 20%).

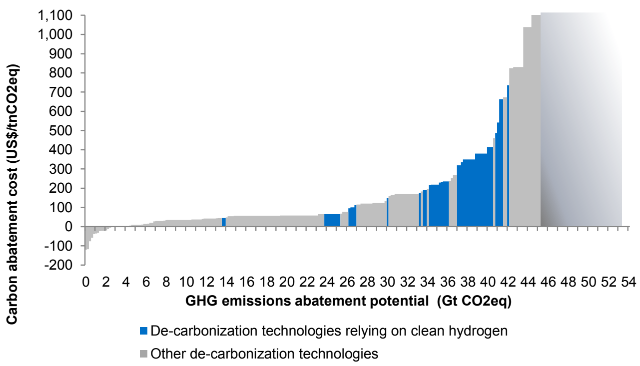
The CEO of Danone also attended our conference, discussing the company's own contribution and initiatives relating to the circular economy and food evolution. Danone's goals include, among others: for every piece of packaging the company is using to be reusable, recyclable or compostable by 2025; reaching 25% of recycled material on average in its plastic packaging, and 50% on average for its water and beverage bottles by 2025; and offering consumers bottles made from 100% bioplastic. The CEO also offered his perspective on the importance of nature-based solutions and biodiversity.

Finally, senior management from Bayer addressed the key theme of 'Farm to Work' and how the world can continue to sustainably grow while reducing its emissions without compromising food security. The company has re-iterated its ambition to become climate-neutral itself by 2030 while also stating its intention to work with farmers to reduce the ecological footprint of their agricultural operations (working towards the target of reducing the emissions footprint of crops by 30% by 2030), which currently account for c.25% of global anthropogenic GHG emissions.

Theme #4: The rise of Clean Hydrogen: Emerging as a breakthrough technology for some of the harder to de-carbonize sectors

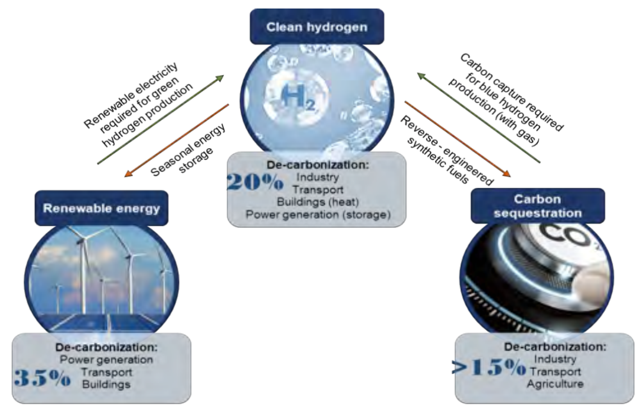
Clean hydrogen is the single **most important and transformational technology addition to our 2020 Carbonomics cost curve of de-carbonization, underpinning the vast majority of technologies added** in this year's updated cost curve (including FCEVs for long-haul transport, hydrogen energy storage enabling the full uptake of renewables in power generation, and hydrogen for buildings' heating systems and for other industrial applications such as iron & steel and petrochemicals).

Exhibit 48: We estimate that c.20% of total GHG anthropogenic emissions could be abated through de-carbonization technologies that rely on clean hydrogen...



Source: Goldman Sachs Global Investment Research

Exhibit 49: ...with hydrogen forming a key connecting pillar between the renewable power and carbon capture



Source: Goldman Sachs Global Investment Research

The revival of hydrogen: A new wave of support and policy action

As highlighted in our primer report *Carbonomics: The rise of clean hydrogen*, hydrogen as a fuel screens attractively among other conventionally used fuels for its low weight (hydrogen is the lightest element) and high energy content per unit mass, >2.5x the energy content per unit mass of both natural gas and gasoline.

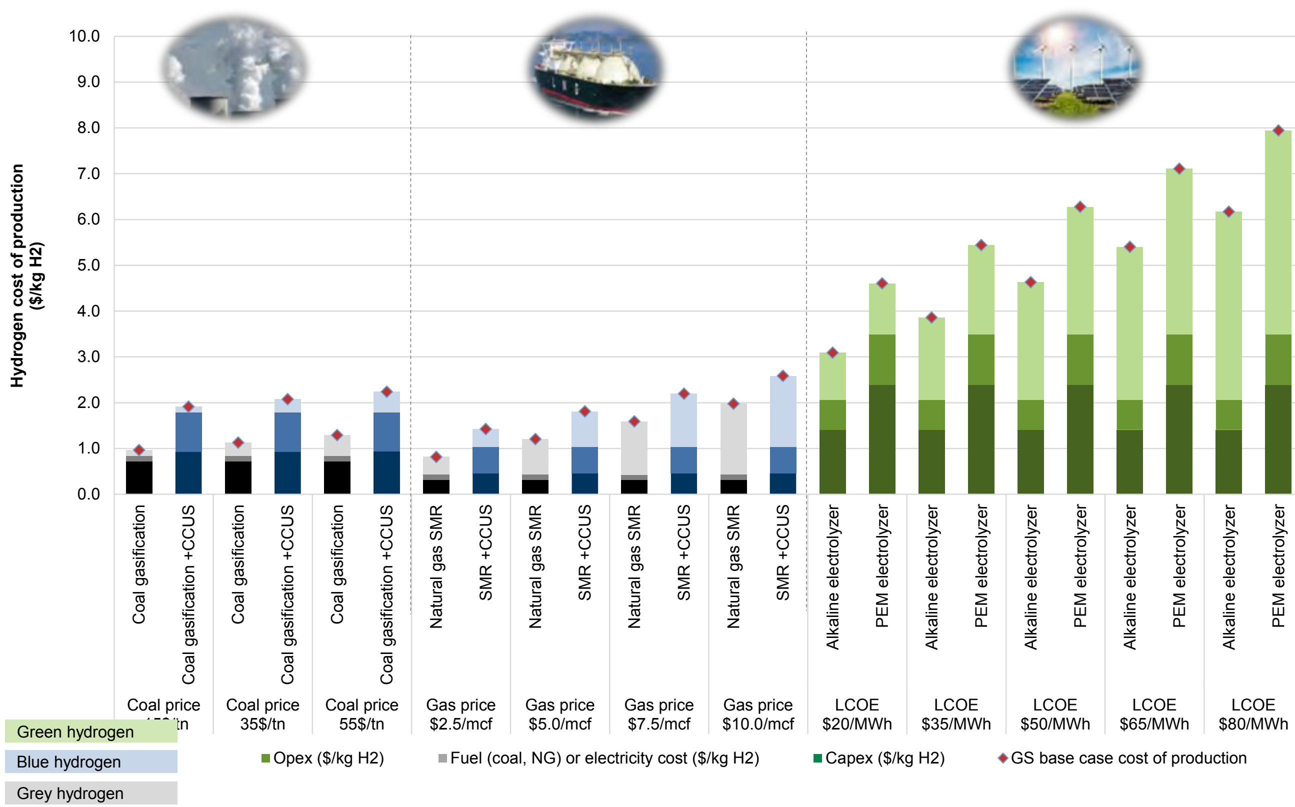
While hydrogen has gone through several waves of interest in the past 50 years, none has translated into sustainably rising investment and broader adoption in energy systems. Nonetheless, the recent focus on de-carbonization and the scaling up and accelerated growth of low-carbon technologies such as renewables have sparked a new wave of interest in the properties and the supply chain scale-up of hydrogen. Over the past few years, the intensified focus on de-carbonization and climate change solutions has led to renewed policy action aimed at the wider adoption of clean hydrogen. Policy support and economic considerations, and the acceleration of low-cost renewables and electrification infrastructure, seem to be converging to **create unprecedented momentum in the use of hydrogen and paving the way for potentially more rapid deployment and investment** in hydrogen technologies and the required infrastructure.

Clean hydrogen could be the key missing piece of the puzzle to reach net zero, connecting two critical components of the de-carbonization technological ecosystem: carbon sequestration and clean power generation

The low-carbon intensity pathways for hydrogen production and what makes the fuel **uniquely positioned to benefit from two key technologies in the clean tech ecosystem – carbon capture and renewable power generation –** are '**blue**' and '**green**' hydrogen. 'Blue' hydrogen refers to the conventional natural gas-based hydrogen production process (SMR or ATR) coupled with carbon capture, while 'green' hydrogen refers to the production of hydrogen from water electrolysis whereby electricity is sourced from zero carbon (renewable) energies.

While 'blue' and 'green' hydrogen are the lowest-carbon-intensity hydrogen production pathways, our hydrogen cost of production analysis, shown in Exhibit 50, suggests that both of these technologies are more costly when compared with the traditional hydrocarbon-based 'grey' hydrogen production. For 'blue' hydrogen, the cost of production is dependent on a number of technological and economics factors, the price of natural gas being the most critical followed by the additional cost for carbon capture technology integration with the SMR plant.

Exhibit 50: 'Blue' and 'green' hydrogen set the stage for de-carbonization, with 'blue' currently having a lower cost of production compared with 'green' hydrogen, but both being more costly than traditional 'grey' hydrogen



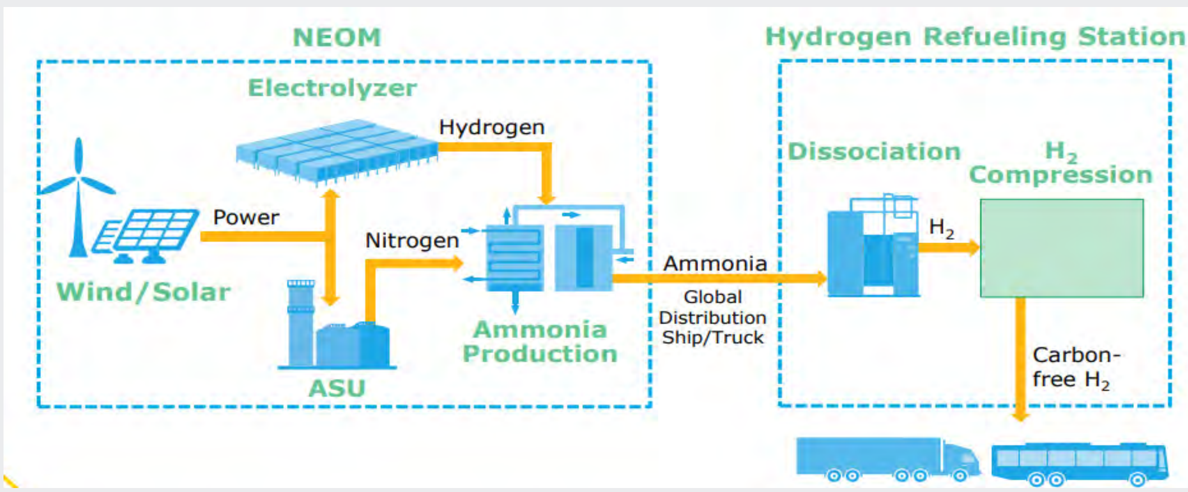
Source: Company data, Goldman Sachs Global Investment Research

Clean hydrogen projects are gaining momentum

Green hydrogen projects examples

Air Products, NEOM, ACWA Power project in Saudi Arabia: Air Products is one of the global leaders in hydrogen supply, with activities and technologies that span the whole spectrum of the hydrogen supply chain, providing storage, transport, production, separation systems and being involved in fueling infrastructure development. This year, the company announced that it has signed an agreement with ACWA Power and NEOM for a **US$5 bn large-scale green hydrogen-based ammonia production facility** powered by renewable energy. The project, which will be equally owned by the three partners, will be sited in NEOM, a new model for sustainable living located in the northwest corner of the Kingdom of Saudi Arabia, and will produce green ammonia for export to global markets. This comes a year after Air Products' 2019 unveiled pilot project to generate some of Europe's first Guarantees of Origin (GO) for sustainable, renewable hydrogen produced in the Netherlands, under the CertifHy scheme.

Exhibit 51: Air Products earlier this year reached an agreement with ACWA and NEOM for the development of a US$5 bn large-scale green hydrogen-based ammonia production facility (schematic presented below)



Source: Air Products, Company data

Iberdrola's project in Spain: Earlier this year, Iberdrola announced plans for one of the largest plants producing green hydrogen for industrial use in Europe. The Puertollano (Ciudad Real) plant will consist of a 100 MW photovoltaic solar plant, a lithium-ion battery system with a storage capacity of 20 MWh and one of the largest electrolytic hydrogen production systems in the world (20 MW). All of the energy will be from renewable sources.

H2FUTURE: A week after the publication of the European Commission Second Report on the State of the Energy Union, the FCH JU launched one of its biggest energy projects, H2FUTURE. The consortium leading this project includes companies such as voestalpine, Siemens, VERBUND and Austrian Power Grid (APG), as well as the research partners K1-MET and ECN, and the project aims to construct one of the world's largest electrolysis plants for producing green hydrogen. The project partners will work and research cooperatively on implementing an innovative hydrogen demonstration plant at the voestalpine site in Linz.

HyBalance project in the Netherlands: HyBalance is a green hydrogen project in the Netherlands with a number of global partners involved in its development, including Air Liquide, CHN, Hydrogenics (Cummins), Centrica and more. The project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking and the Danish EUDP program, which is administered by the EUDP Board. This unit's specificity is that it uses electrolysis technology, which allows it to balance the electricity grid and store surplus electricity in the form of hydrogen that will be used in industry and transportation. The electrolyzer, with a capacity of 1.2 MW, enables the production of around 500kg of hydrogen a day without releasing CO_2.

BP and Ørsted's project in Germany: BP and Ørsted have signed a Letter of Intent (LOI) to develop a project for industrial-scale production of green hydrogen. In their proposed Lingen Green Hydrogen project, the two firms intend to build an initial 50 megawatt (MW) electrolyzer and associated infrastructure at BP's Lingen Refinery in Germany. The project will be powered by renewable energy generated by Ørsted's offshore wind farm in the North Sea and the hydrogen produced will be used in the refinery. According to the companies, a final investment decision (FID) could be made in early 2022, subject to appropriate enabling policies being in place, and the companies anticipate the project could be operational by 2024.

Blue hydrogen project examples

H2H Saltend: Equinor announced earlier this year its involvement in the development of one of the UK's largest facilities to produce blue hydrogen in a project called Hydrogen to Humber Saltend (H2H Saltend) in one of the first large-scale efforts to de-carbonize the cluster in the Humber region. H2H Saltend supports the UK government's aim to establish at least one low-carbon industrial cluster by 2030 and also paves the way for the vision set out by the Zero Carbon Humber alliance, which Equinor and its partners launched in 2019. The project's initial phase comprises a 600 megawatt auto thermal reformer (ATR) with carbon capture.

Acorn CCS and hydrogen project: There are two elements to the Acorn project – carbon capture and storage (CCS) and hydrogen, with the former being a carbon capture and storage project that provides CO_2 mitigation infrastructure essential for meeting the Scottish and UK Government Net Zero targets. Through the latter, the Acorn Hydrogen project, North Sea natural gas would be reformed into clean hydrogen, with CO_2 emissions safely mitigated through the Acorn CCS infrastructure. Hydrogen would be used in transport applications, and in the gas grid to de-carbonize heating in our homes and industries. The Storegga Geotechnologies CEO joined our conference and referred to the partnership of the company with Pale Blue Dot Energy, the lead developer of the Acorn project.

At our Carbonomics conference, we hosted CEOs and senior management from companies active across the clean hydrogen supply chain. The CEO of Air Products laid out the company's view on the critical role of hydrogen in achieving net zero, with the company having announced one of the largest green hydrogen projects globally earlier this year (outlined in the section above). The CEO of SNAM, the first company in Europe to introduce a mix of 5% hydrogen and natural gas in its transmission network, also joined our conference. SNAM is one of the companies heavily involved in the energy transition, having committed €850 mn of investments in the Snamtec project, primarily focusing on efficiency, emissions reduction and promoting innovation in new activities, one of which is hydrogen. Senior management from Air Liquide and Linde, two of the leading industrial gas producers, laid out the importance of hydrogen and innovation in de-carbonizing some of the harder-to-abate emissions sectors, with both developing ways to produce both 'blue' and 'green' hydrogen.

The CEO of Ballard Power, one of the leading PEM fuel cell manufacturers globally attended our conference discussing the vast end-market opportunities for clean hydrogen. One of these is mobility, with applications varying from forklifts to transit buses, heavy duty long-haul trucks, rail and shipping. The President of Cummins' New Power segment attended our conference discussing the company's integrated hydrogen capabilities, including the manufacturing of fuel cell and electrolyzer systems, having in 2019 completed the acquisition of Hydrogenics, one of the largest hydrogen production and fuel cell technologies providers.

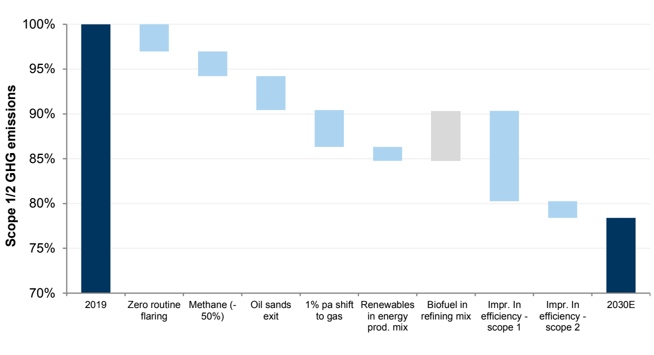
Theme #5: Re-Imagining Big Oils: The Age of Transformation

From Big Oils to Big Energy, a de-carbonization path consistent with >20% reduction in carbon intensity by 2030E

Big Oils have shown tremendous ability to adapt to technological change in their 100+ years of history. We believe it is now strategically important that they drive a low-carbon transition consistent with the global ambition to contain global warming within 2° C. During our conference, we hosted discussions with the **CEOs of BP, TOTAL, ENI, OMV** and **Lundin**, and representatives of **RDShell** analyzing how Big Oils could utilize their areas of technical expertise, competitive advantage and brands/customer relationships to evolve into Big Energy and deliver carbon reduction in their portfolio consistent with the ambitions of the Paris Agreement (such as the IEA Sustainable Development Scenario). Big Oils have many tools to achieve this transition towards Big Energy and become broader, cleaner energy providers: a deeper presence in the global gas and power chains, including retail, EV charging and renewables; biofuels; petrochemicals; improved upstream and industrial operations; clean hydrogen; and carbon sequestration.

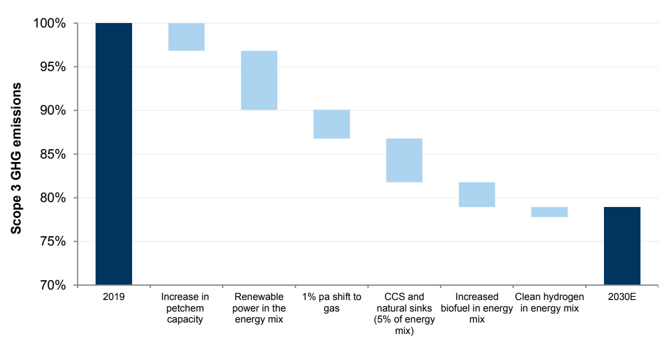
To better examine the 'well-to-wheel' carbon reduction opportunity, we analyze separately in our deep-dive report *Carbonomics: Re-Imagining Big Oils* what the industry could deliver in each of Scope 1, Scope 2 and Scope 3 carbon emissions. In this analysis, we look at the percentage change in Big Oils' emission intensity (MtCO2eq/Mtoe) and compare it to the IEA intensity reduction path. We do not analyze the absolute amount of emissions in order not to penalize companies that are growing their business vs. shrinking corporates. We look out to 2030 in this analysis, as we believe that technological advancements in the coming decade will materially re-shape the carbon strategy beyond 2030, making today's analysis obsolete. On our estimates, Big Oils can potentially reduce their Scope 1 & 2 emissions by c.22% by 2030, while Scope 3 emissions could be reduced by >20% in a similar timeframe through a mix change of the energy products produced and sold, as we show in Exhibit 53.

Exhibit 52: Scope 1/2 GHG emissions intensity could be reduced by c.22% by 2030 (from 2019 base), we estimate...
Scope 1/2 GHG emissions intensity 2019-30E bridge



Source: Company data, Goldman Sachs Global Investment Research

Exhibit 53: ...while Scope 3 could be cut by c.21% through a mix change of the energy products produced and sold
Scope 3 GHG emissions 2019-30E bridge



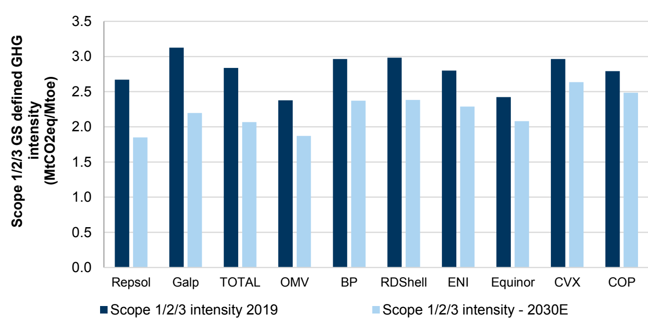
Source: Company data, Goldman Sachs Global Investment Research

Exhibit 54 shows companies' Scope 1+2+3 carbon intensity (calculated by dividing their total emissions by their Scope 3 energy volumes), which in our view is the best approximation available of their well-to-wheel carbon intensity, for 2019 and for 2030E based on our emission reduction expectations. Exhibit 54 shows the percentage reduction in carbon intensity that we estimate the companies could achieve by 2030, including all the low-carbon initiatives that we estimate they may implement in the coming decade. The calculation based on product sales gives many more potential strategic levers to reduce carbon intensity than the disclosures based on production or refining throughput. This is why companies such as Equinor, ENI, CVX and COP (that have adopted the upstream volumes method) end up at the top of the scale in Exhibit 55. A second observation from our analysis is that **European Big Oils could achieve a percentage reduction in intensity in line with the Paris Agreement aim to stay within 2°C of global warming and meet the percentage reduction in energy carbon intensity that underpins the IEA's Sustainable Development Scenario** (c.20% reduction in energy carbon intensity by 2030).

GS Scope 1,2,3 GHG emissions intensity (MtCO2eq/Mtoe)	**Definition:** Sum of Scopes 1,2,3 absolute emissions as reported by the companies ('use of products sold' for Scope 3 category)/ Energy volumes used by the company in deriving Scope 3 absolute emissions ** Implies volumes based on upstream production* *** Implies volumes based on refined volumes and natural gas sales* **** Implies volumes based on final sales of products*

Exhibit 54: We estimate the potential for a c.20% reduction in the overall carbon intensity of Big Oils by 2030...

Scope 1+2+3 GHG intensity by company (2019 and 2030E)

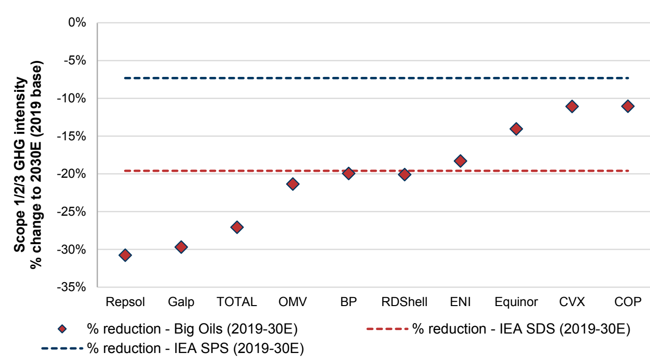


Note: ExxonMobil and Saudi Aramco have not historically disclosed Scope 3 emissions and as such are excluded from this analysis

Source: Company data, Goldman Sachs Global Investment Research

Exhibit 55: ...a reduction in line with what is expected by the IEA's Sustainable Development Scenario

Scope 1+2+3 GHG intensity by company % change to 2030E, from 2019 base

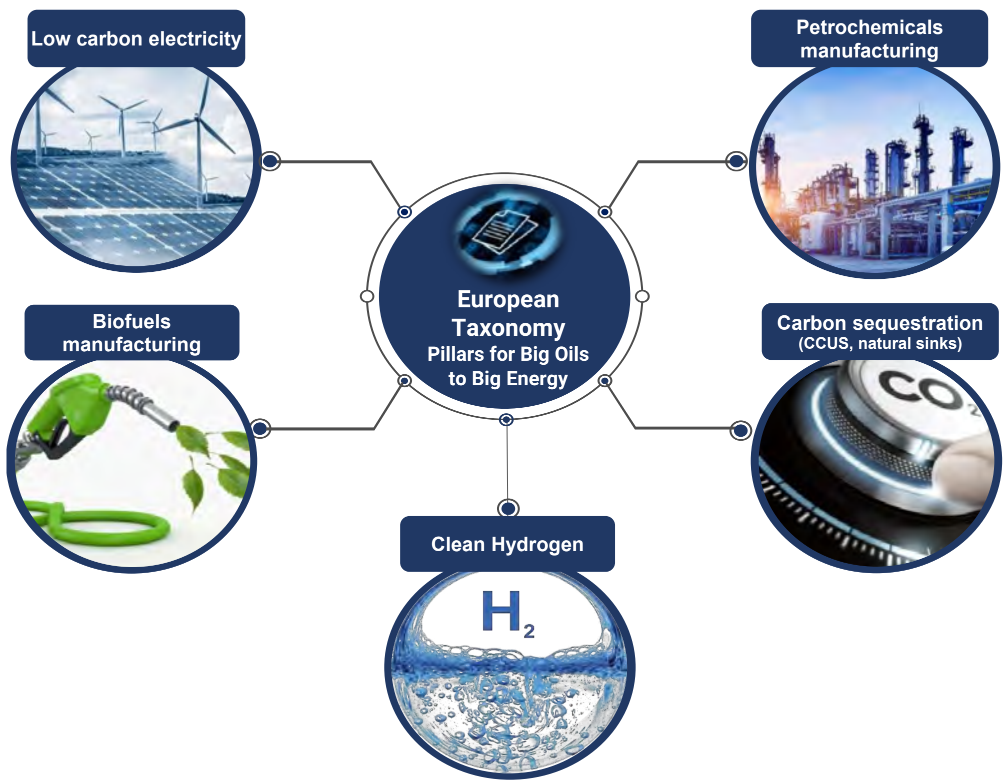


Note: ExxonMobil and Saudi Aramco have not historically disclosed Scope 3 emissions and as such are excluded from this intensity measure analysis

Source: Company data, IEA WEO 2019, Goldman Sachs Global Investment Research

Five key pillars of integration, de-carbonization and EU Taxonomy alignment as Big Oils re-imagine themselves into Big Energy

The de-carbonization process is evolving from one dimensional (renewable power) to a multi-dimensional ecosystem, requiring greater complexity, risk management and vertical integration. We believe that Big Oils are favorably positioned to benefit in such an energy ecosystem, having historically demonstrated the ability to manage complex, integrated value chains. Oils have been vertically integrated in oil, from production to retail, for over a century. We believe the coming decade will see them integrating vertically in gas (already evident) and in power, leveraging their brand/customer relationships, technical expertise and trading capabilities to acquire power customers. At the same time, their long-standing experience in the energy sector could provide them with a technological advantage in areas that remain currently underinvested and underdeveloped but which will be critical for net zero, such as carbon capture technologies and clean hydrogen (leveraging their natural gas expertise and supply chain integration).



Source: Goldman Sachs Global Investment Research

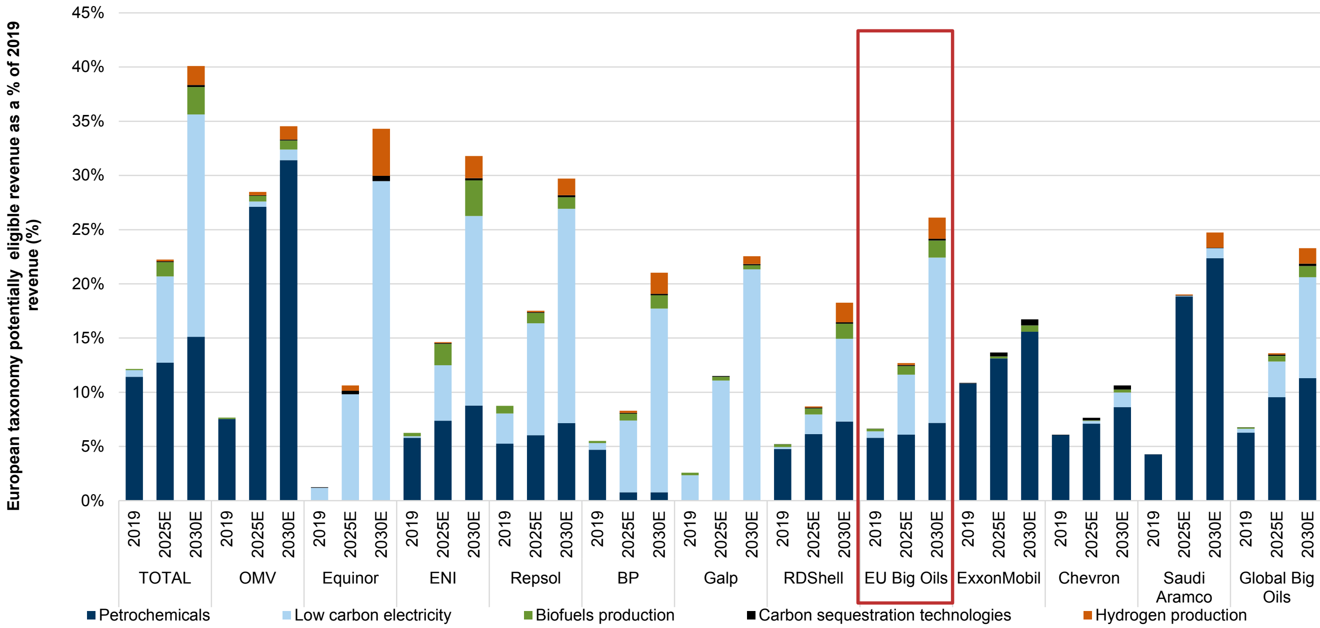
The EU Taxonomy is the first detailed attempt to classify economic activities with regard to their sustainability

The EU Taxonomy, driven by the EU Commission with advice from the Technical Expert Group (TEG), is currently the first and most detailed attempt to classify economic activities with regard to their sustainability (Taxonomy-eligible and Taxonomy-aligned or not), and serves as a tool for investors, companies, issuers and project promoters to navigate the low-carbon transition. The taxonomy aims to cover six key environmental objectives: climate change mitigation; climate change adaptation; sustainable and protected water and marine resources; transition to a circular economy; pollution prevention and control; and protection and restoration of biodiversity and ecosystems.

We estimate that the European Big Oils could increase their share of Taxonomy-eligible revenues to **c.25% of group revenue by 2030, from c.7% currently**, as they pursue their transformation towards Big Energy. Similarly, looking at capital expenditure (capex), we estimate that **c.50% of Big Oils' capex** (2019 as a base) could be allocated to activities that are Taxonomy-eligible by 2030, from c.10% today. In our view, this transformation will be driven by: (1) a large expansion of the low-carbon electricity business, consistent with the targets laid out by the companies, with increased penetration in solar PV, onshore and offshore wind, supported by growing power retail and trading activity. We estimate a c.10% global market share in renewable developments by 2030 – consistent with today's market share in oil & gas; (2) a strong presence in petrochemicals, providing a growing non-combustion market for hydrocarbons; (3) expansion of the production capacity of biofuels, particularly advanced biofuels; (4) a leading role in carbon sequestration technologies; and (5) a pioneering role in the rise of clean hydrogen. The first three categories (low-carbon electricity, petrochemicals and biofuels manufacturing) dominate the Taxonomy-compliant capex and revenue exposure in the near and medium term (to 2030), while the remaining two (carbon sequestration and hydrogen) are likely to have a wider role and adoption post 2030, contributing significantly towards the EU Green Deal and companies' net zero targets by 2050.

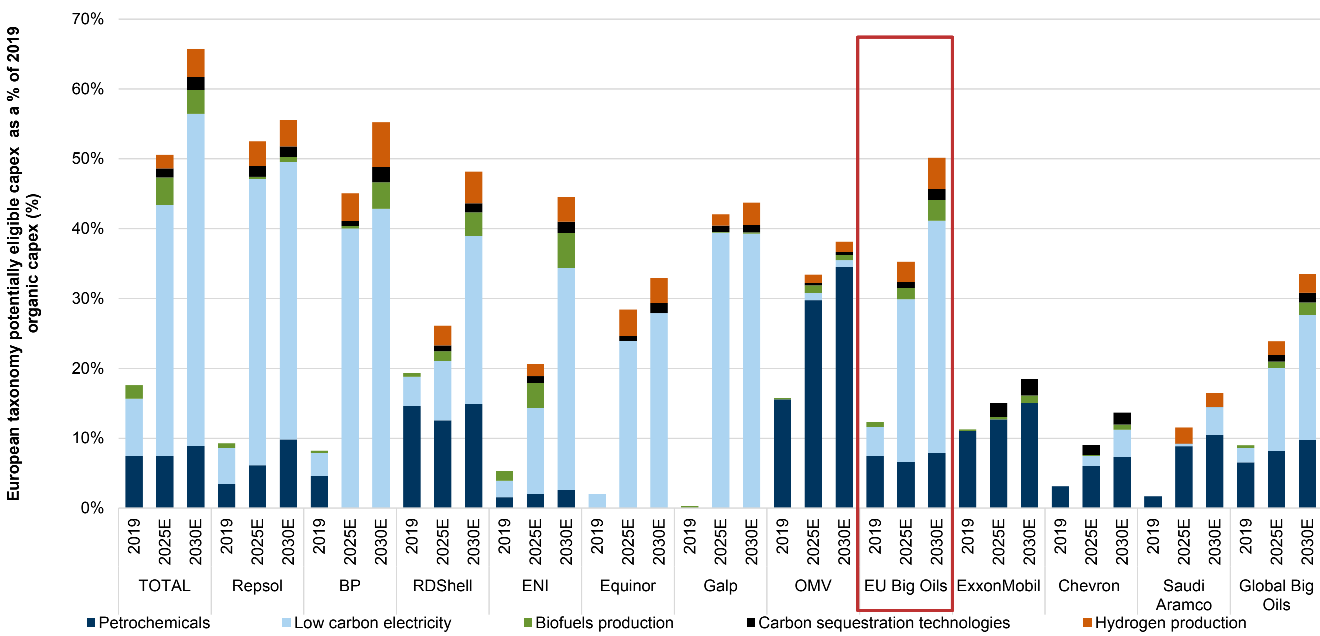
Big Oils' move towards low carbon has been implemented so far with a 'business as usual' approach, minimizing its impact on corporate metrics through unconsolidated associates and JVs. We do not believe this strategy is sustainable in the Age of Transformation, and we argue for full consolidation and disclosure of the low-carbon activities, driving a structural change to the traditional ROACE, WACC and gearing metrics for the sector. For Taxonomy eligibility and alignment, we note that these activities **need to be consolidated** (as exposure is measured through revenue and capex, not profits) and that **information around the critical threshold screening criteria needs to be readily available** for investors to be able to address the alignment (such as absolute carbon intensity for each petrochemical product category in $tnCO_2eq$ per ton of product, split of conventional vs. advanced biofuels, and carbon intensity of the electricity generation).

Exhibit 56: We estimate that close to c.25% of Big Oils' revenue (2019 base) could be Taxonomy-eligible and potentially Taxonomy aligned by 2030, from only c.7% in 2019
European taxonomy potentially eligible revenue as a % of 2019 group revenue (%)



Source: European Commission - European Taxonomy, Company data, Goldman Sachs Global Investment Research

Exhibit 57: We estimate that European and Global Big Oils could spend close to c.50% and c.35% of their capex on low-carbon activities that are Taxonomy-eligible by 2030, respectively, from only c.10% in 2019
European taxonomy potentially eligible capex as a % of 2019 organic capex



Source: European Commission - European Taxonomy, Company data, Goldman Sachs Global Investment Research

Re-Imagining Big Oils: The path to net zero carbon			
Company	**Latest targets introduced**	**Details of targets introduced in 2019-2020** (ytd)	**Net zero target**
Repsol	2019	• Repsol was the first company in the oil & gas industry to aim to become a net zero company by 2050. • To achieve this objective, Repsol has set goals for the reduction of its carbon intensity indicator from a 2016 baseline: 10% by 2025, 20% by 2030, 40% by 2040, and net zero CO2 emissions by 2050. • Key pillars outlined to contribute to the low carbon transformation of the company include but are not limited to: natural gas expansion, energy efficiency (3 Mt CO2 reduction for 2018-25), power (renewable installed capacity to reach 7.5 GW by 2025), technological developments (such as CCUS), EV charging, natural sinks.	By 2050
BP	2020	• Net zero across BP's operations on an absolute basis by 2050 or sooner. • Net zero on carbon in BP's oil and gas production on an absolute basis by 2050 or sooner. • 50% cut in the carbon intensity of products BP sells by 2050 or sooner. • Install methane measurement at all BP's major oil and gas processing sites by 2023 and reduce methane intensity of operations by 50%. • Increase the proportion of investment into non-oil and gas businesses over time.	By 2050 or sooner
RDShell	2020	• Become a net-zero emissions energy business by 2050 or sooner (covering scope 1, 2, 3 emissions). • An ambition to be net zero on all the emissions from the manufacture of all RDShell products (scope 1 + 2) by 2050 at the latest. • Accelerating its Net Carbon Footprint ambition, now aiming to reduce the Net Carbon Footprint of the energy products Shell sells to its customers by around 65% by 2050, and by around 30% by 2035. • A pivot towards serving businesses and sectors that by 2050 are also net-zero emissions.	By 2050 or sooner
TOTAL	2020	• Net Zero across Total's worldwide operations by 2050 or sooner (scope 1+2) • Net Zero across all its production and energy products used by its customers in Europe by 2050 or sooner (scope 1+2+3). • 60% or more reduction in the average net carbon intensity of energy products used worldwide by Total customers by 2050 (less than 27.5 gCO2/MJ) - with intermediate steps of 15% by 2030 and 35% by 2040 (scope 1 + 2 + 3). • 20% of capex in low carbon electricity by 2030 or sooner. • Re-affirmation of strategy in action since 2015, with Total having reduced its global scope 1,2 & 3 net carbon intensity by 6% in 2019, compared to 2015, and setting its target for its scope 1,2 & 3 net carbon intensity to be reduced to less than 27.5 GCO2/MJ by 2050.	By 2050 or sooner
ENI	2019, enhanced 2020	• Net zero emissions in the upstream by 2030 (Scope 1 & 2). • Net zero carbon footprint for ENI group businesses' scope 1 & 2 emissions by 2040. • 80% reduction in absolute net GHG lifecycle emissions (Scope 1, 2, 3) by 2050, 30% reduction by 2035. • 55% reduction in net carbon intensity (scope 1, 2, 3) by 2050 and a 15% reduction by 2035. • Zero process flaring by 2025 and reduction of methane emissions from operated assets. • The company is leveraging on a number of pillars including sequestration with forest and CCS, renewables (installed capacity expected to grow to over 55GW by 2050, 3GW by 2023 and 5GW by 2025), expansion of customer base in gas & power, increased bio-refining and recycling in refining and chemicals.	By 2030 for upstream By 2040 (scope 1,2) -80% by 2050 (Scope 1,2,3)
Equinor	2020	• Equinor announced its ambition to become net zero company by 2050 including emissions from production and final consumption of energy (scopes 1,2,3) • Equinor targets to reach <8 kg per boe CO2 upstream emissions intensity by 2025, become carbon neutral in its global operations by 2030 and reduce absolute GHG emissions from operated offshore fields and onshore plants in Norway towards net zero by 2050 without offsets. • Eliminate routine flaring before 2030 and maintain methane emissions intensity near zero. • The company aims to increase its equity generation renewables capacity to 4-6 GW by 2026 and 12-16 GW by 2035.	By 2050
OMV	2020	• Net-zero emissions in operations is the ambition by 2050 or sooner • By 2025, OMV will reduce the carbon intensity of its operations by at least 30% (from 2010 base) • In absolute numbers, at least 1 mn metric tons of CO2 emissions will be reduced in the period 2020-2025 from operated assets • Low/zero-carbon products to make up at least 60% of the portfolio by 2025	By 2050 or sooner on Scope 1
Galp	2020	• The investment in low-carbon energy and new business models is expected to account for c. 5% of total capital by 2020, and 5% to 15% from 2020 onwards. • Aims to scale new upstream projects to zero flaring under normal operating conditions. • The company is focused on expansing its renewable power generation business, with 10 GW of total installed capacity expected by 2030.	

Source: Company data, Goldman Sachs Global Investment Research

Theme #6: Re-Thinking Mobility

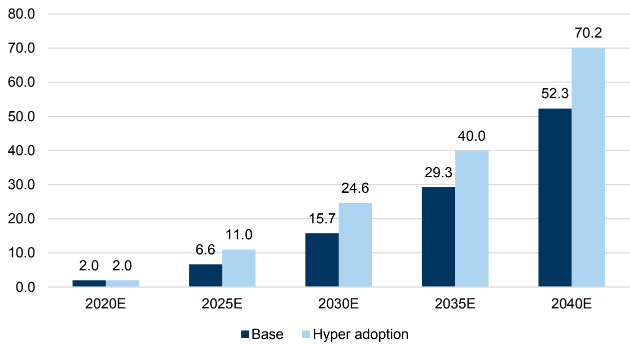
Re-Thinking Mobility: Electrification, autonomous driving and clean hydrogen pave the way for the most significant technological change in a century

Road transport is at the start of its most significant technological change in a century, with electrification, autonomous driving and clean hydrogen at the core of the de-carbonization challenge. The CEOs of Daimler and Nikola Motor joined our conference discussing the opportunities and challenges of this clean tech revolution. Daimler is one of the leading companies in re-thinking mobility, with accelerated efforts that span the whole spectrum of de-carbonization technologies for road transport. The company has launched its ambition to make its fleet of new cars CO_2 -neutral by 2039, and achieving in the near term more than 50% of car unit sales with plug-in hybrids or all-electric vehicles (by 2030). Its goals cover all stages of the automotive value chain, from technical development to the extraction of raw materials, to production, service life and recycling. Nikola Motor is another company heavily focused on the de-carbonization of road transport, with a particular focus on battery-electric and fuel-cell electric powertrain options for long-haul heavy transport.

Electrification: At the heart of the mobility technological evolution

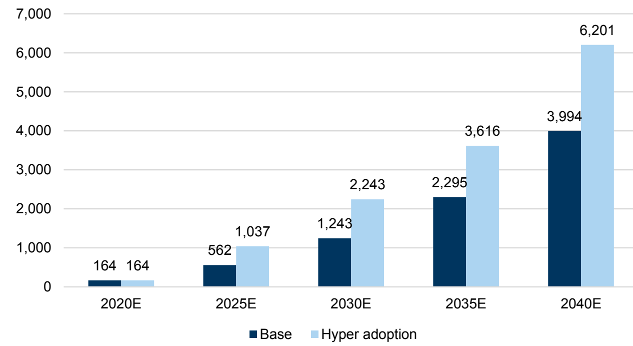
The electrification trend sits at the heart of the mobility technological evolution, and as analyzed by our colleagues in their report series on *Electric Vehicles: What's Next*, over 2020-40, our Autos team's base case is for EV sales to grow at an 18% CAGR to 52.3 mn units in 2040 (from 2 mn in 2020), with EVs accounting for 38% of global automobile sales in 2040 under this scenario. Their hyper-adoption scenario assumes CO_2 emission regulations that are 20%-30% stricter than the base scenario, and implies EV sales increasing at a CAGR of 20% to 24.6 mn units in 2030 and 70.2 mn units in 2040. As EV sales increase, we also expect automotive battery sales to grow significantly. Our Autos team's base scenario is for battery demand to increase at a CAGR of 17% from 164 GWh in 2020 to 1,243 GWh in 2030 and then to 3,994 GWh in 2040. Under their hyper-adoption scenario, they estimate that battery demand would increase considerably (CAGR of 20%) to 2,243 GWh in 2030 and 6,201 GWh in 2040.

Exhibit 58: EV sales grow at an 18% CAGR to 2040 in our GS Autos team's base case scenario...
EV demand estimates (base/hyper-adoption scenarios, mn units)



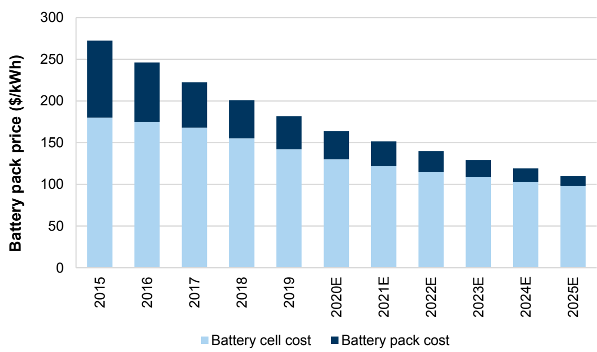
Source: Goldman Sachs Global Investment Research

Exhibit 59: ...driving significant growth in automotive batteries
GS battery demand estimates (base/hyper-adoption scenarios, GWh)



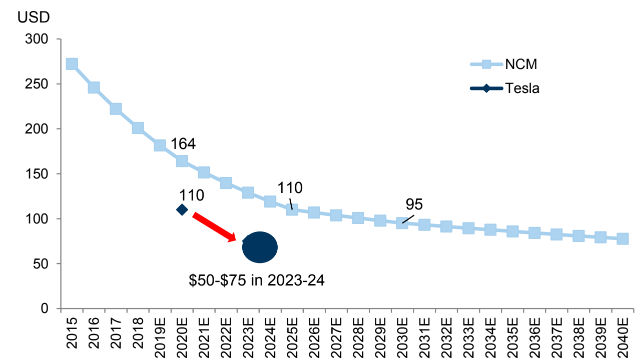
Source: Goldman Sachs Global Investment Research

Exhibit 60: Battery pack prices have fallen materially over the past few years, primarily driven by battery pack cost reductions...
Battery pack and cell price (US$/kWh, LHS)



Source: Company data, Goldman Sachs Global Investment Research

Exhibit 61: ...and we expect further reductions, albeit at a notably slower pace
Battery cost over time (US$/kWh)



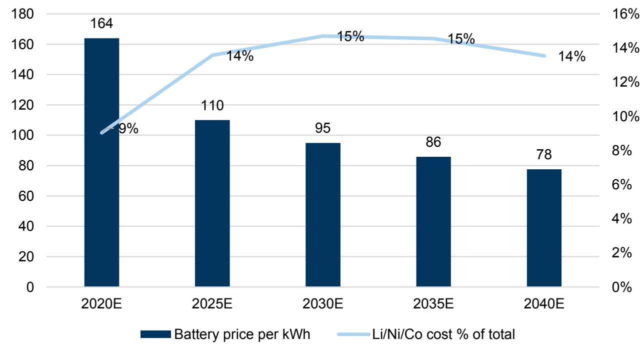
Source: Company data, Goldman Sachs Global Investment Research

Lithium (Li), nickel (Ni), and cobalt (Co), are the three main natural resources used in LIBs. We estimate that these three inputs account for around 9% of battery cost per kWh in 2020. Although we expect the amount of each of these inputs to change over time, and see cobalt content declining in particular, we estimate that the battery cost weighting of these inputs will stabilize in the 13%-15% range as total battery costs decline (cost estimates are based on September 2020 spot prices). However, with substantial battery market growth expected in absolute terms, overall demand for these three natural resources will likely continue to strengthen.

This cost analysis is based on current spot market prices, but natural resource prices are always at risk of large fluctuations depending on supply/demand conditions. At present, the three main natural resources cost US$15 per kWh (9% of total battery cost), but if each input's price returned to its historical peak, the total cost would rise to US$40 (around 25%), thereby increasing battery cost per kWh by US$25. A surge in natural resource prices could therefore erase steadily accumulated battery cost reductions achieved via higher energy densities and volume production benefits.

Exhibit 62: We expect the three main natural resources to account for 9%-15% of battery costs

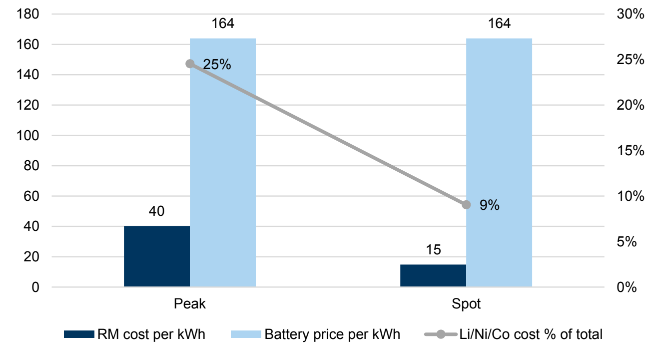
Cost weighting of three main natural resources in batteries (US$/kWh)



Source: Goldman Sachs Global Investment Research

Exhibit 63: Battery costs would rise to 25% should input costs return to historical peak prices

Cost analysis based on historical peak prices (US$/kWh)



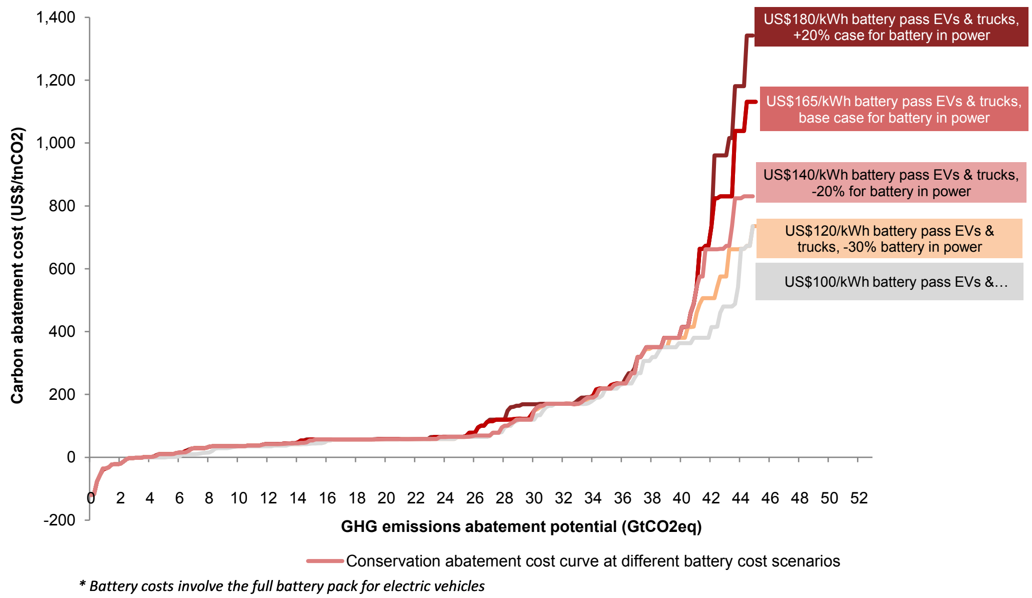
Source: IHS Global Insight, Goldman Sachs Global Investment Research

Assessing the potential impact of a breakthrough in battery technology on the de-carbonization cost curve

In the exhibit below, we analyze the case for different battery cost scenarios (full battery pack cost) for electric vehicles, including short-haul trucks, and for energy storage in power generation. This shows a relatively high sensitivity of the shape of the cost curve to battery costs, suggesting the battery technology has the potential to transform the higher end of the de-carbonization cost spectrum, which is dominated by transport. Lower battery costs for passenger EVs, both rural and urban, as well as trucks, could have a notable impact in reducing the overall cost of de-carbonization. However, battery technology in its current construct remains unlikely to offer a solution to the de-carbonization of aviation and shipping and seasonal variations in power demand, providing hydrogen with a key role to play in these areas, as we outlined in the previous section.

Exhibit 64: A potential breakthrough in battery technology and associated costs could help transform the current de-carbonization cost curve through lower costs in transport and power generation

Conservation carbon abatement cost curve for anthropogenic GHG emissions, for different battery cost scenarios in passenger transport and power generation

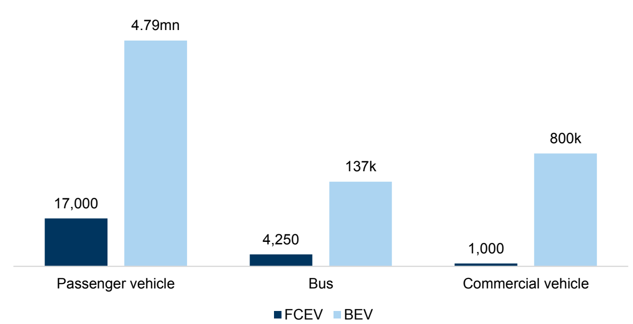


Source: Goldman Sachs Global Investment Research

The role of clean hydrogen: In for the long-haul?

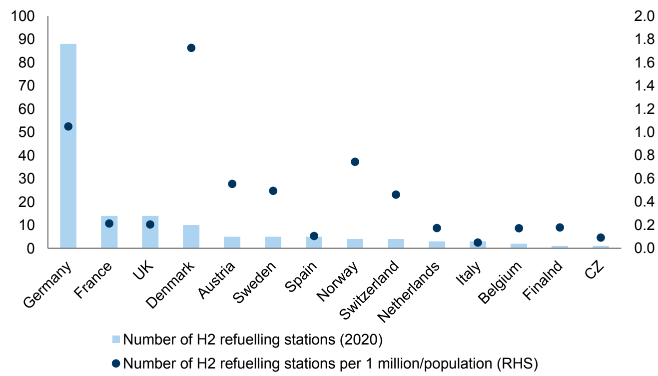
As highlighted by our Autos team in their reports _FCEVs: In for the long-haul?_ and _What's the outlook for alternative powertrain technologies in global truck markets?_ clean hydrogen is emerging as another key technology that could be a promising candidate for the de-carbonization of long-haul transport. Although there are estimated to be only 22k FCEVs on the road today (out of a global vehicle parc of 1.3bn) due to limited product offering, noncompetitive price points and little infrastructure, we see the recent policy drive towards de-carbonization as a reason to reconsider the potential for FCEVs. Moreover, with the European Union targeting a zero emissions future for vehicles, from the tailpipe, this goal is only achievable under currently existing commercial technology with the aid of hydrogen FCEVs for long-haul heavy transport. For a deep dive on the future of trucking, please see our global team's published report and presentation.

Exhibit 65: There are currently less than 25k FCEVs on the road, considerably less compared with BEVs...
FCEVs and BEVs on road globally (as of FY19)



Source: BNEF

Exhibit 66: ...with limited hydrogen refuelling infrastructure a key constraint to higher deployment
Number of hydrogen refueling stations across Europe



Source: Company data

Hydrogen's key attributes (low weight and high energy per unit mass, short refueling time, zero direct emissions when sourced from renewable energy sources) make it an attractive candidate as a transportation fuel. Hydrogen can be used in its pure form in fuel cell electric vehicles (FCEVs), but can also be converted into hydrogen-based fuels including synthetic methane, methanol and ammonia in a process commonly known as 'power-to-liquid', potentially applicable for aviation and shipping, where the use of direct hydrogen or electricity is particularly challenging.

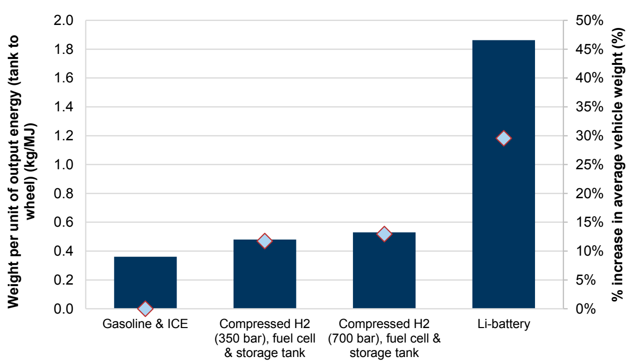
For all hydrogen applications, the **volume requirement** for on-board storage remains, along with the comparatively low **overall well-to-wheel (or power generation to wheel) efficiency**, the **two key challenges for use of hydrogen**. Hydrogen has some unique properties that make it screen attractively as a fuel, for example having >2.5x the energy density per unit mass compared with conventional fossil fuels. Nonetheless, hydrogen in ambient conditions (1 bar atmospheric pressure) has eight times lower energy density than conventional fuels such as natural gas under equivalent conditions, which typically creates the need for compression for use in on-board storage such as in FCEVs. To date, compressed hydrogen has been used for road transport (including light-duty but also buses, trucks and trains), with passenger vehicles accounting for the vast majority of fuel cell electric vehicles deployed. Japan, the US, the EU and South

Korea are leading the current FCEV fleet, yet many other countries have recently set hydrogen adoption targets in mobility. Among companies, Toyota, Hyundai, Honda and Daimler have all released or announced pipelines of FCEVs.

The exhibits that follow present our **comparative analysis for hydrogen** fuel cell electric vehicles (FCEVs) and how these screen on a weight per unit of output energy and volume per unit of output energy compared with other large-scale employed commercial vehicles – electric vehicles (EVs) and gasoline internal combustion engine vehicles (ICE). Exhibit 67 shows that for a fully loaded (or fully charged) average passenger vehicle, compressed hydrogen FCEVs screen attractively compared with Li-battery EVs on a weight per unit of output energy basis (tank-to-wheel). Similarly, hydrogen in its compressed form leads to FCEVs screening attractively on a volume per unit of energy output compared with EVs.

Exhibit 67: FCEVs (average passenger vehicle) using compressed hydrogen screen attractively on a weight per unit of output energy basis when compared with Li-battery EVs...

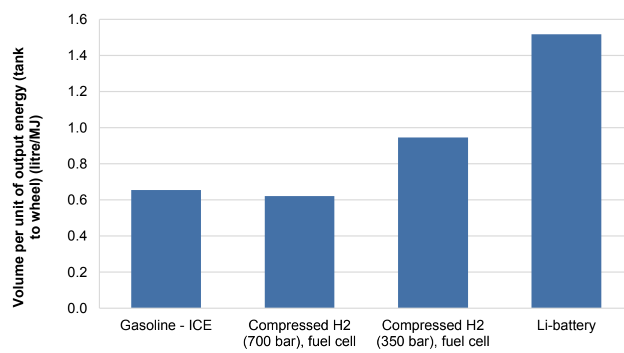
Weight per unit of output energy (tank-to-wheel basis, kg/MJ) for different average passenger vehicles and % increase in average vehicle weight



Source: US Department of Energy, EIA, Goldman Sachs Global Investment Research

Exhibit 68: ...and considering the compressed form of hydrogen used in FCEVs, they also screen attractively on a volume per unit of output basis

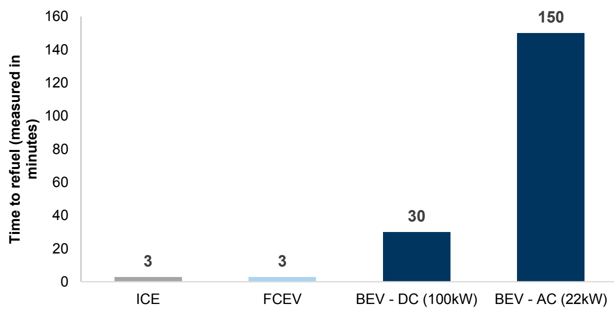
Volume per unit of output energy (tank-to-wheel basis) (litre/MJ)



Source: US Department of Energy, Company data, Goldman Sachs Global Investment Research

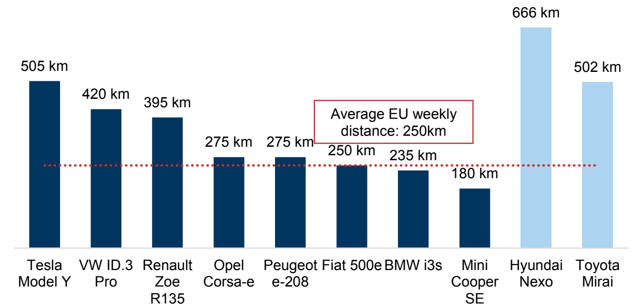
However, FCEVs screen less attractively in terms of the cost (US$) per unit of output energy, which is >2x the cost for equivalent EVs and ICE gasoline passenger vehicles. The cost per unit of energy output for FCEVs becomes more competitive when considering long-haul heavy transport, as their long range implies less frequent refueling required and as large capacity (>300kWh) batteries in EVs remain costly. This makes **FCEVs attractive for long-haul transport applications such as buses and trucks**. For the purpose of this analysis, we consider the weight and the volume of the system that stores and converts input energy to output energy across all three types of vehicles. This includes the internal combustion engine and gasoline tank components for ICE passenger vehicles, the Li-battery for EVs, and the fuel cell and compressed hydrogen storage tank for FCEVs.

Exhibit 69: Hydrogen outperforms significantly when we compare the refueling times of FCEVs versus BEVs at different kW charging ratings...
mins to refuel/recharge



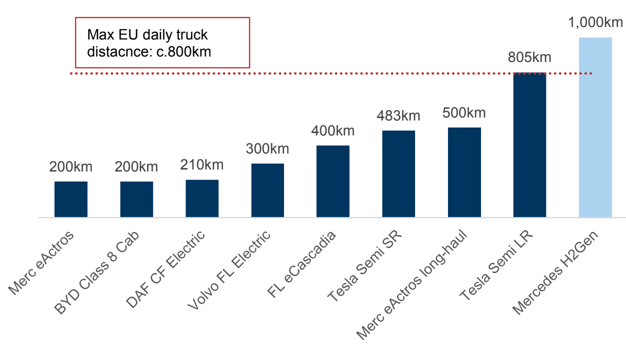
Source: Company data, Goldman Sachs Global Investment Research

Exhibit 70: ...and also provides a range advantage for passenger vehicles, albeit other models meet the average weekly threshold too...
BEV/FCEV model range overview



Source: Company data, Goldman Sachs Global Investment Research

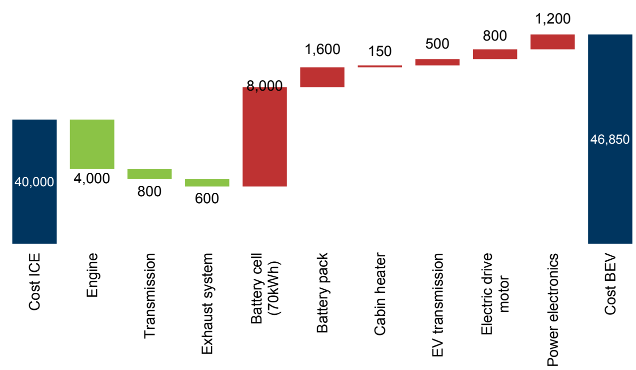
Exhibit 71: ...with the application where the range advantage is most important being long-haul trucks
ZEV Class 8 trucks and range (km)



EU max daily driving time at 9 hours (assuming average speed of 90km/h)

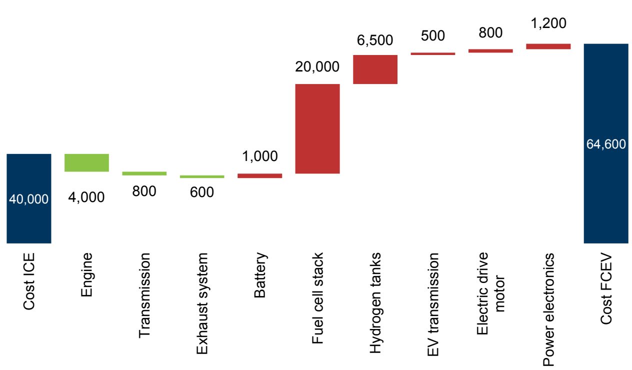
Source: Transport & Environment, EU, Goldman Sachs Global Investment Research

Exhibit 72: We estimate that a mid-size EV costs on average c.€6-7k more than a comparable ICE version...
ICE to BEV walk (€) for passenger vehicles



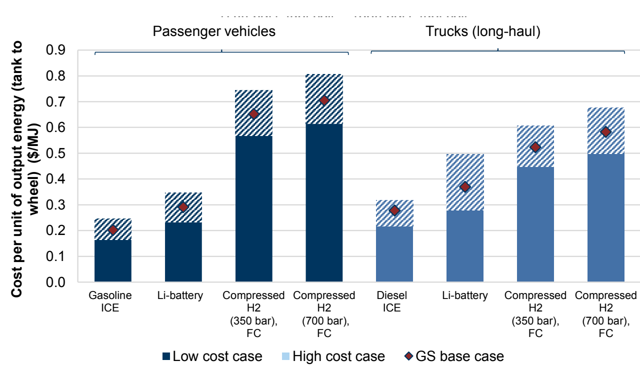
Source: Goldman Sachs Global Investment Research

Exhibit 73: ...by comparison, we estimate that a comparable FCEV costs €25k more per vehicle in production for passenger vehicles
ICE to FCEV walk (€) for passenger vehicles



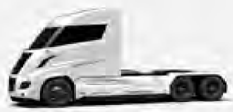
Source: Goldman Sachs Global Investment Research

Exhibit 74: While FCEVs are not cost competitive for short-haul passenger vehicles, on our estimates they become more competitive in long-haul heavy transport given hydrogen's high energy content per unit mass (and need for less frequent refuelling)
Cost per unit of output energy (tank-to-wheel, $/MJ)



Source: Company data, Goldman Sachs Global Investment Research

Exhibit 75: Looking at current prices, FCEV trucks are more expensive on a TCO basis, but with large cost reduction potential
Total cost of ownership of a Class 8 truck (15 years)

Model	Hydrogen truck		BEV truck		Diesel Truck
	2020	2025	2020	2025	2020
Model					
Cost of Truck	$250,000	$210,000	$250,000	$190,000	$120,000
Cost of fuel	$6 per kg/H2	$4.80 per kg/H2	0.10 $ per kWH	0.10 $ per kWH	$2.58 per gallon
Fuel consumption	7.5 miles per kg	7.5 miles per kg	0.4 miles per kWh	0.45 miles per kWh	8 MPG
Fuel cost over 15 years	$1,200,000	$960,000	$375,000	$333,333	$483,750
Maintenance costs	$259,500	$259,500	$242,400	$242,400	$311,800
Battery costs	$8,400	$5,688	$120,000	$81,262	$0
Payload losses	$0	$0	$266,667	$200,000	$0
Total cost	$1,717,900	$1,435,188	$1,254,067	$1,046,996	$915,550
$ per mile	$1.15	$0.96	$0.84	$0.70	$0.61
$ per mile (ex-payload)	$1.15	$0.96	$0.66	$0.56	$0.61

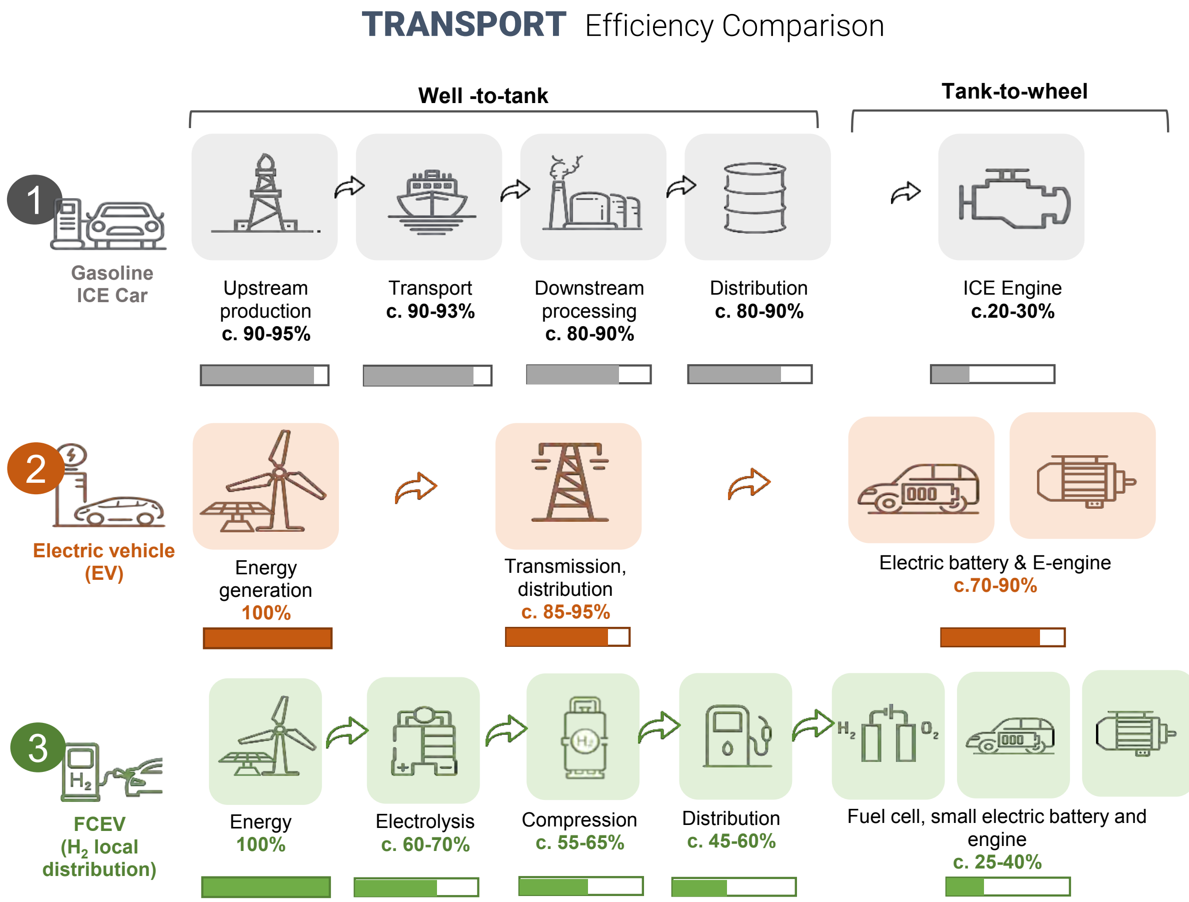
Source: Company data, Goldman Sachs Global Investment Research

Exhibit 76: BEVs appear to be the most attractive current de-carbonization alternative technology for short-haul passenger transport

Model	Tesla Model 3 SR	BMW 330i	Toyota Mirai
Model			
Type of vehicle	BEV	ICE	FCEV
Price ($, ex-subsidies)	$37,990	$41,250	$57,500
EPA range (km)	402 km	714 km	502 km
Curb weight	1726 kg	1614 kg	1850 kg
Energy source	50 kWh battery pack	60 litre fuel tank	Two hydrogen tanks (5kg, 700 bar)
Cost of refuelling (CA)	$6.5	$52.2	$83.2
Refuelling time	30 minutes (80% DC charge)	2 minutes	5 minutes
0-60 mph	5.3s	5.5s	9.0s
CO2 g/km	0 g/km	150 g/km	0 g/km

Source: Company data, Goldman Sachs Global Investment Research

Exhibit 77: Hydrogen's low 'power to wheel' efficiency remains its main weakness compared with electricity alternatives such as BEVs



Source: Company data, Goldman Sachs Global Investment Research

Theme #7: Flying Sustainably

Aviation sits at the top of our Carbonomics cost curve, and is one of the toughest sectors to de-carbonize. Aviation biofuels (sustainable aviation fuels – SAFs), synthetic fuels and improved aircraft efficiency are key parts of the solution, as we discussed with the CEO of Neste, the world's biofuels leader, and senior management from Lufthansa, Airbus and Rolls Royce during our conference.

As outlined in our Transportation team's *Aviation decarbonisation toolkit* report, we expect rising policy focus on air emissions to continue in the wake of large-scale financial support for airlines. Intervention will need to be balanced, however, with preserving a key industry and employer, with tourism accounting for 4% of Europe's GDP and 11% of employment.

Double-digit organic emissions reduction possible post Covid-19...

Covid-19 is likely to result in the deepest civil aviation traffic recession in history, multiple times worse than in 1991, 2001 or 2009. As focus turns to the pace and shape of a recovery, we believe a key consideration in assessing the sector's growth profile beyond 2020 is rising environmental policy constraints. Indeed, some announced rescue packages for the sector have "green" conditions (e.g. Austrian Airlines, Air France). That said, policy intervention will have to be balanced with economic concerns: tourism's share of GDP and employment is 4%/11% in Europe, and higher in Southern Europe.

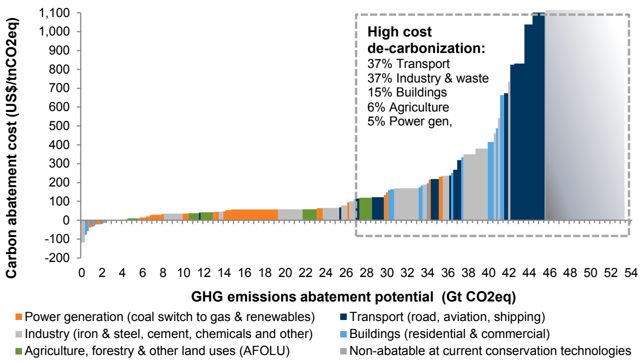
Our Transportation team do not expect a return to 2019 EU air traffic levels until the mid-2020s. Taking this as a base case, replacing old with new engine technology alone could see absolute emissions drop by up to 10% over the next five years (assuming a historical run-rate in fuel efficiency gains of ~2% pa). Our Aerospace team assess the potential for emissions reduction from a technological perspective in a companion piece here. Improvement in fuel efficiency will likely be assisted by accelerated aircraft retirements post Covid as some airlines make double-digit structural capacity reductions across their networks. Our Transportation team expect these to center on old aircraft deployed on national routes, which would facilitate a shift to rail: they estimate that up to 15% of EU short-haul travel could shift to high-speed rail.

...with policy flex on top

On the rest of the airline networks, incremental taxes embedded into fares and/or jet fuel could be used to curb demand further, depending on pass-through; our elasticity analysis shows that a 10% increase in fares would see traffic fall 2%-5%. Thus far, announced passenger taxes would add ~5%/15% to flag/LCC fares, translating into a mid-single-digit hit to EU short-haul traffic on average.

Exhibit 78: Transport occupies mostly the higher-cost end of the Carbonomics de-carbonizing cost curve, with aviation being one of the toughest sectors to de-carbonize...

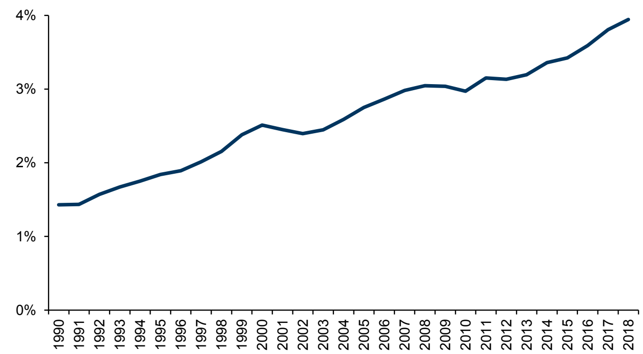
Conservation abatement cost curve for anthropogenic GHG emissions



Source: Goldman Sachs Global Investment Research

Exhibit 79: Airlines' share of CO2 emissions in Europe has increased >2x since 1990...

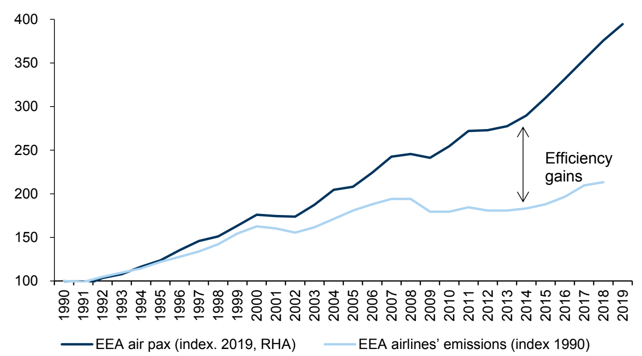
Aviation's share of EEA CO2 emissions



Source: European Commission, EEA

Exhibit 80: ...driven by traffic growth, while aircraft efficiency has improved

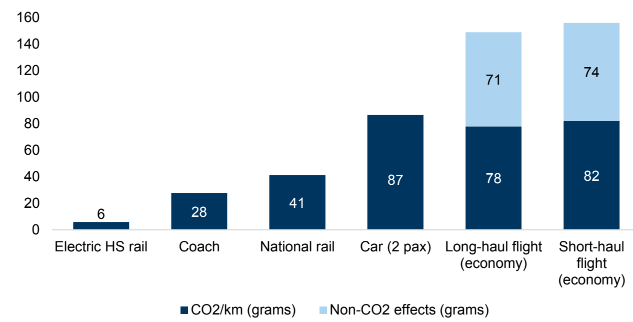
EEA air passenger traffic vs. airlines' emissions, indexed



Source: European Commission, Goldman Sachs Global Investment Research

Exhibit 81: Air travel has the highest carbon footprint within transport

Emissions per passenger-km (UK average), 2019

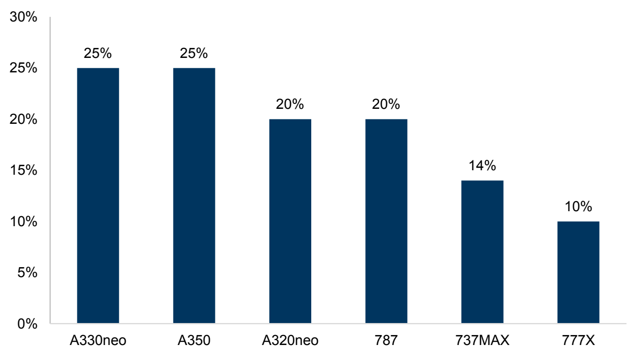


Source: DEFRA

New generation aircraft/fleet renewal, sustainable aviation fuels (SAFs) and other new propulsion technologies pave the way for the technological transformation of aviation

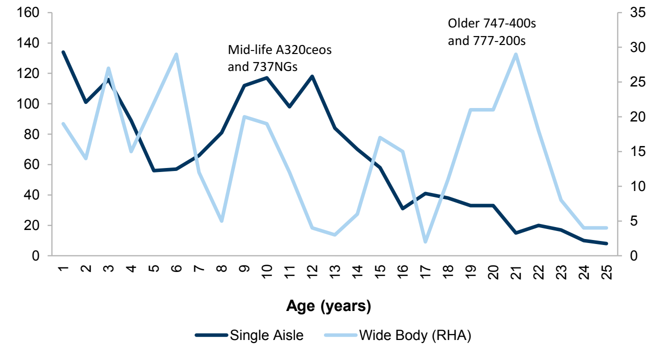
New generation aircraft/fleet renewal: One way of reducing aviation's carbon footprint would be through fleet renewal. As laid out by our Aerospace & Defense team, new gen aircraft, which burn ~15% less fuel vs. their predecessors, have only ~9% penetration across the EU fleet, with more efficient engine technology not expected before 2030. Given fuel costs typically account for ~25% of airline opex, simplistically assuming a unilateral switch to new gen aircraft could boost airline margins by 375 bp, all else equal. In reality, while this benefit would occur over a number of years for a given airline, the economics are compelling given generally thin airline operating margins. A switch to a more efficient aircraft sits at the lower end of the transportation section of our Carbonomics de-carbonization cost curve and is likely to be the most economic solution in the near term. Although lower investment capacity amid weakened balance sheets post Covid is resulting in near-term aircraft deferrals, we don't expect medium-term fleet renewal plans to change. Senior management from both Airbus and Rolls Royce highlighted the importance of aircraft efficiency in aiding the de-carbonization of aviation.

Exhibit 82: The switch to a more efficient aircraft has the potential to lead to c.15%-20% fuel burn improvement...
Fuel burn improvement vs. previous generation as per company data



Source: Company data

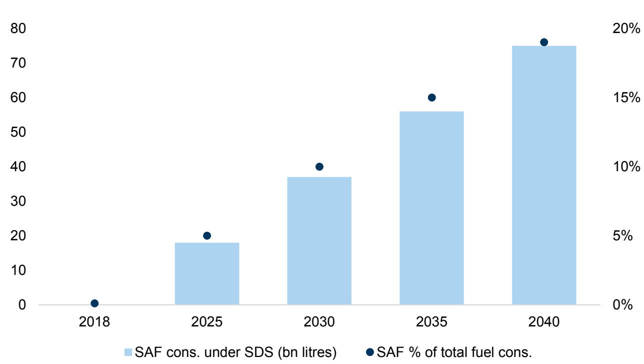
Exhibit 83: ...and there is currently a large number of older wide-bodies and mid-life narrow-bodies which could be replaced before 2030
European active passenger fleet split by age



Source: Cirium

Sustainable Aviation Fuels (SAFs): SAFs can be used interchangeably with jet fuel in current aircraft and have the potential to cut emissions by up to 80% vs. kerosene. As shown in Exhibit 84, under the International Government Agency's "Sustainable Development Scenario" (WEO 2019, with targets aligned with the Paris Agreement), SAF would account for ~20% of aviation fuel by 2040. This is consistent with IAG's target for 30% of its fuel to be produced from SAF by 2050. That said, SAF requires significant investment before it can be considered an economically viable alternative, with the current production cost typically ~4x of jet fuel. The CEO of Neste, one of the world's leading biofuel (and SAFs) producers, laid out the case for the scale-up and acceleration of SAF efforts, highlighting the potential for those sourced from waste residues.

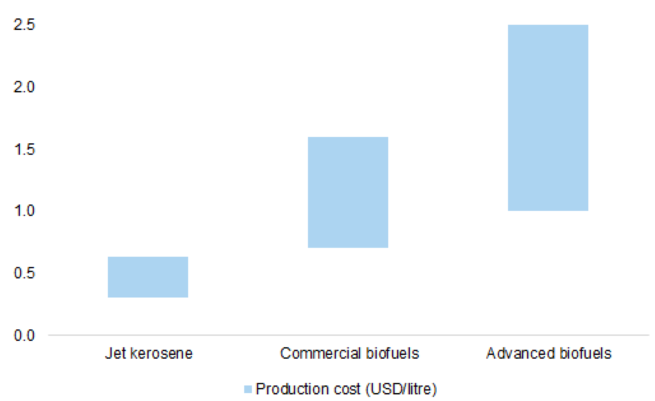
Exhibit 84: Under IEA's Sustainable Development Scenario (aligned with the Paris Agreement), biofuels would account for ~20% of airline fuel consumption by 2040
SAF consumption under SDS* (bn litres) vs. SAF share of total aviation fuel consumption (SDS)



*Sustainable Development Scenario (IEA) - WEO 2019

Source: IEA, Goldman Sachs Global Investment Research

Exhibit 85: Getting there however requires significant investment given the current production cost gap between SAFs and kerosene
Production cost range by fuel type, USD/litre (2019)



Source: IEA

New propulsion technologies: Meanwhile, other technologies are emerging, among which are hydrogen-based synthetic fuels, which rely on carbon capture and are generally cleaner than SAFs, generating only water as a bi-product from running the engine. Other technologies include electrification, but technological constraints are evident when it comes to long-haul heavy transport.

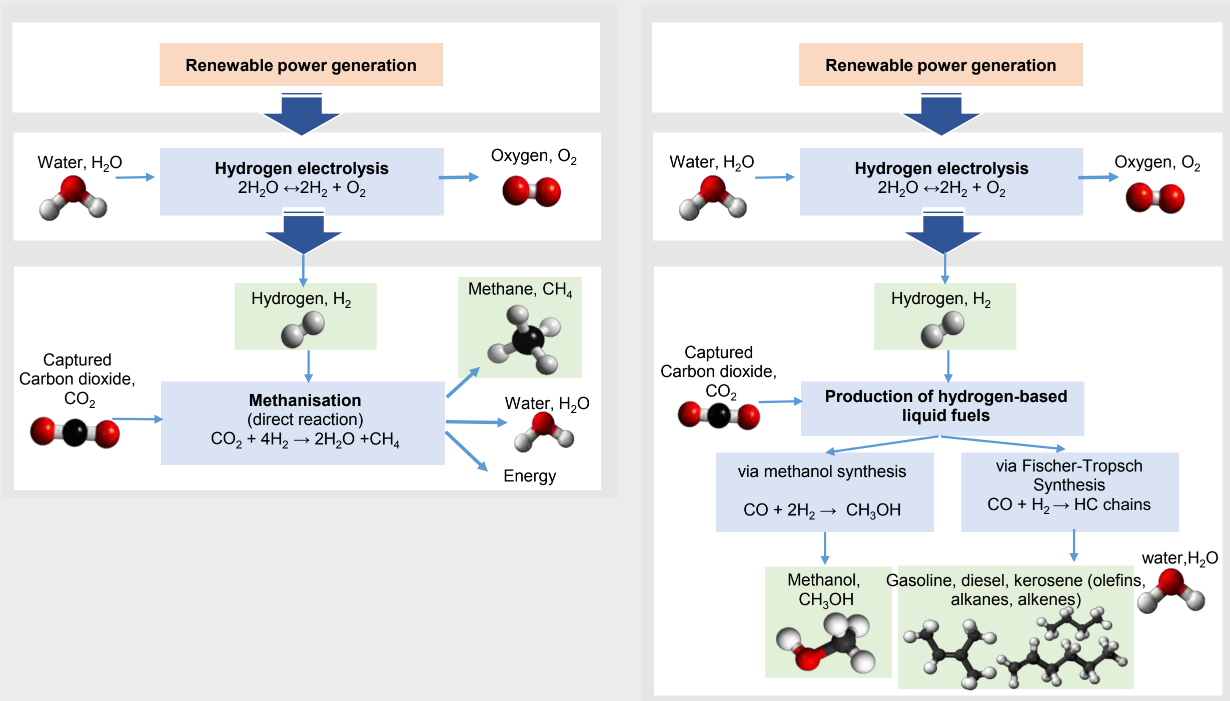
Carbon offsets also have a key role to play: Carbon offsets will also play a large role in reducing net emissions. There are two different regulatory measures that can help offset aviation's emissions, one in place today (ETS) and another proposed (CORSIA), which is likely to complement ETS in Europe from 2021. The aviation industry plans to offset c.2.5bn tonnes of CO_2 between 2021 and 2035, through the CORSIA scheme. At the current price, offsetting could add c.23% to the effective fuel cost for airlines.

Synthetic hydrogen-based fuels and feedstocks

Synthetic fuels are another means of dealing with the de-carbonization challenge for industries such as aviation. An acceleration of hydrogen large-scale adoption in long-haul transport could materialize on the back of its ability to form ammonia and other liquid organic hydrogen carriers (LOHCs), but also its ability to combine with CO_2/CO to produce synthetic hydrocarbons /liquid fuels such as synthetic methanol, diesel and jet fuel. In our view, the former (ability to form ammonia and LOHCs) has the potential to enhance the pace of hydrogen adoption by aiding storage and transportation (liquid ammonia has a higher volumetric density than liquid hydrogen and can be liquefied at a higher temperature of -33°C vs hydrogen at -253°C and methane at -160°C), while the latter (ability to combine with CO_2/CO) acts as a CO_2 utilization route with a wide range of applications. Some hydrogen-based synthetic feedbacks and fuels developed to date include:

- **Synthetic methane:** This is the most commonly produced synthetic hydrogen-based fuel, and the production pathway involves a methanation process (mostly catalytic but biological routes are also possible) that utilizes the direct reaction between hydrogen and CO_2 to produce methane, with water the main reaction by-product.
- **Synthetic methanol**: Methanol has c.80% higher energy density than hydrogen, and its production route from syngas (through hydrogen) is well developed commercially. The first CO_2-to-methanol facility, known as George Olah Renewable Methane Plant, is located in Iceland and was commissioned in 2012 with a capacity of 1,000 tpa of methanol before its expansion to 4,000 tpa in 2015. The CO_2 feedstock is captured from a nearby power plant while hydrogen is produced via electrolysis and used to directly hydronate the captured CO_2. The 'Vulcanol' product is then sold for use as a gasoline additive and feedstock for biodiesel production.
- **Synthetic diesel, kerosene and other fuels:** Synthetic diesel or kerosene is the result of a reaction occurring between carbon monoxide (CO) and hydrogen. Carbon monoxide could be obtained from captured CO_2, with the resulting syngas, CO_2 and hydrogen converted into synthetic fuels via the Fischer Tropsch synthesis route.

Exhibit 86: Clean hydrogen can be used in CO2 utilization processes for the production of synthetic hydrogen-based fuels such as methane, methanol, diesel and gasoline



Source: The Royal Society, Goldman Sachs Global Investment Research

Theme #8: Carbon sequestration

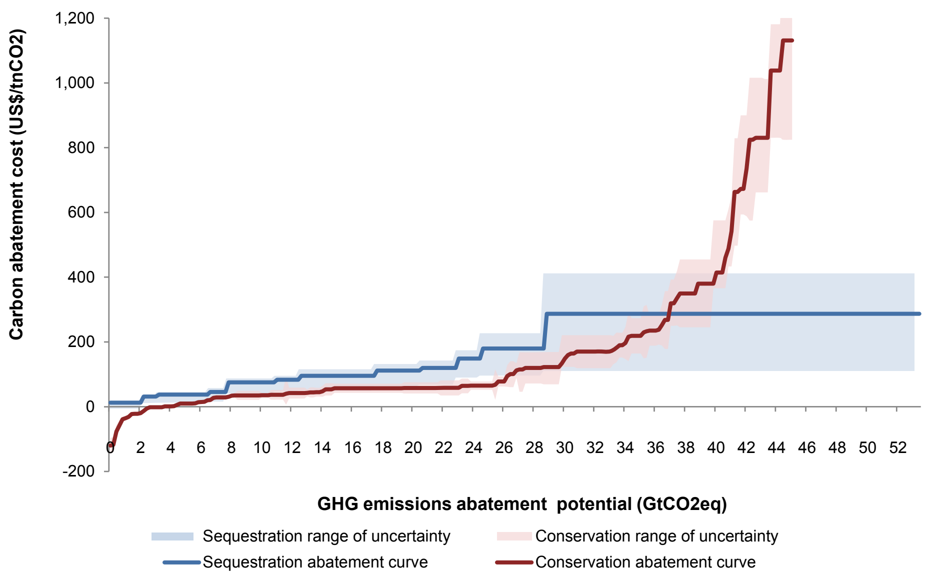
Conservation efforts alone are unlikely to reach net zero carbon in the absence of carbon sequestration

We envisage two complementary paths to enable the world to reach net zero emissions: conservation and sequestration. The former refers to all technologies enabling the reduction of gross greenhouse gases emitted (already presented in the conservation cost curve in Exhibit 13) and the latter refers to natural sinks and carbon capture, usage and storage technologies (CCUS) that reduce net emissions by subtracting carbon from the atmosphere. The need for technological breakthroughs to unlock the potential abatement of the **c.15% of total current anthropogenic emissions that cannot at present be abated** through existing conservation technologies **makes the role of sequestration a critical piece of the puzzle in solving the climate change challenge and leading the world to net zero carbon** emissions at the lowest possible cost.

The cost curves for sequestration and conservation are both presented in Exhibit 87 below. While the conservation cost curve has larger scope for low-cost de-carbonization opportunities and a smaller range of uncertainty, it steepens exponentially beyond 50%. The sequestration cost curve, on the other hand, offers fewer low-cost solutions and has greater cost uncertainty, but provides tremendous long-term potential if a commercially feasible solution for Direct Air Carbon Capture is developed. We believe that carbon sequestration can be an attractive competing technology for sectors in which emissions are harder or more expensive to abate, with industry being a prominent example.

Exhibit 87: The path to de-carbonization will be driven by technological innovation and economies of scale for both conservation and sequestration initiatives

Carbon abatement cost curves (US$/tnCO2) for conservation and sequestration technologies vs. the GHG emissions abatement potential (GtCO2eq)



Source: Goldman Sachs Global Investment Research

The carbon sequestration cost curve

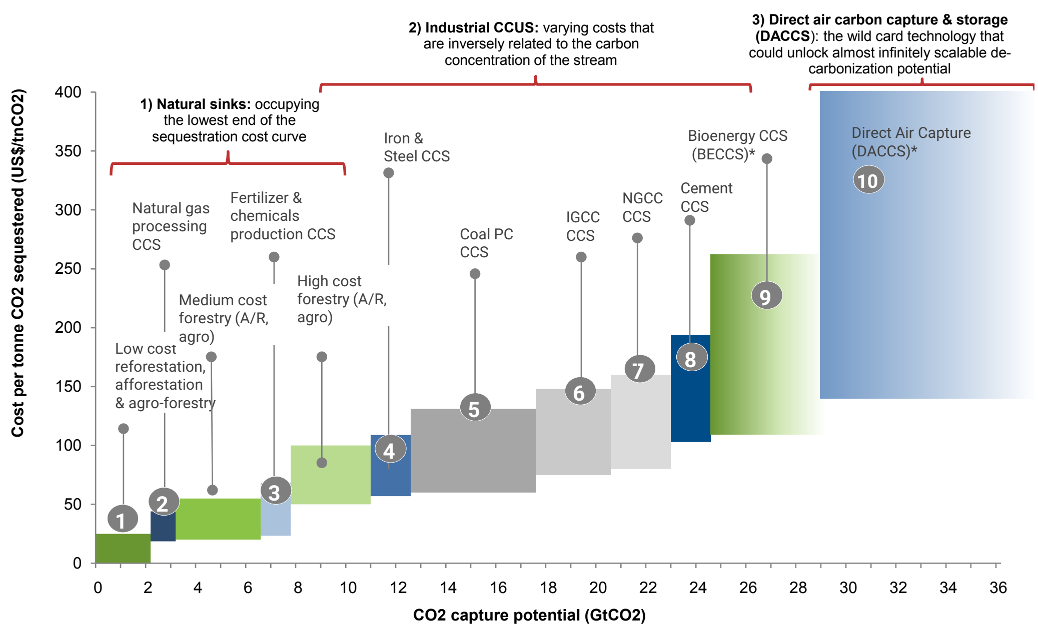
As part of our analysis, we have constructed a carbon abatement cost curve for sequestration (Exhibit 88) although we see a greater range of uncertainty in these technologies, given their under-invested state and the largely pilot nature of the CCUS plants. **Carbon sequestration** efforts can be broadly classified into three main categories:

1) Natural sinks, encompassing natural carbon reservoirs that can remove carbon dioxide. Efforts include reforestation, afforestation and agro-forestry practices.

2) Carbon capture, utilization and storage technologies (CCUS) covering the whole spectrum of carbon capture technologies applicable to the concentrated CO_2 stream coming out of industrial plants, carbon utilization and storage.

3) Direct air carbon capture (DACCS), the pilot carbon capture technology that could recoup CO_2 from the air, unlocking almost infinite de-carbonization potential, irrespective of the CO_2 source.

Exhibit 88: The carbon sequestration curve is less steep vs. the conservation curve but has a higher range of uncertainty given the limited investment to date and the largely pilot nature of these technologies
Carbon sequestration cost curve (US$/tnCO2eq) and the GHG emissions abatement potential (GtCO2eq)



* Indicates technologies primarily in early development/ pilot phase with wide variability in the estimates of costs

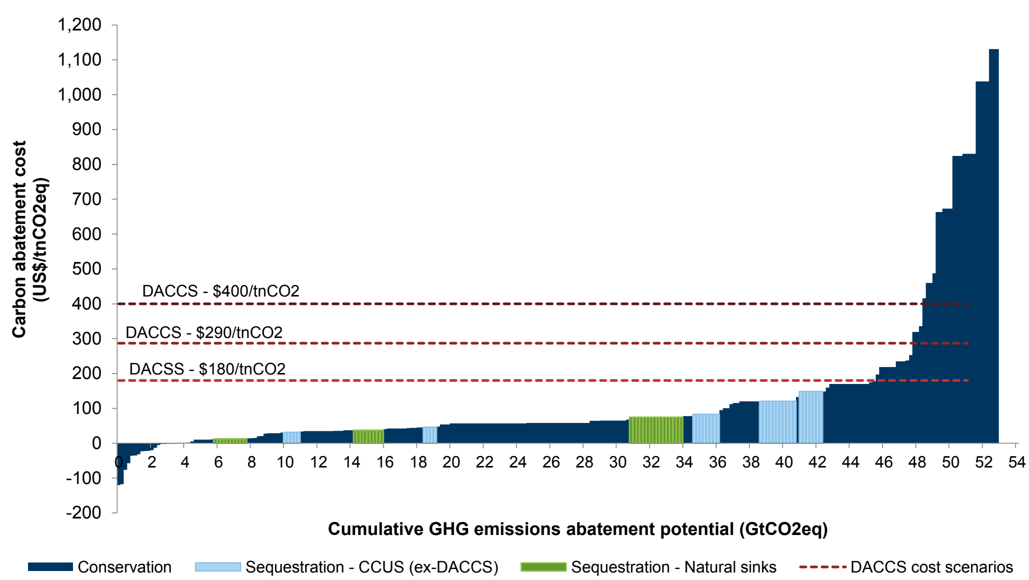
Source: IPCC, Global CCS Institute, Goldman Sachs Global Investment Research

Carbon sequestration is a vital part of achieving net zero carbon, helping to unlock the last 15% of de-carbonization and offering an alternative to high-cost carbon conservation

In the exhibit below, we present the **merged cost curve of de-carbonization that incorporates both conservation** (Exhibit 16) **and sequestration** (Exhibit 88) **initiatives**. We exclude from the merged cost curve the technology of direct air carbon capture (DACCS), as in theory this technology could unlock almost infinite de-carbonization potential, ultimately determining the carbon price required to reach net zero. Instead, we present three cost scenarios for DACC below using straight cut-off lines. Conservation technologies overall contribute c.70% of total abatement, with natural sinks and carbon capture contributing the remaining c.30% of total abatement. We **conclude that the combined conservation and sequestration path to net zero results in c.US$4.8 tn of annual investments required to achieve full de-carbonization** (at today's costs – which are likely to move lower in the coming years on the back on continued clean tech innovation). **In contrast**, **following a path relying solely on conservation technologies results in c.US$7.7 tn pa of required investments for only c.85% global de-carbonization.** This reinforces our view that carbon sequestration is vital to unlock affordable full de-carbonization potential.

Exhibit 89: The merged cost of de-carbonization (including all conservation and sequestration approaches) indicates that >60% of emissions can be abated at a price <US$100/tnCO2, comprising mostly low-cost clean alternatives in power generation and natural sinks

Total conservation and sequestration abatement cost curve of de-carbonization for anthropogenic GHG emissions, based on current technologies and associated costs

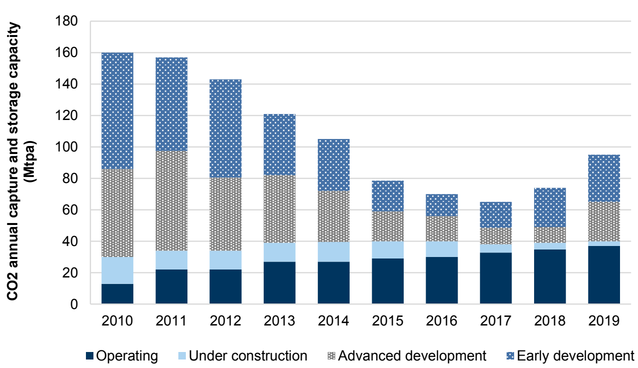


Source: Goldman Sachs Global Investment Research

Carbon capture: A largely under-invested technology coming back after a 'lost decade'

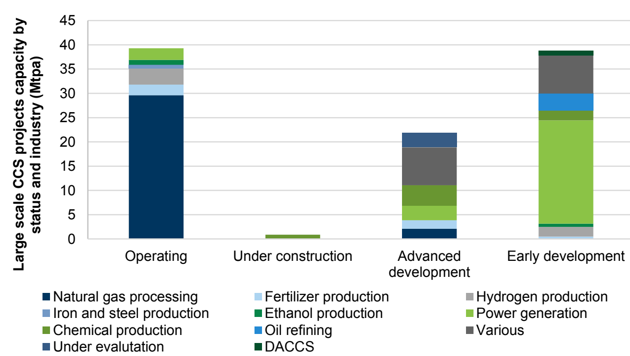
CCUS technologies can be an **effective route to global de-carbonization for industrial and power sources**: they can be used to significantly reduce emissions from coal and gas power generation, as well as across industrial processes with emissions characterized as 'harder to abate' such as iron & steel, cement and chemicals. CCUS encompasses a range of technologies and processes that are designed to capture the majority of CO_2 emissions from large industrial point sources and then to provide long-term storage solution or utilization. The CCUS chain constitutes processes that can be broadly categorized into three major parts: (1) **the separation and capture** of CO_2 from gaseous emissions; (2) the subsequent **transport** of this captured CO_2, typically through pipelines, to suitable geological formations; and (3) the **storage** of the CO_2, primarily in deep geological formations such as former oil and gas fields, saline formations or depleting oil fields or the **utilization** of captured CO_2 for alternative uses and applications. When CO_2 is injected into an oil field to recover oil reserves, the method is known as Enhanced Oil Recovery (EOR), and the majority of existing operating CCS projects globally have adopted this route of storage as it offers the potential for higher return on investment. Ocean and mineral storage options also exist.

Exhibit 90: The pipeline of large-scale CCS facilities is regaining momentum after a 'lost decade'...
Annual CO2 capture & storage capacity from large-scale CCS facilities



Source: Global CCS Institute Status Report 2019

Exhibit 91: ...as more projects in the development stage start to focus on industries with lower CO2 stream concentrations (industrial & power generation as opposed to natural gas processing)
Large-scale CCS projects by status and industry of capture (Mtpa, 2019)



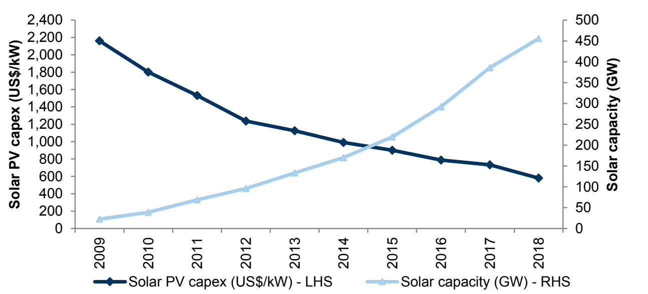
Source: Global CCS Institute, Goldman Sachs Global Investment Research

Currently, we identify **c.20 large-scale CCS facilities operating globally**, with a total capacity of c.40 Mtpa, as highlighted by the Global CCS Institute at our conference. 2019 was marked by the advancement of two large-scale CCS facilities: the start of CO_2 injection at the Gorgon natural gas processing plant in Australia, the largest dedicated geological CO_2 storage facility when ramped up to full capacity (4.0 Mtpa of CO_2), and the Alberta Carbon Trunk Line (ACTL) development. In 2020, the Northern Lights project made its entry. According to the involved companies, Phase 1 includes capacity to transport, inject and store up to 1.5 $MtCO_2$ per year in the North Sea. There are more CCS projects in the pipeline longer term, with a notable example of large-scale projects being Net Zero Teesside in the North East of England, aiming to de-carbonize a cluster of carbon-intensive businesses by as early as 2030 and deliver the UK's first zero-carbon industrial cluster, as highlighted by OGCI during our conference.

Cost remains the primary barrier to the deployment of CCS technologies. The incremental costs of capture and the development of transport and storage infrastructure are not sufficiently offset by government and market incentives, albeit efforts have intensified in regions such as Norway (where carbon prices are at the higher end of the global carbon price spectrum) and the US (with the introduction of the 45Q scheme). The cost of individual CCS projects can vary substantially depending on the source of the carbon dioxide to be captured, the distance to the storage site and the characteristics of the storage site, although the cost of capture is typically the largest driver of the total expense and it shows an inverse relation to the concentration of CO_2 in the stream of capture.

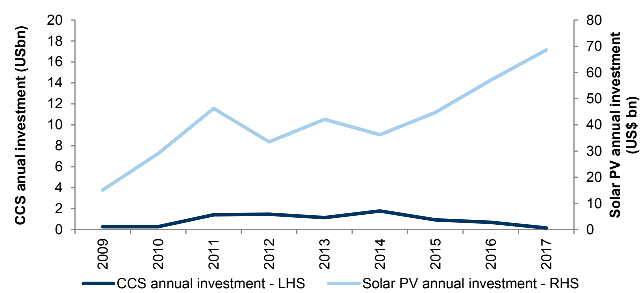
Although carbon sequestration has seen a revival in recent years, it **has not yet reached large-scale adoption and economies of scale that traditionally lead to a breakthrough in cost competitiveness**, especially when compared with other CO_2-reducing technologies such as renewables. Despite the key role of sequestration in any scenario of net carbon neutrality, investments in CCS plants over the past decade have been <1% of the investments in renewable power. Although we are seeing a clear pick-up in CCS pilot plants after a 'lost decade', we do not yet know where costs could settle if CCS attracted similar economies of scale as solar and wind. The vast majority of the cost of carbon capture and storage comes from the process of sequestration and is inversely related to the CO_2 concentration in the air stream from which CO_2 is sequestered. The cost curve of CCS therefore follows the availability of CO_2 streams from industrial processes and reaches its highest cost with direct air carbon capture and storage (DACCS), where economics are highly uncertain, with most estimates at US$40-400/ton and only small pilot plants currently in activity. The importance of DACCS lies in its potential to be almost infinitely scalable and standardized, therefore setting the price of carbon in a net zero emission scenario.

Exhibit 92: Solar PV cost per unit of electricity has fallen 70%+ over the last decade as cumulative solar capacity has increased exponentially...
Solar PV capex (US$/kW) vs. global cumulative solar PV capacity (GW)



Source: Company data, Goldman Sachs Global Investment Research

Exhibit 93: ...while the languishing investment in CCS sequestration technologies has possibly prevented a similar cost improvement
Annual investment in solar PV (LHS) and large-scale CCS (RHS)



Source: Company data, IEA, IRENA, Goldman Sachs Global Investment Research

The most scalable technology: Direct Air Carbon Capture and Storage (DACCS)

Direct air capture (DAC) is a different form of sequestration, as it does not apply to a specific process (like traditional CCUS), but takes CO_2 from the air in any location and scale. Nascent DAC technologies are capable of **achieving physical and/or chemical separation and concentration of CO_2 from atmospheric air**, unlike CCS, which captures carbon emitted from 'point source' industrial processing streams (flue gas). Carbon captured through DAC can then be repurposed for other uses, for example to make carbon-neutral hydrocarbon fuels. It is early days for DACCS, however, as the technology is still being developed and existing implementation projects are small-scale and very high cost. Nonetheless, we identify this technology as a potential wild card in the challenge of climate change as **it could in theory unlock almost infinitely scalable de-carbonization potential**. A summary of the most prominent DACCS designs to date and the associated details is described in the summary box that follows.

Exhibit 94: DACCS: A roadmap of challenges with yet unique opportunities ahead

Direct Air Carbon Capture (DACCS)		
Strengths	**Challenges**	**Opportunities**
1) Very large cumulative potential in relation to other carbon removal pathways that could be infinitely scalable	**1)** New concept in need of further technological innovation required to bring energy requirements and costs down to a level that is commercially competitive.	**1)** Primary energy consumption in DACCS is attributed to the heat required for sorbent/solvent regeneration. Identifying sorbents that optimize the binding to CO2 such that it is strong enough to enable efficient capture but weak enough to reduce heat requirement during regeneration is key.
2) DACCS can be sited in a very wide range of locations including areas near high energy sources and geological storage potential since there is no need to be close to sources of emissions	**2)** The very small concentration of CO2 in air (c0.04%) compared to industrial streams makes the economics of the capture process unattractive and calls for further innovation.	**2)** Reaction kinetics are important as they impact the rate at which CO2 can be removed from air. If the rate is low a much larger area for air-sorbent/solvent material contact will be required which translates into a large air contactor area and thus higher capital costs. Optimization of air contactor design through geomtery and pumping strategy is another key technological aspect.
3) There are limited land and water requirements for DAC relative to other pathways such as natural sinks or BECCS.	**3)** Given the high energy intensity of carbon capture technologies, there is an evident need for zero carbon electricity for the most efficient, from a climate change standpoint, operation.	**3)** CO2 offtake, transport and utilization is a key component for an efficient system operation. Finding new opportunities for CO2 utilization is therefore vital. Examples include synthetic fuels and petrochemicals.
4) Technological advantages over conventional CCS include the absence of high levels of contaminants present in plants' flue gas streams, and no need for a design targetting the complete CO2 capture with a single stream pass which is usually the case for CCS applied to industrial flue gas streams.		

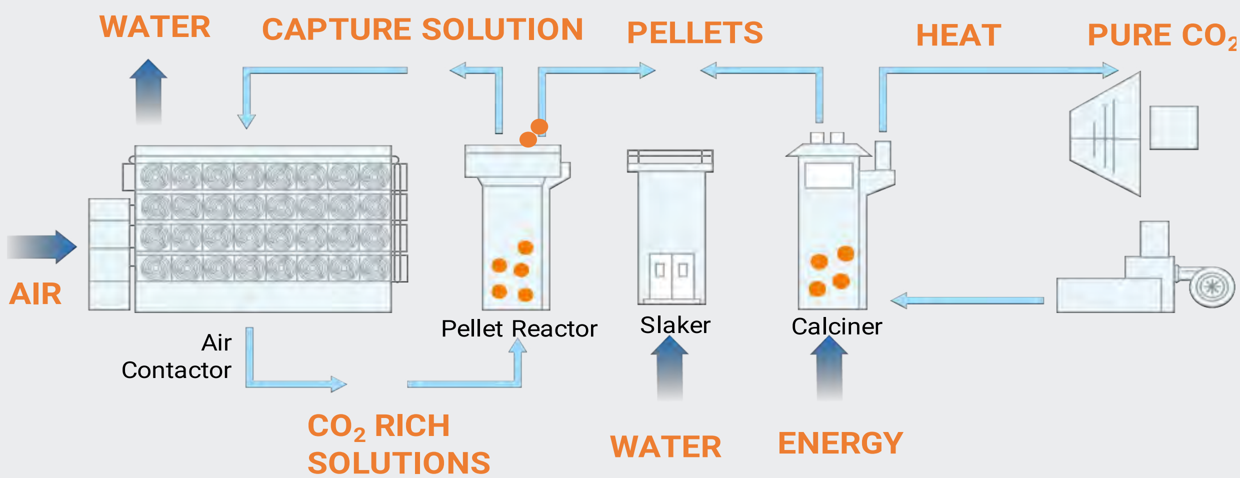
Source: ICEF Roadmap, Goldman Sachs Global Investment Research

Direct air carbon capture: Companies leading the race

Carbon Engineering Ltd

Carbon Engineering (Canada-based) was founded in 2009 and is currently adopting a solvent-based cycle process for direct air carbon capture. The process involves an air contactor which includes a fan that brings air into the structure. The air is then passed over thin plastic surfaces that contain the solvent — an aqueous solution of potassium hydroxide solution that binds to the CO_2 molecules, capturing them in a liquid solution (forming carbonate salt). A series of chemical processes subsequently increase the CO_2 concentration. Those processes involve salt separation from the solution into small pellets (pellet slurry reactor), the heating of the pellets in a calciner releasing the captured CO_2 in gaseous form and recycling the pellets (through hydration in a slaker) back in the system for further capture. The captured CO_2 is then used for geological storage or the production of synthetic fuels. Carbon Engineering is currently the only known company to use a liquid-solvent based approach to DACCS, enabling the potential for a continuous process which could operate at steady state. Its process relies mostly on equipment that are widely used in industry and that therefore have an established supply chain and performance.

Exhibit 95: Schematic of the DACCS process adopted by Carbon Engineering

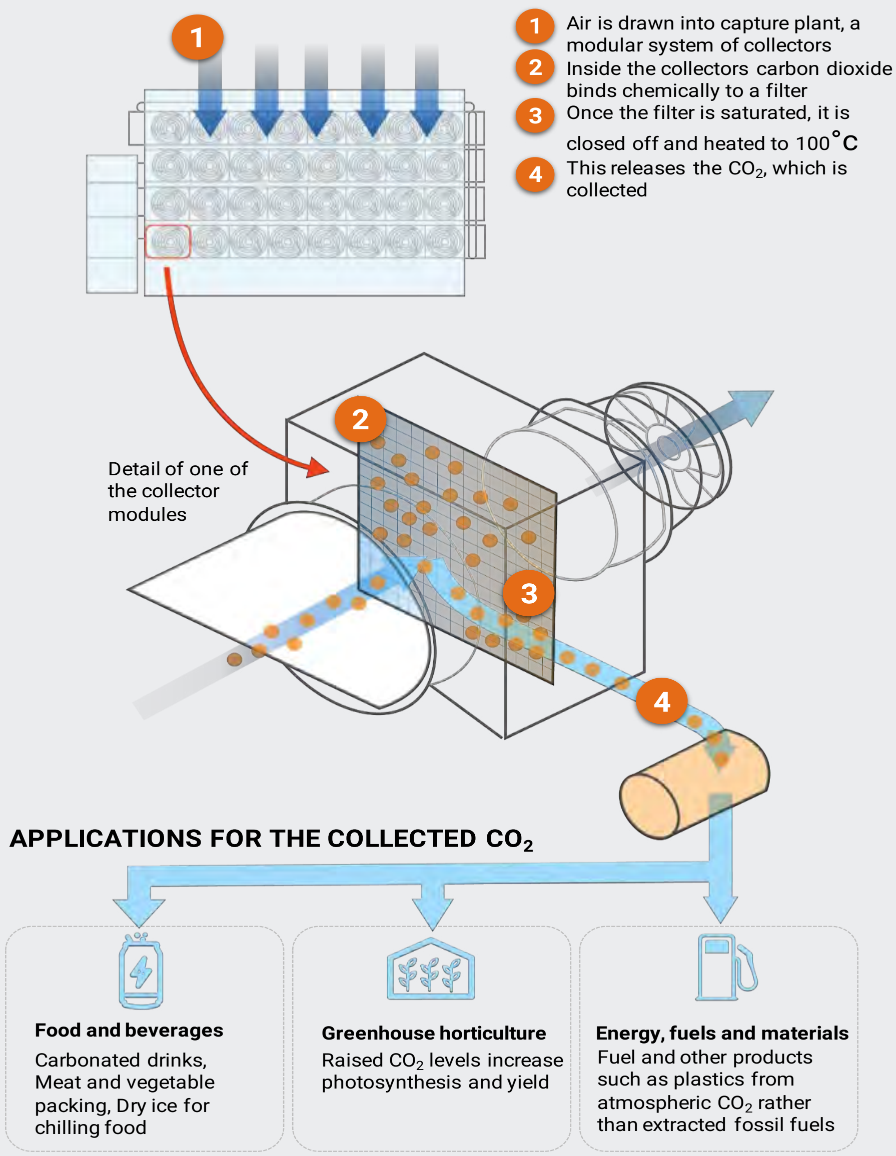


Source: Carbon Engineering

Climeworks

Climeworks is another company that is focused on delivering direct air carbon capture solutions. It currently has several pilot plans in operation, notably the ones in Switzerland, Iceland and Italy, which capture c.900/50/150 tCO_2pa, respectively. The sorbent used to capture CO_2 is an amine supported on solid porous granules arranged on a filter. The air contactor system consists of fans that move air horizontally across the sorbent filters. Once those filters become saturated with CO_2, they are heated at temperatures around 100°C (combined temperature and pressure swing regeneration process) with the gaseous CO_2 being released from the filter and collected as concentrated CO_2 supply. Climeworks was the first company to deliver commercial CO_2 from DACCS and sell it as a commercial product, with its facility in Switzerland being the first DACCS facility operating with a capacity near $ktCO_2$pa. The captured CO2 is used to supply greenhouses (Gebruder Meier in Switzerland), food & beverages and for the production of synthetic fuels (partnership with Audi and Sunfire).

Exhibit 96: Schematic of ClimeWorks DACCS project



Source: Climeworks

Global Thermostat

Founded in 2010, Global Thermostat's DACCS approach involves amine-based chemical sorbents that are bounded to porous ceramic 'monolith' structure. The captured CO_2 is then stripped and collected over steam at temperatures 80-100°C with the sorbent regenerated (temperature-vacuum swing regeneration). The plants are modular in design and can be stand-alone. Global Thermostat's monolith design for air contraction provides a high surface area per unit of pressure drop, reducing the energy requirement of air flow through the contactor. The company is partnering with some major companies including Exxon Mobil.

Theme #9: Assuring Sustainability

In a world where consumers are increasingly aware of the importance of climate change, and demand lower-carbon products and services, assuring the carbon content of different products and processes becomes an important business opportunity, as we discussed with the CEO of Intertek, a leading Total Quality Assurance provider to industries worldwide. Drawing on Intertek's experience in providing assurance, testing, inspection and certification services to the energy industry, CarbonClear™ is a new global program providing companies with independent carbon intensity certification across their entire oil and gas production portfolio, in aggregate or by field, powered by Intertek's global network of technical experts. In July 2020, the company announced the first certification awarded under its new CarbonClear independent upstream carbon intensity certification program to Lundin Energy (whose CEO also attended our Carbonomics conference), for its Edvard Grieg field in the central North Sea.

The CEOs of the leaders in voluntary carbon credit certifications, Verra and the Gold Standard Foundation, also joined our conference, discussing the importance of standards and certifications for a sustainable future. We examine in the section below the importance of carbon offsets and the voluntary carbon credits market.

An overview of carbon offsets

Voluntary market: Voluntary emission reduction carbon credits

Carbon offsets are produced by projects that carry out emissions reduction activities, and are typically measured in metric tonnes of carbon dioxide equivalent, or tCO_2e. They can **either be traded on the voluntary markets** or **as part of a compliance market**. The distinction is important, with voluntary markets enabling companies and individuals to offset their carbon emissions on a purely voluntary basis by purchasing carbon credits that reduce GHG emissions or capture them from the atmosphere. While voluntary markets are distinct from compliance markets, they typically operate in parallel and are largely based on the Kyoto CDM and JI models. Voluntary market standards for instance have been developed to ensure the principles of additionality, permanence and leakage are complied with. The majority of those standards also require the use of independent auditors to assess a project. Examples of these standards include the **Verified Carbon Standard (VCS) by Verra**, **Gold Standard VERs, Climate, Community & Biodiversity Standards (CCBS), Climate Action Reserve (CAR)** and **Plan Vivo.**

Similar to the compliance market, voluntary markets define a carbon credit on the basis of 1 $tnCO_2eq$, and these credits are known as verified emission reductions. It is important, however, to distinguish between the types of carbon credits:

- **Ex-post credit:** The typical carbon credit that is sold after the credit has been produced and issued by the certification body (one of the 'Standards' outlined above).

- **Ex-ante credit**: This credit is issued by the certification body before the emission reduction occurs. The project is first certified by an independent auditor who also verifies the conservative estimate of abatement potential and credits to be generated within a timeframe. The auditor also needs to periodically verify whether these credits have been indeed produced. This type of credit is quite rare and only a few standards (certification bodies) in the voluntary market provide them. The compliance market, such as CDM, does not offer this option. The reasoning behind ex-ante credits typically lies in the fact that those credits can generate income from the start of the project, which is particularly important for forestry projects, in which it may take 5-15 years before the first revenue is received and 25-30 years before significant revenue materializes. Given the riskier nature of this credit, typically a buffer is put in place to compensate for this.
- **Forward Emission Reduction Purchase Agreement (ERPA):** An agreement whereby the seller and buyer agree the sale of a fixed amount of credits before they are produced and issued, with the actual payment typically happening when emissions have been verified and credits issued.

Certification standards:

While in voluntary markets there is not a strict procedure to be followed (in the same sense that CDM outlines), the typical project process involves: 1) Feasibility study, 2) Estimates of abatement volumes, 3) Acquiring finance, 4) Development of project design document (PDD), 5) Certification (validation of project design), 6) Credit production and monitoring, 7) Verification of emissions, 8) Credit issuance, and 9) Continuing monitoring and re-verification.

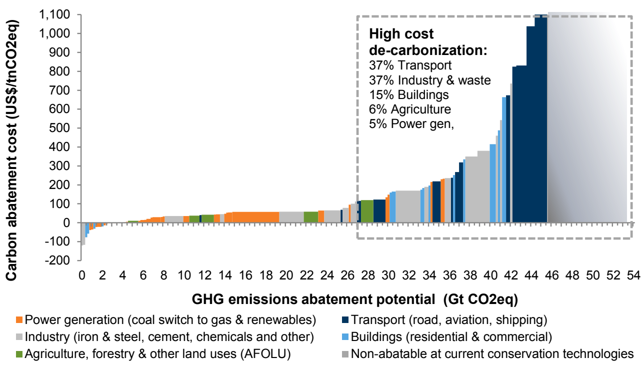
One of the most critical parts of the process for voluntary emission reductions carbon credit issuance is the **certification** process (validity) whereby a third-party audit is used to assess the conformance of the project design and documentation to the certification body's standards. Once certified, the project can start producing credits, with the project manager monitoring the emission reductions made over the course of time. Following that, the **verification** of emissions is required whereby an independent auditor periodically verifies that the emission reductions have indeed taken place.

Certification bodies are therefore the ones that design and issue certification standards and assess the project's compliance with those. All standards require a third party to verify a project's emission reduction prior to credit issuance. This auditor must first be approved by the certification body; therefore, certification bodies or standards have one of the most critical roles of the credit issuance process. There exists a wide variety of such bodies, each with different types of credit permitted for certification.

Theme #10: De-carbonizing Basic Materials

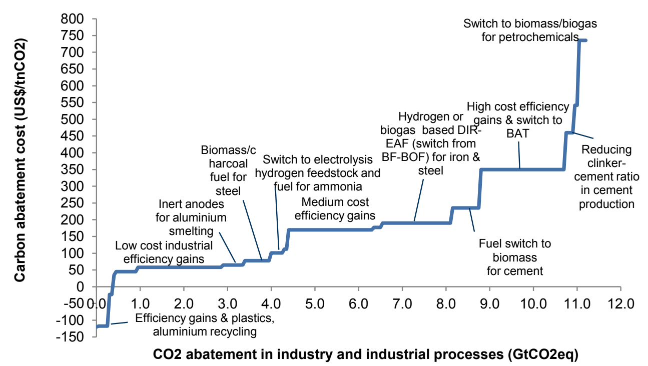
De-carbonizing industry (including industrial waste) is one of the most complex and important areas of carbon abatement. Key emitting industrial sub-sectors include, among others, iron & steel, cement and petrochemicals manufacturing, as well as emissions associated with industrial heating/combustion and industrial waste. As industrial output continues to grow in line with a growing economy to 2050, the industrial sector could face challenges in balancing the rising output while simultaneously meeting the emission reduction targets implied by the Paris Agreement.

Exhibit 97: Industry and industrial waste is another sector which is hard and costly to de-carbonize...
Conservation abatement cost curve for anthropogenic GHG emissions



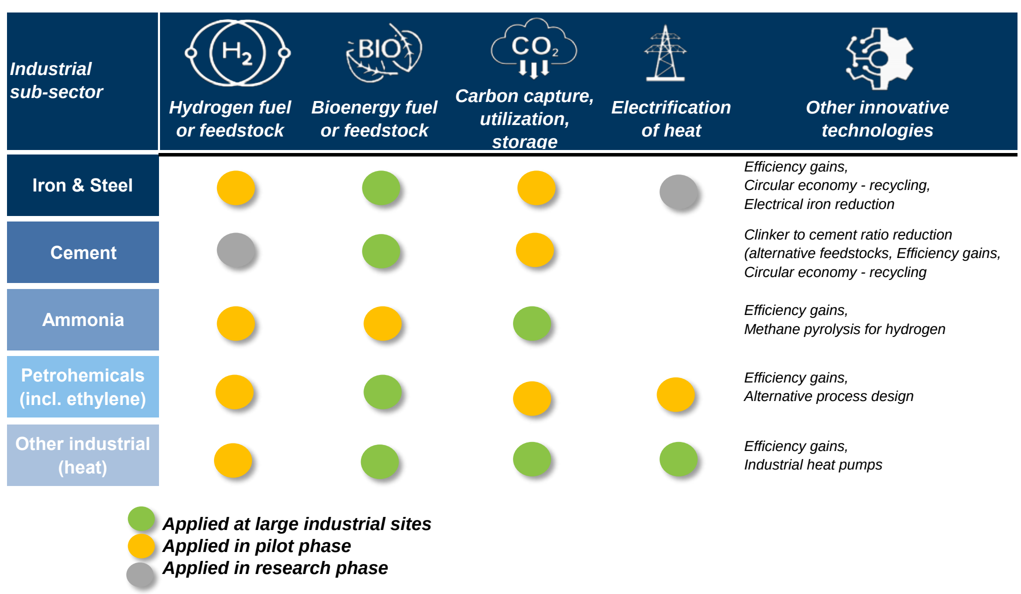
Source: Goldman Sachs Global Investment Research

Exhibit 98: ...with available technologies including, among others, the use of bioenergy, hydrogen, higher efficiency, circular economy (recycling), alternative feedstocks and carbon capture
Emissions conservation cost curve for industry



Source: Goldman Sachs Global Investment Research

Exhibit 99: Summary of key de-carbonization technologies for major industrial emitting sub-sectors



Source: Company data, Goldman Sachs Global Investment Research

The case for the de-carbonization of iron & steel

Iron & steel is, along with cement, one of the highest emitting industrial sub-sectors, emitting directly c.3GtCO2eq pa. Industrial emissions are typically classified into two categories, process and energy emissions, with the former referring to the emissions associated with the processing of feedstocks and the latter typically referring to the emissions associated with the production of high-temperature heat (combustion). There currently exists a range of conservation de-carbonization technologies that could aid the iron & steel industry's emissions (which primarily stem from the iron ore reduction process) abatement, such as switching from the traditional blast furnace BOF-BF process to hydrogen-based DIR-EAF (H2-DIR-EAF), bioenergy to fuel the process (biogas, charcoal) and circular economy, zero-carbon electrolysis for iron reduction. Sequestration (carbon capture) is also a critical technology that could help unlock full de-carbonization of several industrial sectors, as mentioned in the Theme 8 chapter, including iron & steel.

At our Carbonomics conference, we hosted senior management from ArcelorMittal, one of the leading steel suppliers globally, discussing some of these technologies and the company's building blocks to help it achieve its emission reduction targets (reduce emissions by 30% by 2030 and be carbon neutral in Europe by 2050). The company's €250 mn innovation program pilots a range of technologies that could enable a significant reduction in its carbon footprint and help it to achieve its goal. Among these are (1) the use of clean power as the energy source for hydrogen-based steelmaking, and longer term for direct electrolysis steelmaking (the company has made a €65 mn investment at its Hamburg site to increase the use of hydrogen for the direct reduction of iron ore), (2) circular carbon steelmaking, which uses circular carbon energy sources, such as waste biomass, to displace fossil fuels in steelmaking (Torero – €40 mn investment to convert waste wood into bio-coal to displace the fossil fuel coal currently injected into the blast furnace; Carbalyst – a technology to capture waste gases from the blast furnace and biologically convert it into bio-ethanol. The €120 mn launch project at ArcelorMittal Ghent is expected to be completed by the end of 2020), and (3) carbon capture and storage, where the current method of steel production is maintained but the carbon is then captured and stored or re-used rather than emitted into the atmosphere (IGAR – captures waste CO_2 from the blast furnace and converts it into a synthetic gas that can be re-injected into the blast furnace in place of fossil fuels to reduce iron ore. An industrial pilot of this technology is being developed at ArcelorMittal Dunkirk in France.).

The case for the de-carbonization of cement

Cement is another highly emitting industrial sub-sector. About 80% of cement is today used as a binder in concrete, which is a mixture of aggregate (sand or gravel), cement, and water. Cement production is expected to rise substantially by 2050, with most of the new production occurring in developing regions. Nearly all of the emissions from cement manufacturing result from two activities: (1) the combustion of fuel (such as coal, petcoke, biomass or waste) to heat cement kilns where calcination takes place to a temperature that exceeds 1,600 °C (accounting for c.40% of emissions), and (2) the calcination process in which calcium carbonate turns into calcium oxide. The substance that results from the kiln firing process, known as clinker, is ground and sometimes blended with other minerals to form cement.

Technologies to de-carbonize cement manufacturing include, among others, the switch to a zero-carbon fuel such as biomass, circular economy, reducing or substituting the clinker or limestone with other minerals to help reduce process emissions and carbon capture of the exhaust gases of cement kilns. We hosted the CFO of LafargeHolcim at our Carbonomics conference, speaking about the company's vision for the de-carbonization of the cement industry, as well as its pledge to become a net zero company by 2050. LafargeHolcim's buildings blocks to net zero include the reduction of the clinker to cement ratio to 68% by 2030, increasing the use of waste-derived fuels (biomass) to 37% in a similar timeframe, and carbon capture and storage, with LafargeHolcim stating that it is currently piloting over 20 CCUS projects across Europe and North America. Moving beyond scope 1 emissions, the company also aims to expand its renewable energy portfolio and waste heat recovery.

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Reg AC

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