HSBC Global Research

Free to View
Equities - Global

March 2021
www.research.hsbc.com

By: Tarek Soliman

SPOTLIGHT

Carbon Capture & Sequestration

Back in the debate, but no silver bullet

Carbon capture has re-emerged as a key decarbonisation option, but does not represent a 'silver bullet' or a substitute for deep emissions cuts

After a decade of losing ground to wind and solar, the 2020s are likely 'make or break' for the technology to play a key role in reaching global net zero emissions

Corporate appetite to invest in CCS is growing but remains sensitive to policy support

This is an abridged version of a report by the same title published on 23-Mar-21. Please contact your HSBC representative or email AskResearch@hsbc.com for more information.

Play video with Tarek Soliman

Why read this report

- Carbon capture is forcing its way into the net zero emissions debate, but captures less than 0.5% of global CO_2 today
- The 2020s are likely to be 'make or break' for its role to 2050, in our view, after losing ground to other technologies
- Direct policy support is needed for its development; we think it's too early to rely solely on carbon price expectations

Why are people talking about carbon capture?

After a decade when other emission-reducing technologies have dominated the narrative on energy transition, carbon capture & sequestration (CCS) is making its bid to be part of the global push for 'net zero'. Its key attribute is offering 90% reduction in CO_2 intensive activities and even so-called 'negative emissions'. However, to date there has been more talk than action, and the merits of CCS as a meaningful part-solution to the climate issue are debated. Nonetheless, an increase in interest from countries, corporates and even Elon Musk – who has offered a USD100m grant for CO_2 removal technology development – is tangible.

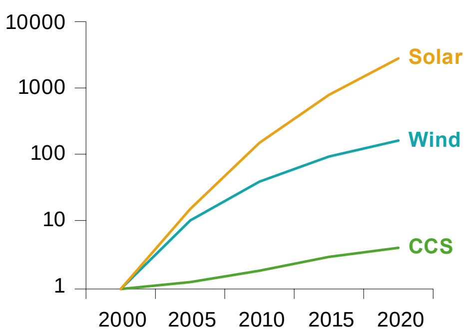
In assessing CCS's future, we believe the themes outlined below are the most pertinent issues:

- **2020s are likely 'make or break' for carbon capture.** After years of losing ground to other emissions reduction technologies, we think this decade is likely to define whether the technology takes a leap on its development journey or remains in the shadows.
- **Its current impact and potential future role need important context.** Carbon capture has a negligible effect on global CO_2 levels today, and even in our high case scenario for 2050 deployment it is no substitute for deep emissions reductions across the energy system, rather it is a part of the 'net zero' technology toolbox.
- **Costs need to fall and deployment to be ramped up; policy is crucial.** For carbon capture to go mainstream it needs direct policy support to kick-start adoption, drive cost reductions, provide track record learnings and improve private sector investor confidence.
- **Its ability to cut emissions in 'hard to abate' sectors is key to its mandate.** Areas of the energy system (eg cement or steel) that can't decarbonise via electrification or other low-carbon options could be a key catalyst for carbon capture use in coming years.
- **Mostly a developed market story.** Carbon capture activity mirrors policy support and momentum, which is highest in North America and Europe, with limited scope in emerging market nations to date.
- **Appetite to invest is improving, but faces numerous hurdles.** Private investment in carbon capture is often limited to involvement alongside governments or where financial incentives are available; headwinds to invest are numerous and will need to be overcome.
- **Image issues linger.** Carbon capture does have its detractors on a number of issues that will need to be addressed for the technology to become more widely accepted.

This is an abridged version of a report by the same title published on 23-Mar-21. Please contact your HSBC representative or email AskResearch@hsbc.com for more information.

Make or break decade for carbon capture

Carbon capture deployment has lagged that of solar and wind (indexed to 1 in 2000, log scale)

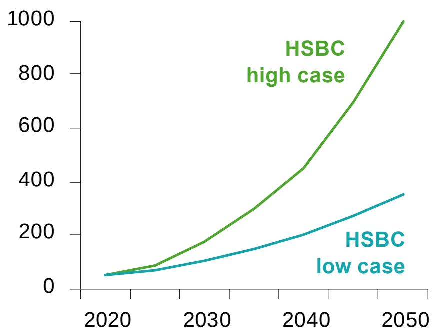


Up to

60%

of global CO_2 could be addressed using CCS, but today less than 0.5% of emissions are captured

Carbon capture use by 2050 is uncertain (CCS capacity, m tonnes CO_2)



Carbon capture & sequestration (CCS) value chain

1. Capture
Capturing CO_2 from fossil or biomass-fueled powerstations, industrial facilities, or directly from the air

Key sectors which can use carbon capture

INDUSTRY

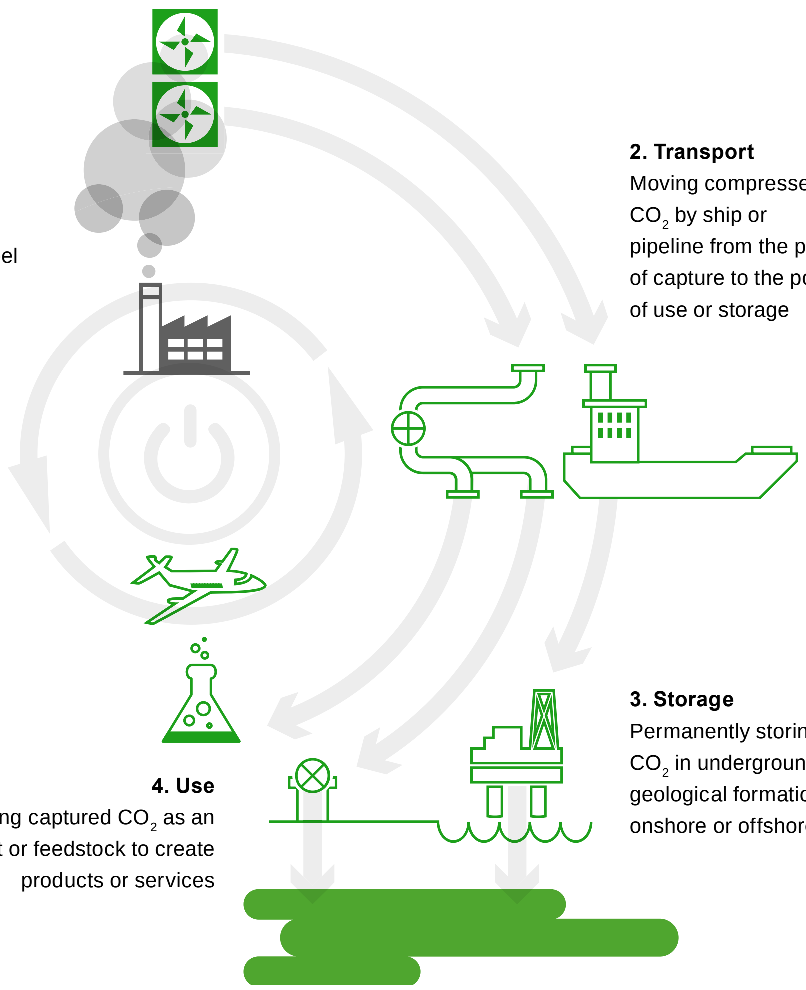
Chemicals | Hydrogen | Cement | Iron and steel

ELECTRICITY GENERATION

Natural gas-fired | Coal-fired | Bio-energy | Waste-to-energy

ENERGY

Natural gas processing / LNG | Oil refining



2. Transport
Moving compressed CO_2 by ship or pipeline from the point of capture to the point of use or storage

3. Storage
Permanently storing CO_2 in underground geological formations, onshore or offshore

4. Use
Using captured CO_2 as an input or feedstock to create products or services

Source: BNEF, IEA, Global CCS Institute, HSBC estimates

Executive summary

- Carbon capture can play a key role in getting the world to 'net zero' but its deployment to date has been a stop-start story
- To 'move the needle' in global emissions it needs policy support, cost reductions, technological advancement and more investment
- In our view, the 2020s will represent a fork in the road that will likely define carbon capture's future role

Make or break

Carbon capture & sequestration (CCS) is not particularly new – some large-scale plants have been operating for over 20 years. It can offer a potential 90% reduction in CO_2 from carbon-intensive processes and fossil fuel use in a range of industries, but its adoption as an emission-lowering technology of choice by policy-makers and corporates has been underwhelming so far.

The stop-start story around CCS has meant its adoption rate pales in comparison to the very strong growth witnessed in wind and solar as forms of zero-carbon electricity since the mid-2000s; it also lacks the widespread optimism that has accompanied the recent rise of green hydrogen as a future energy source.

As carbon capture has remained somewhat 'dormant' in recent years it does not have a meaningful impact on global emissions today and is a prime example of a technology that is talked about more than it is actually used.

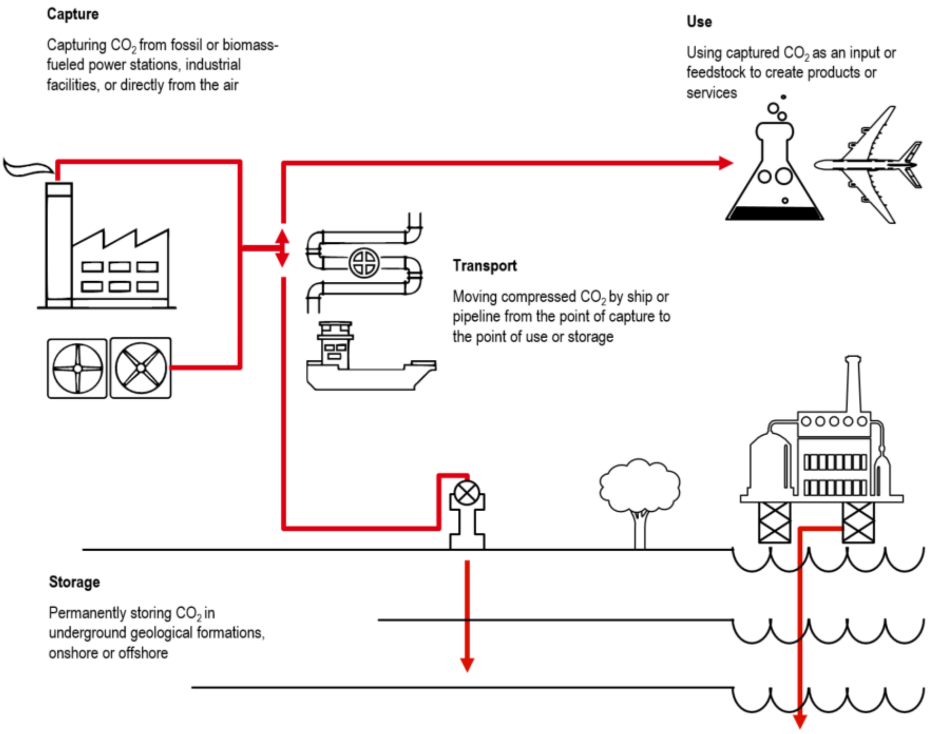
However, as the world increases its focus on ever more ambitious climate targets that imply major changes to the energy system, all avenues to reduce CO_2 emissions are making their way back into the fold. Interest in carbon capture has seen a notable uptick recently, especially in Europe where it has a limited presence today but is increasingly seen as a key part of the toolbox to reach 2050 'net zero' emissions goals set at a country and regional level (sentiment echoed by the IEA and IPCC, that note the difficulty of reaching net zero without using CCS).

Nonetheless the idea of spending potentially hundreds of billions of US dollars to ramp up the global carbon capture footprint is also divisive; some think that the assumption CCS will be deployed at scale in the future risks giving the impression that actions today to cut emissions elsewhere in the energy system are either not necessary or less urgent. We do not consider carbon capture a 'silver bullet' but rather a piece of the jigsaw to drive the decarbonisation push.

In this report we outline why we think the 2020s are potentially defining for carbon capture to earn a prominent role in a future lower-carbon energy system, as well as highlighting some of the hurdles that will need to be overcome along the way.

CCS works by capturing exhaust CO_2 from emissions-intensive activities and permanently sequestering them underground

Illustration of the carbon capture & sequestration value chain



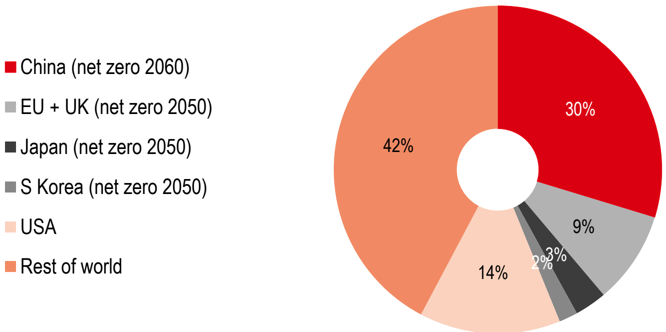
Source: IEA

As much as over 60% of global CO_2 could be under 'net zero' aims by the end of 2021

Global net zero ambitions have heightened focus on carbon capture

As nations around the globe have increased their climate ambitions, a critical mass of world energy-related emissions are now subject to a 'net zero' aim of some sort. The total currently stands at around 45% of global CO_2, but as the US has indicated it may follow suit, this could rise to over 60% in 2021. This backdrop has helped carbon capture re-emerge as one of the potential tools for deep, economy-wide, decarbonisation.

Countries with 'net zero' ambitions as a share of 2019 global CO_2



Source: EU EGDAR data base

We list some attributes that apply to carbon capture …

What carbon capture & sequestration is …

- Carbon capture remains one of the few technological options for deep decarbonisation in certain emissions-intensive activities; in particular, these are so-called 'hard to abate' sectors where other options may be limited and include cement, steel and iron.
- It can help avoid significant 'locked-in' emissions from existing assets where the capital stock is young enough to warrant retrofitting – the IEA estimates that CCS could be fitted to sites that would otherwise still be emitting 8bn tonnes of CO_2 in 2050 (~25% of 2019 global total energy-related emissions).
- Depending on the project scale and new infrastructure needs, CCS can be deployed quite quickly (two to four years) and is a permanent CO_2 sequestration solution with a lower risk of reversal (eg compared to forests, which can take longer to sequester CO_2).
- With no medium-term shortage of suitable CO_2 sequestration sites globally, there is scope for carbon capture to be scaled up to a much larger extent than is being deployed today.
- Carbon capture can expect to realise cost and performance improvements as it benefits from 'learning from doing' and economies of scale through deployment.
- Certain forms of carbon capture – BECCS (bio-energy and CCS) or DAC (Direct Air Capture) – can offer feasible routes to carbon dioxide removal or so-called 'negative CO_2' energy streams to help balance out emissions that are unavoidable elsewhere.
- Captured CO_2 can also be a key input to the production of synthetic fuels as a lower carbon option for long distance transport (eg synthetic kerosene for aviation).

… and others that we do not think represent the technology's role

... and what it isn't

- The technology isn't currently a major contributor to emissions reductions, and in our view should not be considered as a substitute for, or a way to avoid, structural changes in the energy system on the assumption that CCS can 'fix the problem'.
- Carbon capture isn't always a relatively easy or cost-effective solution for all types of emissions (eg it is typically applicable to fixed or stationary sources of CO_2); in many cases other options such as renewables, efficiency or hydrogen can be better trade-offs.
- Capture rates are often assumed at 90% and will therefore leave residual CO_2. The assumption also doesn't account for potential emissions that occur elsewhere in a process, such as CO_2 from upstream gas production before its use (with carbon capture).
- Few high-emitting companies will be able to completely decarbonise solely using carbon capture.
- There isn't one cost of CCS per tonne CO_2 globally or within industries, costs can also appear high and variable from project to project, reducing the visibility on its economics.
- CCS isn't built in isolation but often requires accompanying infrastructure build-out.
- Large-scale commercial applications and permanent sequestration generally do not have a long operating track record across multiple industries and geographies.
- Carbon capture infrastructure isn't typically very flexible; it's often large, rigid and fixed equipment (although smaller modular CCS units are being developed).
- Attracting private capital has been a struggle to date, with investments often relying on direct policy support or government involvement alongside corporates.
- Carbon capture has also suffered from image issues over the years around its role as a decarbonisation technology, including whether it should be given priority for funding, whether it is a tool to continue fossil fuel use, and its cost-effectiveness.

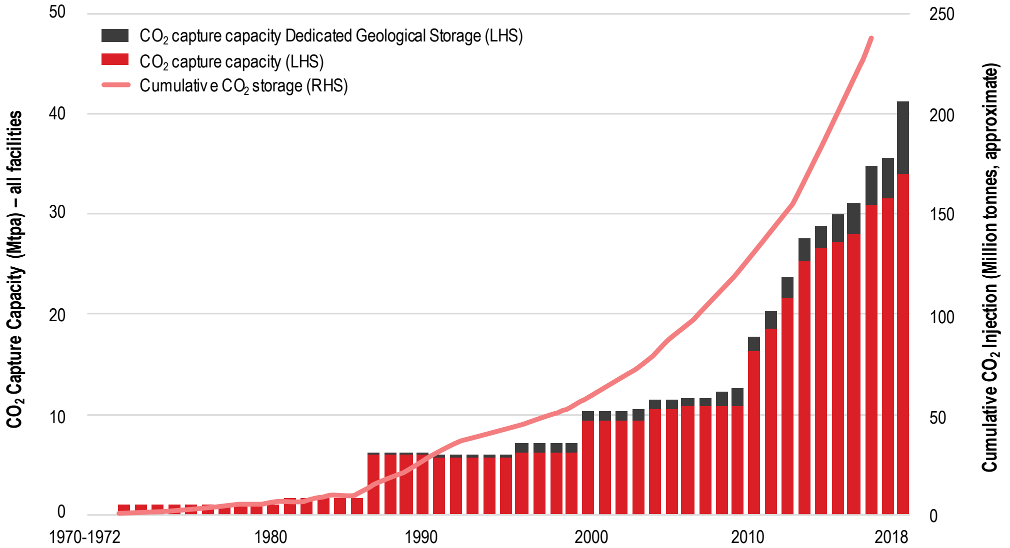
CCS captures <0.5% of global CO_2 today …

Context on carbon capture's current and potential role is important, in our view

CCS is a part of the current energy system, albeit it a small one, capturing less than 0.5% of global energy-related emissions. The c.40m tonnes of CO_2 pa of large-scale capture capacity deployed today roughly equate to the operational (scope 1-2) emissions of a single oil major. Although it is a technology used in the field today, the majority of CCS industry applications are classified by the IEA as either in 'early adoption' or 'demonstration' phases and certainly not at the scale required to make a more meaningful impact on global emissions.

…. with most of it used in enhanced oil recovery

Historical global carbon capture capacity 1970-2019

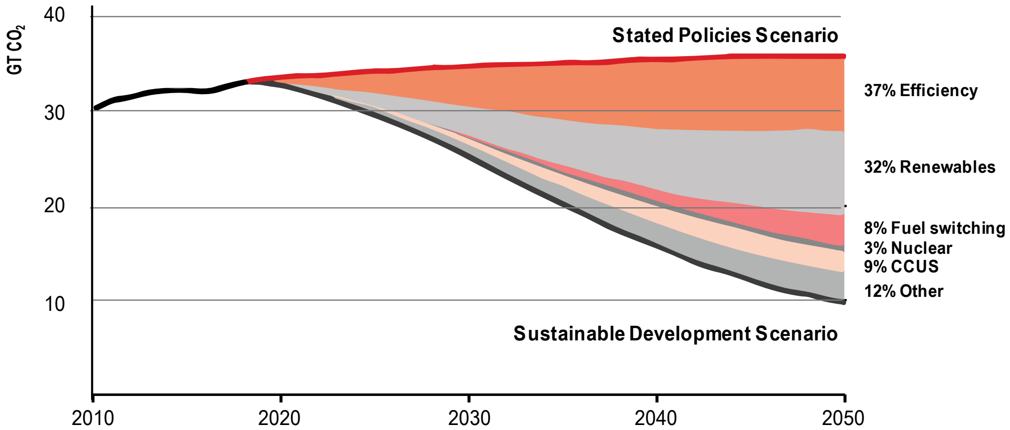


Source: Global CCS Institute

CCS is the third largest contributor to cumulative 2050 emission reductions in IEA's low-carbon scenario

Its potential future scale and role are widely debated. The IEA and IPCC believe that reaching global 'net zero' is near impossible without carbon capture, but it is also a technology that cannot alone reduce global CO_2 in the magnitude required to reach climate ambitions – for example, it contributes just under 10% of emissions reductions in one of the IEA's key scenarios below, behind the much larger role of renewables and energy efficiency.

CCS' role in IEA decarbonisation pathways to 2050

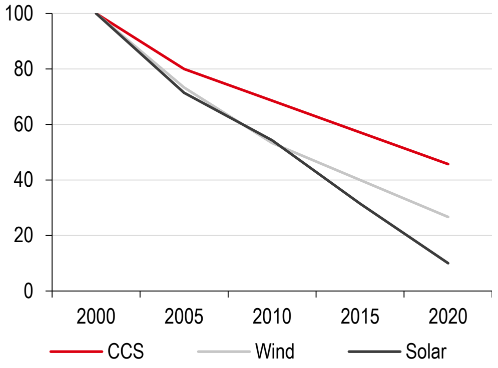


Source: IEA

A lost decade has left CCS well behind wind and solar as efforts focused elsewhere...
Carbon capture has 'sat on the shelf' in the last decade as other forms of clean energy or emissions-reduction technologies, supported by policy and buoyed by capital flows, have driven costs down and scaled up deployment. CCS differs to wind and solar in many ways but the trajectories on these key adoption indicators that each has followed since 2000 are stark to see.

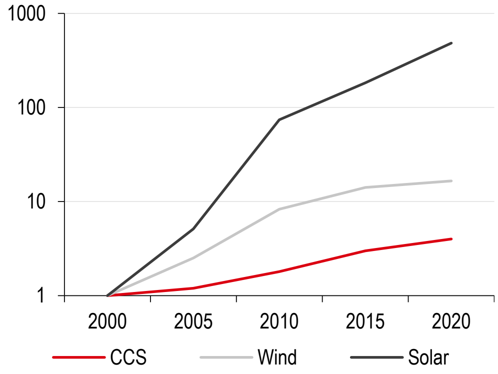
To demonstrate the lack of progress in the last decade, the IEA's 2009 CCS roadmap set a target of developing 100 large-scale carbon capture projects by 2020 to store around 300m tonnes of CO_2 per year; actual capacity today is only around 13% of the target. Momentum behind carbon capture has grown in the last 24 months but without meaningful progress in the 2020s around cost, breadth of application and scale of deployment, we think its potential role in wider decarbonisation in coming decades could be materially impaired if it never 'gets off the ground'.

CCS costs have fallen slower than wind and solar (indexed to 100 in 2000)



Source: BNEF, IEA, HSBC estimates

CCS deployment has also lagged solar and wind (indexed to 1 in 2000, log scale)

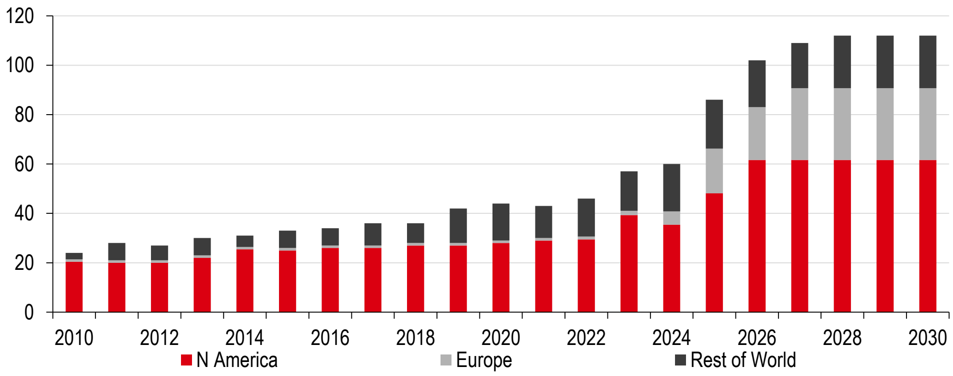


Source: BNEF, Global CCS Institute, HSBC estimates

Carbon capture project activity is growing but constrained to DM markets with policy support, EM involvement is limited

… but the visible pipelines indicate a more than doubling of global capacity by 2030…
A resurgence in interest in carbon capture has been bolstered by net zero emissions aims, policy developments in some geographies and a higher willingness to offer support to 'hard-to-abate' sectors. Expected and announced new carbon capture projects could more than double global capacity this decade and are concentrated in developed markets with either a historical relationship with the technology or where policy focus is shifting in its favour; namely North America, the existing global leader in carbon capture, and Europe, which is seeking to establish a presence in the technology around an industrial cluster model.

Global large-scale carbon capture capacity by region (m tonnes CO_2 per annum)



Source: Rystad Energy

Some climate models see the need for 250x more carbon capture by 2100 to limit global temperature rises…

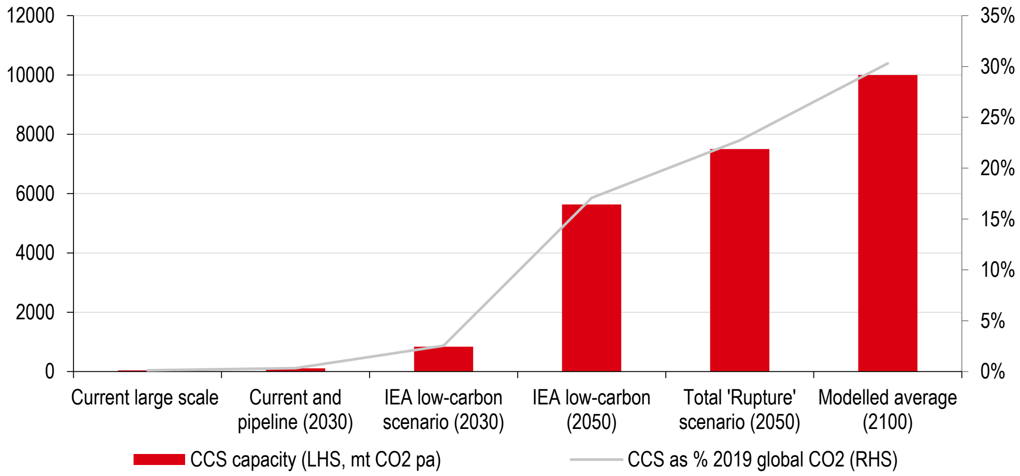
… and we've noticed a growing 'expectation gap' emerging on its potential future role

The potential long-term role of carbon capture is widely debated and uncertain given its current low base and lack of scale track record; this has led to the emergence of an 'expectations gap' of its role post 2030 among different forecasts and scenarios. To some, carbon capture is simply a concept technology with limited deployment to date and a questionable future; to others it's one of only a few ways to facilitate deep emissions cuts across the energy system.

Long-dated energy-climate models that provide pathways to possible energy systems that limit global warming (to say 2°C), offer another insight into how much carbon capture we might *need* to hit climate ambitions – the answer invariably is hundreds-fold increases in coming decades from current levels. For context, the assumed rate of CCS deployment to 2050 in some of these models roughly translates to a new 1m tonne CO_2 pa plant being constructed every other day continually for the next 30 years – whereas the current run rate is one or two plants a year.

… but in our view, 1bn tonnes of CO_2 of CCS capacity by 2050 is a more realistic high-case forecast

Carbon capture & sequestration deployment in various energy-climate models



Source: Global CCS Institute, IEA, Total, HSBC. Note: scenarios vary on global temperature increase limits, and other assumptions.

Private capital has been slow to invest in CCS and needs policy support

The CCS market is immature and appetite to invest can be fragile; policy is crucial

The IEA estimates that in 2020 governments and industry committed more than USD4.5bn to CCS – an improvement from previous years, but a small sum in the overall energy transition. As a technology, carbon capture has historically struggled to attract private capital and in our view many of the hurdles to invest still persist, namely high project risk given a typical individual large CCS development costs several hundred USDm, a lack of market value (explicit or implicit) attached to the act of abating CO_2 in many jurisdictions, and the absence of other supportive policies to aid its deployment.

Policy support mechanisms are central to carbon capture's evolution; for example, federal tax credits for using or sequestering CO_2 in the US have helped build its global leading position, whereas European governments are now developing strategies for corporates to co-invest in projects alongside public entities.

Some company forecasts see a multi-trillion-dollar market for CCS in 2050

Some corporates with exposure to the CCS value chain envisage a multi-trillion-dollar market by 2050, but the size and nature of a future global carbon capture market are still uncertain. CCS deployment to date has largely been where CO_2 capture (and/or use) makes direct and short-term economic sense; the next deployment step for carbon capture appears to be at large emitters looking to reduce their own operating emissions. However, in the medium term we see scope for CO_2 capture and management to become practised as a part of a broader range of services, including 'pay per tonne captured' models.

Carbon capture will need to take significant strides in coming years to be a meaningful part of the 2050 energy system

The 2020s are 'make or break' for carbon capture, in our view

The coming years represent a crucial decade for global climate action. The IPCC calculates that world emissions need to halve from current levels by 2030 to be on track to limit warming to 1.5°C. With growing national and corporate conviction on delivering net zero emission economies and businesses, we think climate action will need to move into a higher gear in the 2020s; however, questions remain around the role of carbon capture on the road to 2050.

Momentum behind carbon capture is higher than it has been in recent times, but if the technology fails to gain a solid foothold in coming years through wider deployment across a number of industries, then it risks stagnating and potentially being overlooked in the race towards decarbonisation. That is to say, in our view, it could be difficult for CCS to scale up in future decades (when it might be needed) if it stays somewhat 'dormant' in the 2020s and does not make meaningful progress towards building a platform for future at-scale deployment.

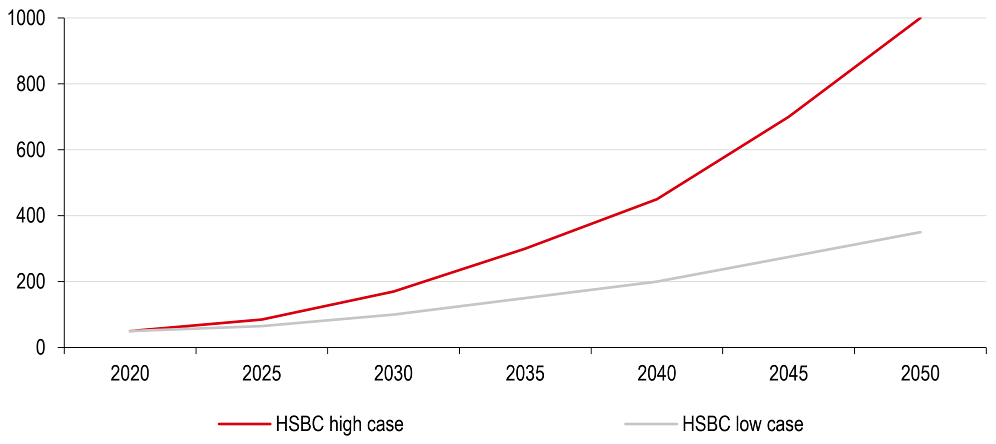
Policy support will be crucial in the technology's journey to provide an incentive framework for investment and build momentum in the industry, which is central to it delivering cost reductions, establishing a stronger track record and increasing the number of successfully de-risked projects. Ultimately, by the end of this decade CCS needs to be at a point where it can begin to tap into private capital and where there is some sort of visibility around a market structure for CO_2 capture that rewards investment with a suitable return.

We think the future will feature more carbon capture as a way to clamp down on emissions in certain sectors, but the outlook to 2050 holds many uncertainties. In a scenario where it does not successfully build on the current project pipeline, and is only deployed in certain corners of the world or in niche industrial applications, we estimate global capture capacity could be in the region of 350m tonnes of CO_2 pa by mid-century.

In a case where conviction to act on carbon emissions tightens, and net zero ambitions are followed up with policies and funds – and specifically a meaningful role for CCS – then we could feasibly see a scenario where 2050 capture capacity is closer to 1 gigatonne (billion tonnes) of CO_2 pa.

Capture capacity of 1bn tonnes of CO_2 a year by 2050 could result in a cumulative capital spend of between USD500bn and USD1 trillion

HSBC scenarios of CCS capacity deployment to 2050 (m tonnes CO_2 pa)



Source: HSBC estimates

This is an abridged version of a report by the same title published on 23-Mar-21. Please contact your HSBC representative or email AskResearch@hsbc.com for more information.

Carbon capture 101

- CCS can offer deep decarbonisation for high-emitting sectors with 90% CO_2 capture, but lacks visible track record and installed base
- Post-combustion capture is most common approach but new methods such as Direct Air Capture are emerging
- After being captured, CO_2 needs to be either used or transported to a suitable permanent sequestration site

Not new, but under-used

In this section we outline the basics of CCS including capture technologies, how CO_2 is used and sequestered

Carbon capture & sequestration has been practised in various forms dating back to as early as the 1990s. In its current form it can offer a potential 90% reduction in CO_2 from certain processes by capturing as much of the emissions as possible to prevent them from reaching the atmosphere and sequestering them underground in a secure geological formation. The broader history of treating flue (exhaust) gases to remove or contain unwanted elements is even older, and includes desulphurisation from fossil fuel-powered power stations.

CO_2 has been stripped out from natural gas for decades (and then usually released into the atmosphere) in a process to improve the purity of the fuel source, rather than as an action to reduce emissions. Injecting CO_2 into oil & gas formations to improve recovery rates – again for economic or performance reasons, rather than climate considerations – has been a use of CO_2 practised in the US since the 1970s.

Purpose-built, at-scale, CCS has a shorter history but the technology has evolved with time, resulting in improved CO_2 capture rates and reduced equipment energy requirements. Bioenergy and CCS – together known as BECCS – emerged as a prospect around the turn of the century, and more recent approaches of taking carbon dioxide directly out of the atmosphere (Direct Air Capture or DAC) are being tested on a commercial scale. Even cement and concrete products that can absorb CO_2 over their lifetime are being researched as possible ways to bring down the amount of carbon dioxide in the atmosphere.

More broadly, CCS (in its various forms and technological approaches) has suffered from numerous false starts over the years and, as such, currently has an installed footprint that makes it a marginal technology in the global discussion around energy and carbon emissions. The need and urgency to cut carbon emissions have not been historically strong enough to warrant R&D funding and scale-up in carbon capture, and its costs and other characteristics have meant that it has somewhat sat on the side-lines in recent years.

Nonetheless, both the IEA and IPCC highlight the critical role that CCS, and other forms of carbon dioxide reduction, will likely need to play in order for the global energy system to reach ‘net zero’ emissions and limit global warming to 1.5-2°C.

Relevant sectors for carbon capture & sequestration

Source: HSBC

Methods to capture carbon dioxide emissions (CO_2)

Post-combustion capture is the most common and currently cheapest approach

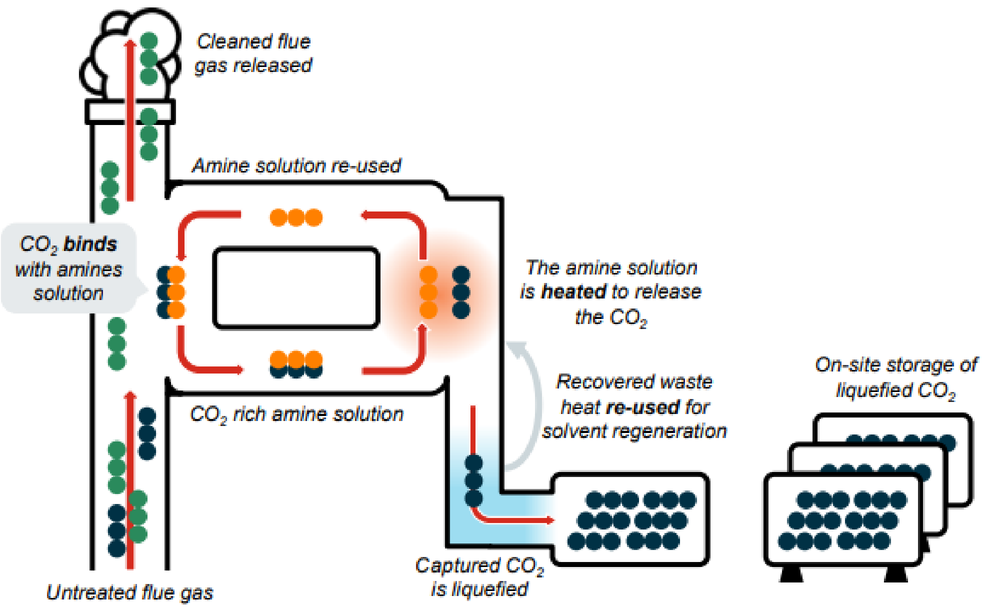
Capturing carbon dioxide emissions is often the most challenging and expensive part of the overall CCS process. Traditional methods of carbon capture work by filtering CO_2 out from flue (waste or exhaust) gases from a process that produces a high level of emissions from a single point, such as an industrial installation (eg chemicals, cement, steel) or a power station. Higher concentrations of CO_2 in flue gases can improve the effectiveness and efficiency of the process, as well as reducing its cost. Carbon capture equipment can, broadly speaking, be integrated into new-build projects or retrofitted to existing assets.

The three technological approaches to capturing CO_2 emissions are:

- **Post-combustion (see diagram below):** CO_2 is captured from the exhaust of a combustion process by absorbing it in a suitable solvent. The CO_2 is absorbed by the solvent (eg an amine) before being separated from it later on in order to be isolated before compression and transportation. This is the most common approach to carbon capture globally, is relatively application-neutral, allows for easier retrofitting to existing installations and is the most mature technology.
- **Oxy-fuel combustion:** The feedstock fossil fuel is burned in pure oxygen rather than ambient air; this produces CO_2-rich flue gas which is ready for capture in a relatively concentrated form. Future potential application of this technology is envisaged in cement and steel processes, but entails a process re-design.
- **Pre-combustion:** This involves converting the fuel (eg coal, gas or oil) into a mixture of hydrogen and high-concentrate carbon dioxide using a processes of gasification or reforming. This is similar to the process by which 'grey' hydrogen is produced.

These approaches to carbon capture typically involve large equipment to be applied to fixed or stationary sources of CO_2 emissions, and are therefore typically rigid; however, there is currently development of smaller-scale and more mobile carbon capture units

Simplified diagram of post-combustion carbon capture



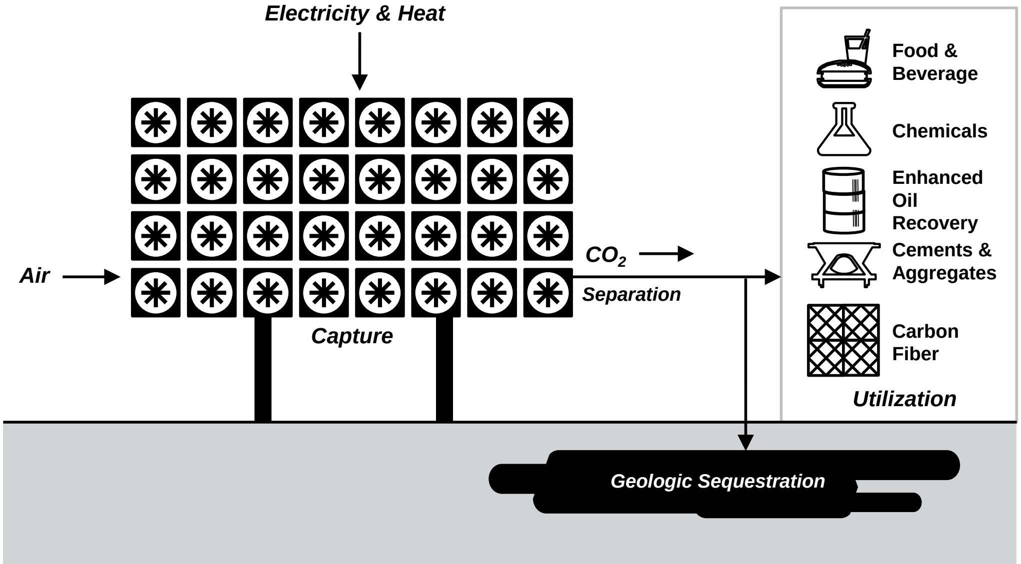
Source: Aker Carbon Capture

Direct Air Capture (DAC) – the alternative

Direct Air Capture – or DAC – is an alternative to traditional carbon capture. The key differentiator is that it extracts CO_2 directly from the atmosphere. Although often placed in the same category as CCS, it is actually a form of '*carbon dioxide removal*' as it takes existing CO_2 out of the air, rather than prevents new emissions entering the atmosphere.

Crucially, this approach allows a DAC site to be location independent – unlike conventional carbon capture (which needs to be placed at a concentrated source of emissions), which may or may not be near a suitable sequestration site. This allows DAC units to be placed optimally at positions where carbon dioxide is needed as an input to another process, or where there is ample sequestration capacity, in both instances reducing the need for transportation of the gas.

Example of Direct Air Capture (DAC)



Source: World Resources Institute

However, atmospheric concentration levels of CO_2 are low – around 415 parts per million – which means that the absorption volumes of DAC units can be small. Therefore, a lot of such units are required in order to capture a given number of tonnes of CO_2, and achieving its use at scale has been a challenge to date. DAC is also energy intensive, as the process involves drawing in large volumes of air into the fans, which means the units need to be situated in proximity to a cost-effective electricity source – ideally with low or zero associated generation carbon emissions.

Today, more than ten direct air capture plants are in operation in Europe and North America on a small scale, with CO_2 captured usually serving local utilisation needs.

This technology, in theory, gives some companies the option to capture their own emissions 'remotely' if conventional carbon capture is not suitable – eg an airline could deploy DAC to take CO_2 out of the atmosphere as a way to reduce its own 'net' emissions, whereas conventional carbon capture cannot be applied to aeroplanes.

Finding a permanent home

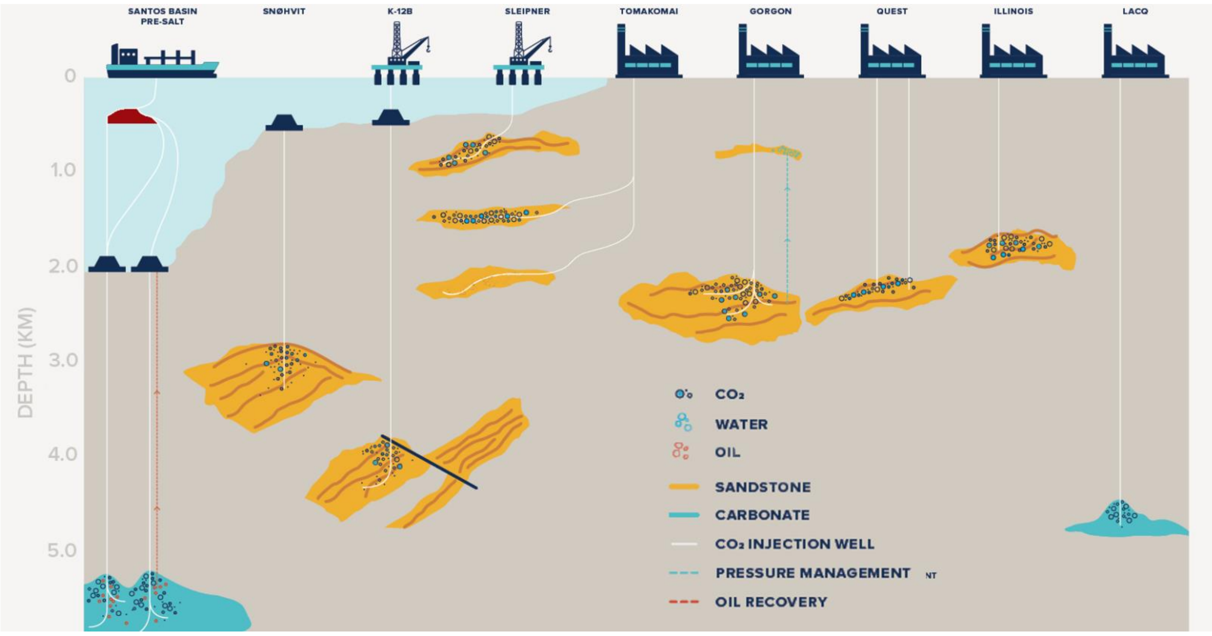
Once captured, the carbon dioxide needs to be handled and transported (via a pipeline or liquefied and shipped) to a suitable sequestration site for permanent storage. Limiting the distance or the complexity of the journey between the capture facility and sequestration site is a key consideration in deployment feasibility. Sequestration sites are usually geological formations (onshore or offshore) that will ‘trap’ the CO_2 once injected – typically active or depleted oil fields, and saline formations. The idea is to identify sites that have sufficiently large fluid capacity and suitable geological characteristics (porosity and permeability) to contain carbon dioxide for an extended period of time – ie potentially hundreds of years (in instances where carbon pricing exceptions are afforded to carbon capture, guarantees that captured CO_2 will remain stored for at least 100 years can be needed).

In the case of oil & gas fields, a lot of reservoir analysis will have been undertaken as part of the field development to indicate how suitable (or not) a given site will be. There is also likely to be existing infrastructure related to hydrocarbon production that may be able to be repurposed for CCS. However, oil & gas sites, by their nature, can be in challenging locations and often geographically concentrated which may or not suit CO_2 sequestration.

Saline formations – which contain low-quality water – are an alternative to oil & gas fields and are commonly found, but less often used for CO_2 sequestration (only two projects, both in Norway, use saline formations today). However, as these formations have typically not served an economic purpose to date, there is less known about them in most instances.

In long-term sequestration, the continual monitoring and verification of emissions is an important aspect of ensuring that CO_2 does not leak over time. Much of the monitoring process uses technologies developed for oil & gas production applications.

Examples of carbon dioxide sequestration at various geological formations globally



Source: Global CCS Institute

Captured CO_2 can also be used – the 'U' in CC(U)S

Carbon dioxide that is captured can be used in a number of applications instead of being sequestered – often referred to by an alternative acronym of carbon capture, use (or utilisation) and sequestration, or CC(U)S. The IEA estimates that more than 220m tonnes of CO_2 a year is used for various purposes globally; this number is larger than the currently installed large-scale purpose-built carbon capture capacity, but a small proportion of overall global emissions (~0.5% of world energy-related CO_2).

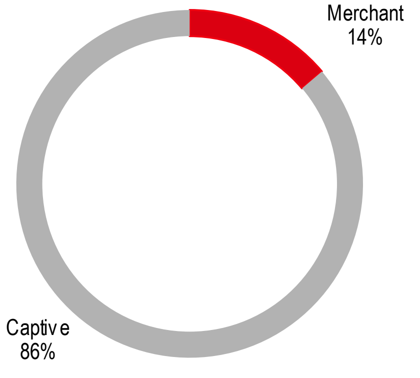
Common uses of CO_2 volumes typically include enhanced oil recovery (EOR) or as a raw material input into the production of synthetic fuels, chemicals or certain building/construction products. The largest consumer of CO_2 globally is the ammonia and fertiliser industry, which consumes in the order of 100m tonnes of CO_2 a year for urea manufacturing; EOR in oil production accounts for almost 80m tonnes of CO_2 use annually, with the balance used across other applications including food and beverage production, mineral carbonation and metal fabrication, according to the IEA.

In the case of EOR, CO_2 is actually 'used' to extract hydrocarbon volumes but also 'sequestered' as it usually remains trapped in the oil reservoir. Where captured CO_2 is used to make a product that is then itself combusted – eg synthetic liquid fuels – the carbon dioxide that was originally captured eventually returns to the atmosphere as the fuel is burned in its use phase. CO_2 that is used for industrial or energy applications is also not always captured; for example, in some EOR processes in the US it is easier and more economical to extract naturally occurring CO_2 in rock formations, which is then pumped into an oil reservoir to aid production.

CO_2 use in processes is also typically fed by captive means and there is no meaningful third-party merchant market for carbon dioxide volumes as a commodity today. IHS Chemical estimates the current CO_2 merchant market is just under 15% of total used volumes (around 30m tonnes of CO_2 a year) with the major end markets being food (25%), beverage carbonation (24%) and fabricated metal products industries (15%).

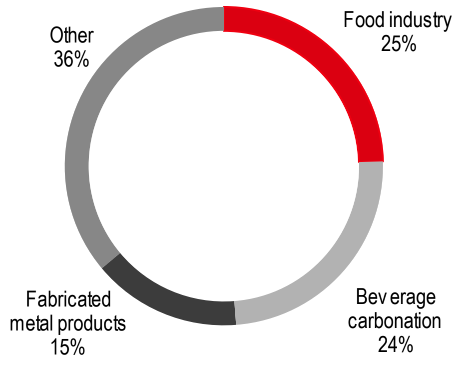
Although more CO_2 is used than captured today, we expect growth in CCS in coming years may lead to a reversal of the trend, depending on the deployment of the technology over time.

Global CO_2 market volume split (206m tonnes), 2019



Source: International Journal of Hydrogen Energy, HSBC

End market split for merchant CO_2, 2019



Source: HSBC, IHS Chemicals

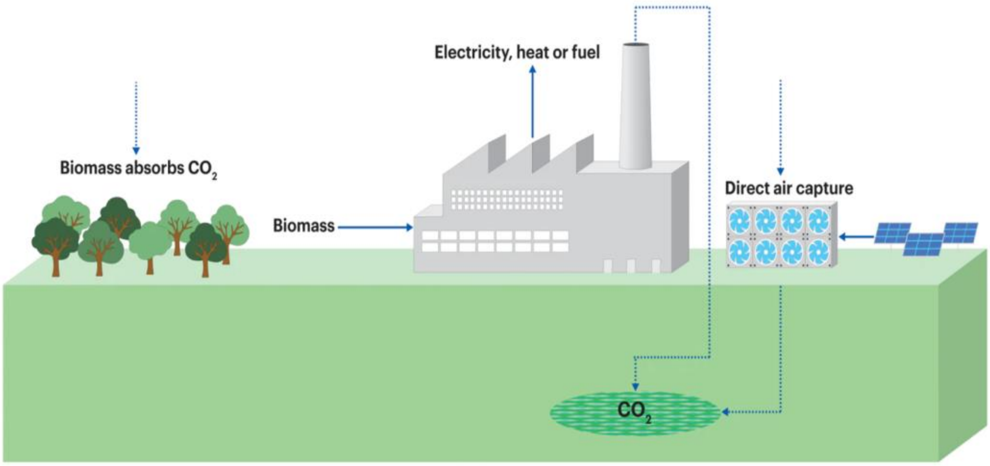
The lure of 'negative emissions' via BECCS

Drax's plans to go 'carbon negative' rely on the use of BECCS

Combining bioenergy (eg wood pellets in electricity generation) and CCS – a combination known as BECCS – is a possible route to 'negative emissions' from an energy source. For example, trees absorb carbon dioxide over their life, which creates a carbon 'sink' and a negative CO_2 balance at the point they are felled. When this biomass material is burned to generate thermal electricity, the CO_2 contained within the biomass is released, which creates (an assumed) net zero emissions process over the lifecycle.

If the emissions that are generated when the biomass is burned to produce energy are captured and sequestrated then, it is argued, the lifecycle process can be viewed as resulting in net negative emissions. This is due to the fact that as the combustion emissions are captured, the only 'net' interaction with the atmosphere is at the early stage of the biomass' life, ie where it absorbs CO_2.

Bio-energy with CCS (BECCS) and Direct Air Capture in carbon dioxide removal (CDR)



Source: IEA

There are a small handful of operational BECCS facilities today, where emissions from the use of biomass in industrial processes (eg ethanol production) or power generation are captured and sequestered.

As previously mentioned, many long-dated energy-climate models often factor in a large role for BECCS in the future, of up to 5bn tonnes of negative CO_2 by 2050, as a way of removing significant amounts of CO_2 from the atmosphere – but we do not view these as realistic expectations of its deployment and use.

The economics of BECCS as a route to negative emissions are currently more favourable than alternative options such as DAC, however, the use of biomass as a fuel source at scale faces its own challenges. These are: (i) debate around the emissions accounting of bioenergy and BECCS, and (ii) the competition for land and water resources that are needed for cultivating industrial amounts of bioenergy feedstock.

Placing carbon capture in the HSBC Disruption Framework

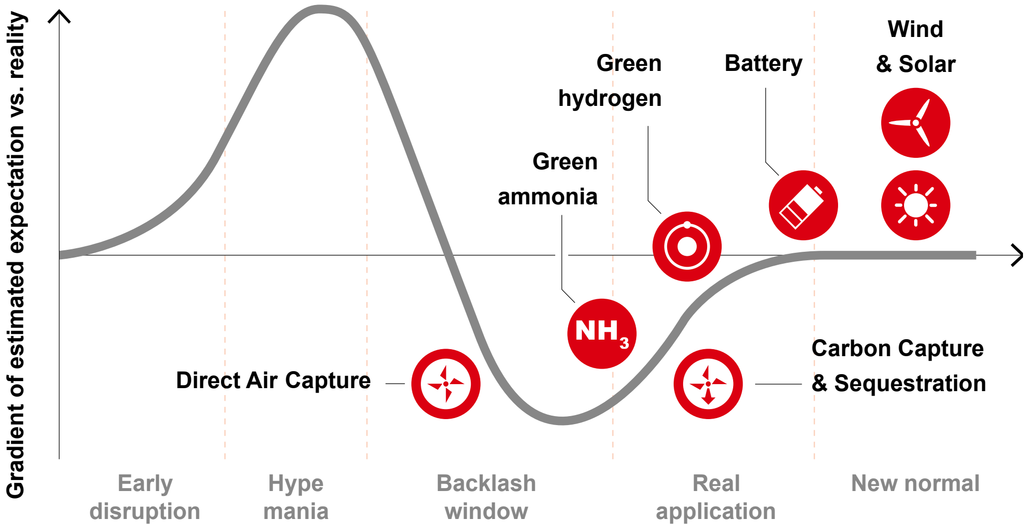
Where do decarbonisation technologies fit into our Disruption Framework?

In a recent HSBC research report, we outlined our four key disruptive technological themes (connectivity, automation, experiential and digital health) and explained why the pandemic has accelerated their adoption with industry and society. We additionally created the HSBC Disruption Framework for each of these themes, placing the different technologies on this framework to help investors understand how mature the innovation was and if it's ready to become the new normal, disrupt business models and have economic implications. Here we outline where various decarbonisation technologies may lay within our framework, relative to the technologies discussed in this report, namely carbon capture & sequestration (CCS) and direct air capture (DAC).

We place carbon capture and direct air capture in our disruptive framework

Backed up by our recent reports on how to decarbonise the energy system we place emerging (and established) low-carbon technologies into various stages of our framework. For example, we believe that green hydrogen is entering its 'real application' phase due to the amount of planned new electrolyser capacity coming into play this decade. The battery electric powered narrative is further ahead in terms of moving to mass adoption, for example in passenger vehicles, while solar and wind for aiding decarbonising power is the "new normal".

HSBC Disruptive Framework – decarbonisation technologies



Source: HSBC

CCS is only small-scale today, placing it in between the "backlash" and "real applications" phases

As we have outlined, CCS isn't a new technology but today captures less than 0.5% of global energy-related CO_2. We note that the IEA classifies the majority of CCS applications in industry as either 'early adoption' or 'demonstration' in nature and not at a meaningful scale. Within our framework, we believe that CCS technology is in between the "backlash" and "real applications" windows – and even though it's small-scale today, a number of companies are exposed to the technology today.

DAC is earlier in its development

However, if CCS has a successful decade of increasing both capacity deployment and the breadth of operational application in the 2020s, then in our view it could put the technology on the road to a more meaningful presence in the energy system by 2050. This would mean the technology would move towards the "real applications" phase and then slowly transition into the "new normal". We believe DAC (a subset of CCS) sits earlier in the backlash window part of the framework because it is still unproven at scale and also faces more challenging economics to become commercially viable.

This is an abridged version of a report by the same title published on 23-Mar-21. Please contact your HSBC representative or email AskResearch@hsbc.com for more information.

Glossary of terms

- **1.5-2°C warming** – reference to targets to limit the rise in average global temperature relative to pre-industrial averages. The 1.5-2°C threshold is cited in scientific work as a potential tipping point, beyond which irreversible changes to the Earth's climate occur.
- **Bioenergy** – also referred to as biomass or biofuel. A fuel source derived from organic matter such as wood.
- **BECCS –** bioenergy combined with carbon capture & sequestration.
- **Blue hydrogen** – the production of hydrogen from fossil fuels (natural gas or coal) where a large proportion of the carbon emissions are captured
- **Carbon offsets** – actions or a project that seek to reduce carbon emissions or other greenhouse gases in order to compensate for emissions made elsewhere (eg planting trees in a location to absorb carbon emissions from aeroplane flights)
- **Carbon sinks** – natural reservoirs that store carbon-containing chemical compounds, such as soil, forestry, oceans.
- **Carbon price** – a cost that is placed on a source of atmospheric pollution and policy tool to regulate levels of carbon emissions. Emissions Trading Systems (ETS) or a carbon tax are examples of carbon pricing.
- **CC(U)S** – carbon capture (utilisation) and sequestration; technology that captures significant proportions of carbon dioxide (CO_2) from a process.
- **CO_2** – carbon-dioxide or carbon emissions, the most common greenhouse gas that is emitted from combusting fossil fuels, chemical processes and some natural sources (agriculture, volcanoes and soil).
- **DAC –** Direct Air Capture, a form of capturing carbon emissions directly from the atmosphere.
- **EU ETS** – European Union Emissions Trading System, a carbon pricing policy in Europe that caps the volume of emissions of a given period through the use of tradeable allowances to emit
- **Fossil fuels –** natural gas, coal, oil and their derivatives
- **Green hydrogen** – production of hydrogen by cracking water through electrolysis using renewable energy, where the process has zero carbon emissions
- **'Net zero' emissions** – a balance (at a company, country or global level) of carbon emissions with absorption from the atmosphere (via carbon sinks or CCS).
- **Sequestration** – the permanent storage of carbon emissions in a secure geological formation.
- **Synthetic fuels** – the production of liquid fuels using a gas base (eg hydrogen, natural gas or gasified coal) with carbon monoxide.

Disclosure appendix

Analyst Certification

The following analyst(s), economist(s), or strategist(s) who is(are) primarily responsible for this report, including any analyst(s) whose name(s) appear(s) as author of an individual section or sections of the report and any analyst(s) named as the covering analyst(s) of a subsidiary company in a sum-of-the-parts valuation certifies(y) that the opinion(s) on the subject security(ies) or issuer(s), any views or forecasts expressed in the section(s) of which such individual(s) is(are) named as author(s), and any other views or forecasts expressed herein, including any views expressed on the back page of the research report, accurately reflect their personal view(s) and that no part of their compensation was, is or will be directly or indirectly related to the specific recommendation(s) or views contained in this research report: Tarek Soliman, CFA, Abhishek Kumar, Verity Mitchell, Sean McLoughlin, Thomas C. Hilboldt, CFA, Gordon Gray, Sriharsha Pappu, Wai-Shin Chan, CFA and Davey Jose

Important disclosures

Equities: Stock ratings and basis for financial analysis

HSBC and its affiliates, including the issuer of this report ("HSBC") believes an investor's decision to buy or sell a stock should depend on individual circumstances such as the investor's existing holdings, risk tolerance and other considerations and that investors utilise various disciplines and investment horizons when making investment decisions. Ratings should not be used or relied on in isolation as investment advice. Different securities firms use a variety of ratings terms as well as different rating systems to describe their recommendations and therefore investors should carefully read the definitions of the ratings used in each research report. Further, investors should carefully read the entire research report and not infer its contents from the rating because research reports contain more complete information concerning the analysts' views and the basis for the rating.

From 23rd March 2015 HSBC has assigned ratings on the following basis:

The target price is based on the analyst's assessment of the stock's actual current value, although we expect it to take six to 12 months for the market price to reflect this. When the target price is more than 20% above the current share price, the stock will be classified as a Buy; when it is between 5% and 20% above the current share price, the stock may be classified as a Buy or a Hold; when it is between 5% below and 5% above the current share price, the stock will be classified as a Hold; when it is between 5% and 20% below the current share price, the stock may be classified as a Hold or a Reduce; and when it is more than 20% below the current share price, the stock will be classified as a Reduce.

Our ratings are re-calibrated against these bands at the time of any 'material change' (initiation or resumption of coverage, change in target price or estimates).

Upside/Downside is the percentage difference between the target price and the share price.

Prior to this date, HSBC's rating structure was applied on the following basis:

For each stock we set a required rate of return calculated from the cost of equity for that stock's domestic or, as appropriate, regional market established by our strategy team. The target price for a stock represented the value the analyst expected the stock to reach over our performance horizon. The performance horizon was 12 months. For a stock to be classified as Overweight, the potential return, which equals the percentage difference between the current share price and the target price, including the forecast dividend yield when indicated, had to exceed the required return by at least 5 percentage points over the succeeding 12 months (or 10 percentage points for a stock classified as Volatile*). For a stock to be classified as Underweight, the stock was expected to underperform its required return by at least 5 percentage points over the succeeding 12 months (or 10 percentage points for a stock classified as Volatile*). Stocks between these bands were classified as Neutral.

*A stock was classified as volatile if its historical volatility had exceeded 40%, if the stock had been listed for less than 12 months (unless it was in an industry or sector where volatility is low) or if the analyst expected significant volatility. However, stocks which we did not consider volatile may in fact also have behaved in such a way. Historical volatility was defined as the past month's average of the daily 365-day moving average volatilities. In order to avoid misleadingly frequent changes in rating, however, volatility had to move 2.5 percentage points past the 40% benchmark in either direction for a stock's status to change.

Rating distribution for long-term investment opportunities

As of 22 March 2021, the distribution of all independent ratings published by HSBC is as follows:

Buy	57%	(30% of these provided with Investment Banking Services)
Hold	34%	(27% of these provided with Investment Banking Services)
Sell	9%	(22% of these provided with Investment Banking Services)

For the purposes of the distribution above the following mapping structure is used during the transition from the previous to current rating models: under our previous model, Overweight = Buy, Neutral = Hold and Underweight = Sell; under our current model Buy = Buy, Hold = Hold and Reduce = Sell. For rating definitions under both models, please see "Stock ratings and basis for financial analysis" above.

For the distribution of non-independent ratings published by HSBC, please see the disclosure page available at http://www.hsbcnet.com/gbm/financial-regulation/investment-recommendations-disclosures.

To view a list of all the independent fundamental ratings disseminated by HSBC during the preceding 12-month period, please use the following links to access the disclosure page:

Clients of Global Research and Global Banking and Markets: www.research.hsbc.com/A/Disclosures

Clients of HSBC Private Banking: www.research.privatebank.hsbc.com/Disclosures

HSBC and its affiliates will from time to time sell to and buy from customers the securities/instruments, both equity and debt (including derivatives) of companies covered in HSBC Research on a principal or agency basis or act as a market maker or liquidity provider in the securities/instruments mentioned in this report.

Analysts, economists, and strategists are paid in part by reference to the profitability of HSBC which includes investment banking, sales & trading, and principal trading revenues.

Whether, or in what time frame, an update of this analysis will be published is not determined in advance.

Non-U.S. analysts may not be associated persons of HSBC Securities (USA) Inc, and therefore may not be subject to FINRA Rule 2241 or FINRA Rule 2242 restrictions on communications with the subject company, public appearances and trading securities held by the analysts.

Economic sanctions imposed by the EU, the UK, the USA, and certain other jurisdictions generally prohibit transacting or dealing in any debt or equity issued by Russian SSI entities on or after 16 July 2014 (Restricted SSI Securities). Economic sanctions imposed by the USA also generally prohibit US persons from purchasing or selling publicly traded securities issued by companies designated by the US Government as "Communist Chinese military companies" (CMCs) or any securities that are derivative of, or designed to provide investment exposure, to the targeted CMC securities (collectively, Restricted CMC Securities). This report does not constitute advice in relation to any Restricted SSI Securities or Restricted CMC Securities, and as such, this report should not be construed as an inducement to transact in any Restricted SSI Securities or Restricted CMC Securities.

For disclosures in respect of any company mentioned in this report, please see the most recently published report on that company available at www.hsbcnet.com/research. HSBC Private Banking clients should contact their Relationship Manager for queries regarding other research reports. In order to find out more about the proprietary models used to produce this report, please contact the authoring analyst.

Additional disclosures

1 This report is dated as at 23 March 2021.

2 All market data included in this report are dated as at close 16 March 2021, unless a different date and/or a specific time of day is indicated in the report.

3 HSBC has procedures in place to identify and manage any potential conflicts of interest that arise in connection with its Research business. HSBC's analysts and its other staff who are involved in the preparation and dissemination of Research operate and have a management reporting line independent of HSBC's Investment Banking business. Information Barrier procedures are in place between the Investment Banking, Principal Trading, and Research businesses to ensure that any confidential and/or price sensitive information is handled in an appropriate manner.

4 You are not permitted to use, for reference, any data in this document for the purpose of (i) determining the interest payable, or other sums due, under loan agreements or under other financial contracts or instruments, (ii) determining the price at which a financial instrument may be bought or sold or traded or redeemed, or the value of a financial instrument, and/or (iii) measuring the performance of a financial instrument or of an investment fund.

Disclaimer

Legal entities as at 1 December 2020

'UAE' HSBC Bank Middle East Limited, DIFC; HSBC Bank Middle East Limited, Dubai; 'HK' The Hongkong and Shanghai Banking Corporation Limited, Hong Kong; 'TW' HSBC Securities (Taiwan) Corporation Limited; 'CA' HSBC Securities (Canada) Inc.; 'France' HSBC Continental Europe; 'Spain' HSBC Continental Europe, Sucursal en España; 'Italy' HSBC Continental Europe, Italy; 'Sweden' HSBC Continental Europe Bank, Sweden Filial; 'DE' HSBC Trinkaus & Burkhardt AG, Düsseldorf; 000 HSBC Bank (RR), Moscow; 'IN' HSBC Securities and Capital Markets (India) Private Limited, Mumbai; 'JP' HSBC Securities (Japan) Limited, Tokyo; 'EG' HSBC Securities Egypt SAE, Cairo; 'CN' HSBC Investment Bank Asia Limited, Beijing Representative Office; The Hongkong and Shanghai Banking Corporation Limited, Singapore Branch; The Hongkong and Shanghai Banking Corporation Limited, Seoul Securities Branch; The Hongkong and Shanghai Banking Corporation Limited, Seoul Branch; HSBC Securities (South Africa) (Pty) Ltd, Johannesburg; HSBC Bank plc, London, Tel Aviv; 'US' HSBC Securities (USA) Inc, New York; HSBC Yatirim Menkul Degerler AS, Istanbul; HSBC México, SA, Institución de Banca Múltiple, Grupo Financiero HSBC; HSBC Bank Australia Limited; HSBC Bank Argentina SA; HSBC Saudi Arabia Limited; The Hongkong and Shanghai Banking Corporation Limited, New Zealand Branch incorporated in Hong Kong SAR; The Hongkong and Shanghai Banking Corporation Limited, Bangkok Branch; PT Bank HSBC Indonesia; HSBC Qianhai Securities Limited; Banco HSBC S.A.

Issuer of report

HSBC Bank plc
8 Canada Square
London, E14 5HQ, United Kingdom
Telephone: +44 20 7991 8888
Fax: +44 20 7992 4880
Website: www.research.hsbc.com

In the UK this document has been issued and approved by HSBC Bank plc ("HSBC") for the information of its Clients (as defined in the Rules of FCA) and those of its affiliates only. It is not intended for Retail Clients in the UK. If this research is received by a customer of an affiliate of HSBC, its provision to the recipient is subject to the terms of business in place between the recipient and such affiliate.

HSBC Securities (USA) Inc. accepts responsibility for the content of this research report prepared by its non-US foreign affiliate. The information contained herein is under no circumstances to be construed as investment advice and is not tailored to the needs of the recipient. All U.S. persons receiving and/or accessing this report and wishing to effect transactions in any security discussed herein should do so with HSBC Securities (USA) Inc. in the United States and not with its non-US foreign affiliate, the issuer of this report.

In the European Economic Area, this publication has been distributed by HSBC Continental Europe or by such other HSBC affiliate from which the recipient receives relevant services

In Singapore, this publication is distributed by The Hongkong and Shanghai Banking Corporation Limited, Singapore Branch for the general information of institutional investors or other persons specified in Sections 274 and 304 of the Securities and Futures Act (Chapter 289) ("SFA") and accredited investors and other persons in accordance with the conditions specified in Sections 275 and 305 of the SFA. Only Economics or Currencies reports are intended for distribution to a person who is not an Accredited Investor, Expert Investor or Institutional Investor as defined in SFA. The Hongkong and Shanghai Banking Corporation Limited, Singapore Branch accepts legal responsibility for the contents of reports pursuant to Regulation 32C(1)(d) of the Financial Advisers Regulations. This publication is not a prospectus as defined in the SFA. This publication is not a prospectus as defined in the SFA. It may not be further distributed in whole or in part for any purpose. The Hongkong and Shanghai Banking Corporation Limited Singapore Branch is regulated by the Monetary Authority of Singapore. Recipients in Singapore should contact a "Hongkong and Shanghai Banking Corporation Limited, Singapore Branch" representative in respect of any matters arising from, or in connection with this report. Please refer to The Hongkong and Shanghai Banking Corporation Limited Singapore Branch's website at www.business.hsbc.com.sg for contact details.

In Australia, this publication has been distributed by The Hongkong and Shanghai Banking Corporation Limited (ABN 65 117 925 970, AFSL 301737) for the general information of its "wholesale" customers (as defined in the Corporations Act 2001). Where distributed to retail customers, this research is distributed by HSBC Bank Australia Limited (ABN 48 006 434 162, AFSL No. 232595). These respective entities make no representations that the products or services mentioned in this document are available to persons in Australia or are necessarily suitable for any particular person or appropriate in accordance with local law. No consideration has been given to the particular investment objectives, financial situation or particular needs of any recipient.

This publication has been distributed in Japan by HSBC Securities (Japan) Limited. It may not be further distributed, in whole or in part, for any purpose. In Hong Kong, this document has been distributed by The Hongkong and Shanghai Banking Corporation Limited in the conduct of its Hong Kong regulated business for the information of its institutional and professional customers; it is not intended for and should not be distributed to retail customers in Hong Kong. The Hongkong and Shanghai Banking Corporation Limited makes no representations that the products or services mentioned in this document are available to persons in Hong Kong or are necessarily suitable for any particular person or appropriate in accordance with local law. All inquiries by such recipients must be directed to The Hongkong and Shanghai Banking Corporation Limited. In Korea, this publication is distributed by The Hongkong and Shanghai Banking Corporation Limited, Seoul Securities Branch ("HBAP SLS") for the general information of professional investors specified in Article 9 of the Financial Investment Services and Capital Markets Act ("FSCMA"). This publication is not a prospectus as defined in the FSCMA. It may not be further distributed in whole or in part for any purpose. HBAP SLS is regulated by the Financial Services Commission and the Financial Supervisory Service of Korea. This publication is distributed in New Zealand by The Hongkong and Shanghai Banking Corporation Limited, New Zealand Branch incorporated in Hong Kong SAR.

In Canada, this document has been distributed by HSBC Securities (Canada) Inc. (member IIROC), and/or its affiliates. The information contained herein is under no circumstances to be construed as investment advice in any province or territory of Canada and is not tailored to the needs of the recipient. No securities commission or similar regulatory authority in Canada has reviewed or in any way passed judgment upon these materials, the information contained herein or the merits of the securities described herein, and any representation to the contrary is an offense. In Brazil, this document has been distributed by Banco HSBC S.A. ("HSBC Brazil"), and/or its affiliates. As required by Instruction No. 598/18 of the Securities and Exchange Commission of Brazil (Comissão de Valores Mobiliários), potential conflicts of interest concerning (i) HSBC Brazil and/or its affiliates; and (ii) the analyst(s) responsible for authoring this report are stated on the chart above labelled "HSBC & Analyst Disclosures".

This document is not and should not be construed as an offer to sell or the solicitation of an offer to purchase or subscribe for any investment. HSBC has based this document on information obtained from sources it believes to be reliable but which it has not independently verified; HSBC makes no guarantee, representation or warranty and accepts no responsibility or liability as to its accuracy or completeness. The opinions contained within the report are based upon publicly available information at the time of publication and are subject to change without notice. From time to time research analysts conduct site visits of covered issuers. HSBC policies prohibit research analysts from accepting payment or reimbursement for travel expenses from the issuer for such visits.

Nothing herein excludes or restricts any duty or liability to a customer which HSBC has under the Financial Services and Markets Act 2000 or under the Rules of FCA and PRA. A recipient who chooses to deal with any person who is not a representative of HSBC in the UK will not enjoy the protections afforded by the UK regulatory regime. Past performance is not necessarily a guide to future performance. The value of any investment or income may go down as well as up and you may not get back the full amount invested. Where an investment is denominated in a currency other than the local currency of the recipient of the research report, changes in the exchange rates may have an adverse effect on the value, price or income of that investment. In case of investments for which there is no recognised market it may be difficult for investors to sell their investments or to obtain reliable information about its value or the extent of the risk to which it is exposed.

HSBC Bank plc is registered in England No 14259, is authorised by the Prudential Regulation Authority and regulated by the Financial Conduct Authority and the Prudential Regulation Authority and is a member of the London Stock Exchange. (070905)

If you are an HSBC Private Banking ("PB") customer with approval for receipt of relevant research publications by an applicable HSBC legal entity, you are eligible to receive this publication. To be eligible to receive such publications, you must have agreed to the applicable HSBC entity's terms and conditions ("KRC Terms") for access to the KRC, and the terms and conditions of any other internet banking service offered by that HSBC entity through which you will access research publications using the KRC. Distribution of this publication is the sole responsibility of the HSBC entity with whom you have agreed the KRC Terms.

If you do not meet the aforementioned eligibility requirements please disregard this publication and, if you are a customer of PB, please notify your Relationship Manager. Receipt of research publications is strictly subject to the KRC Terms, which can be found at https://research.privatebank.hsbc.com/ – we draw your attention also to the provisions contained in the Important Notes section therein.

[1167369]