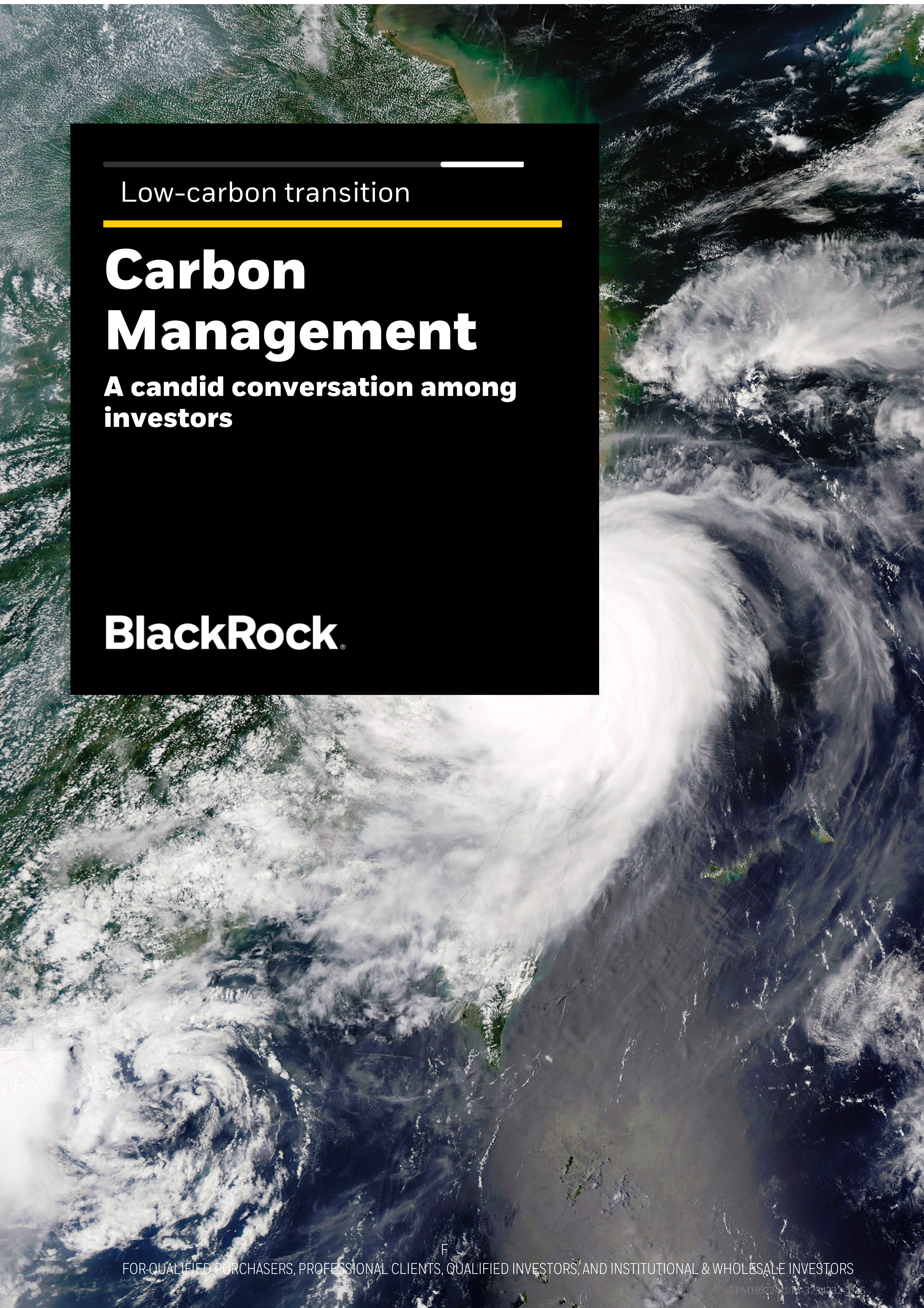

Low-carbon transition

Carbon Management

A candid conversation among investors

BlackRock

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FOR QUALIFIED PURCHASERS, PROFESSIONAL CLIENTS, QUALIFIED INVESTORS, AND INSTITUTIONAL & WHOLESALE INVESTORS

Another side of emissions reductions

August 2024

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Key takeaways

- Carbon management includes technologies that capture, transport and either store or reuse carbon dioxide.
- While essential to reducing emissions in hard-to-decarbonize industries, carbon management still relies heavily on government and other incentives.
- Monetizing removal credits is becoming easier, with voluntary and compliance markets experiencing growth, and maturing.
- CO2 utilization is primarily deployed in enhanced oil recovery today, but should expand as companies take an R&D approach and newer technologies mature.
- To manage the technology and regulatory risks, large companies are bringing in more investment partners through joint ventures and other structures.

Introduction

Low-carbon power generation and the electrification of energy deployment are projected to contribute the lion's share of the global decarbonization. But other strategies are needed for harder-to-abate sectors—with carbon management a leading candidate.

As a category, carbon management encompasses various technologies — both well-known and researched and innovative new ones — that capture, remove and then either deploy or store CO2. As an investment, the economics of carbon management vary, depending on the source and the approach to managing it. The three broad categories include:

Carbon capture and sequestration

involves capturing CO2 emissions from sources such as power plants and industrial processes, transporting it to a storage site, and depositing it underground or in cement. This process prevents CO2 from entering the atmosphere. In this technology, there is no revenue stream and the financial benefit comes from government incentives and voluntary markets.

Carbon dioxide removal

aims to reduce the overall concentration of CO2 in the atmosphere. It can be as simple as reforestation, but also includes more complex techniques such as raising the alkalinity of oceans. The financial incentives are similar to carbon capture and sequestration, with the added cost of capturing carbon from a more diluted source, often through a more energy-intensive process.

Carbon capture and utilization

captures CO2 and uses it to produce fuels, chemical feedstocks, or building materials. This approach offers a dual economic opportunity from the financial incentives related to mitigating emissions, while also creating marketable low-carbon products.

About BlackRock's Transition Centers of Expertise

The transition to a low-carbon economy is among a handful of major structural shifts that we see rewiring economies, sectors and businesses. The transition will likely cause ripple effects around the globe and change where revenues and profits are generated.

The transition's pace of change, however, is highly uncertain, which creates complexity and risk – as well as opportunity – for companies and investors alike.

At BlackRock, we define transition investing as: Investing with a focus on preparing for, being aligned to, benefitting from and/or contributing to the transition to a low-carbon economy. We recognize that clients across the world are investing in the transition to a low-carbon economy to generate returns, manage risk, or execute on commitments.

BlackRock's Transition Centers of Expertise (CoEs), of which our Carbon Management CoE is one, bring together the knowledge of our more than 600 sustainable and transition specialists across the firm, as well as external experts and industry associations. These virtual communities, organized by sector technology, encompass expert views throughout the capital stack and across industry value chains, contribute to the assumptions used in the BlackRock Investment Institute Transition Scenario, and help source new opportunities for our clients.

We hope the insights developed by the CoEs will lead to a better understanding of the uncertainty around the transition by bringing together a range of perspectives and experience.

As a fiduciary who puts our clients' needs and goals first by offering a broad range of investing options, we currently manage US$138 billion in transition-related assets globally, to identify opportunities arising as a result of structural trends shaping the economy, markets, and asset prices. This paper is produced in close cooperation with our Carbon Management CoE.

Source: BlackRock, as of December 31, 2023.

CO2 economics

Carbon management comes with high initial costs for technology and infrastructure. Policy and market incentives such as tax credits, subsidies and carbon-credit markets are critical to making carbon management economically viable in most industries.

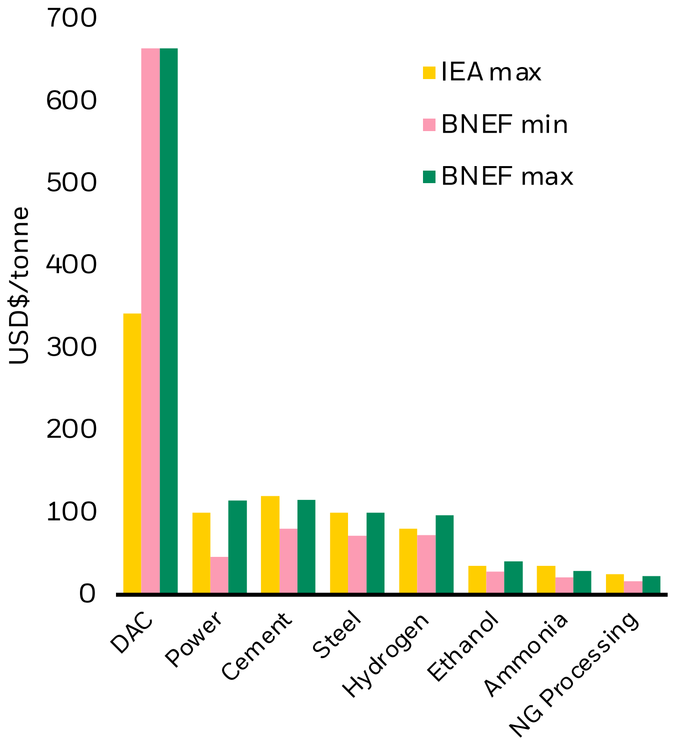
The cost to capture carbon can vary depending on the technology used and the concentration of CO2 in the gas stream or air. For highly concentrated CO2 sources, the cost can be as low as US$10 to US$30 per tonne, with higher costs for more diluted sources.[1]

The cost of capturing CO2 can account for as much as 75% of the total cost of carbon-management projects, especially in applications where it's necessary to separate CO2 from exhaust gas.[2] As operational and permitting experience grows, capture technologies improve and economies of scale accrue, those costs could be expected to fall.

Even as costs fall,[3] carbon-management economics will continue to rely on policy incentives and voluntary carbon credits. Policy frameworks for carbon management have started to accelerate in many countries and markets, notably including the U.S., Europe, Japan, China and India.

A range of approaches

The cost of carbon capture varies widely depending on the strategy and source.[4]



Carbon management 2030

With the acceleration in policy and market support over the past few years, the number of carbon-management projects has started to climb. Currently the total global installed capacity for carbon utilization and removal projects captures roughly 50 million tonnes a year, mostly in natural gas processing, liquid natural gas, chemicals production, and refining. Those sources are where CO2 streams are highly concentrated and easier to capture. If all the announced plants are finished on schedule, capacity would rise to more than 400 million tonnes annually by 2030, with projects across power, heat, hydrogen production, direct air capture, cement, and biofuels accounting for as much as three quarters of capacity. The UN projects total global emissions by 2030 at roughly 56 gigatonnes, slightly lower than in 2019.[5]

The destination of captured CO2 and the geographic locale of projects are also expected to diversify. BloombergNEF estimates the majority of CO2 is captured and used in locations that perform enhanced oil recovery, but by 2030 that's projected to represent only 12% of CO2 storage, with geological sequestration reaching more than 75%.

While the U.S. is responsible for around half of carbon capture today, its lead should fall as the UK, Canada and countries across Europe and the Asia-Pacific region represent the rest of the market, according to BloombergNEF.

The long view

Carbon management relies on government and market incentives. So the long-term projections of its adoption depend on the low-carbon transition policies that countries choose to adopt.

Fast transition scenarios, such as achieving net-zero CO2 emissions by 2050, would call for higher deployment of carbon capture technologies, reaching 6-8 gigatonnes of carbon capture a year, whereas scenarios where current policies continue as they are would see 500 million tonnes to 2 gigatonnes of CO2 captured annually. If costs decline and additional incentives are adopted, however, we see more momentum building for carbon management.

Source: 1. Congressional Budget office, "Carbon Capture and Storage in the United States," December 2023. 2. National Petroleum Council, "Meeting the Dual Challenge – A Roadmap to At-Scale Deployment of Carbon Capture, Use and Storage," 2021. 3. U.S. Department of Energy, "Pathways to Commercial Liftoff: Carbon Management," April 2023. 4. IEA, "CCUS in Clean Energy Transitions," September 2020, BNEF, "CCUS Market Outlook 1H 2024: Trough of Disillusionment," June 11, 2024 (Cost to capture only and excludes transportation and sequestration). 5. United Nations, "Long-term low-emission development strategies," November 30, 2023. Forecasts are based on estimates and assumptions. There is no guarantee that they will be achieved.

Investor Q&A

BlackRock's Centers of Expertise bring together our leading experts for specific industries that we believe will play a key role in the low-carbon transition.

Our Carbon Management CoE includes Pieter Houllebergh s, an investor in late-stage venture capital and early-stage growth equity companies, Doug Vaccari, an investor in private infrastructure assets and operators, and William Su, who leads the firm's research and investment in North American Energy public equities.

How would you describe carbon management?

Pieter Houllebergh s: Carbon management is a broad category of anything that's an emissions reduction or a drawdown of CO2 from the atmosphere.

It could be abatement in the form of avoiding an emission, or a carbon offset where a buyer can reward someone else for having removed the carbon from the atmosphere.

Doug Vaccari: It also encompasses a range of technologies. There are nature-based solutions like forestry, then there's equipment-based solutions to remove carbon.

They're in different stages of commercial readiness, both from a technological and economic perspective.

William Su: Today, most carbon-management projects don't work without subsidies or regulations. I think this is going to require a reliable legislative framework and more public-private partnerships to define what long-term support will look like, because they will almost certainly require ongoing financial assistance in the foreseeable future.

This support could come in the form of direct investment incentives or as we develop greater liquidity in traded markets like low-carbon fuel credits in California and the emissions trading system in Europe.

What do you see as the impact of incentives in the space?

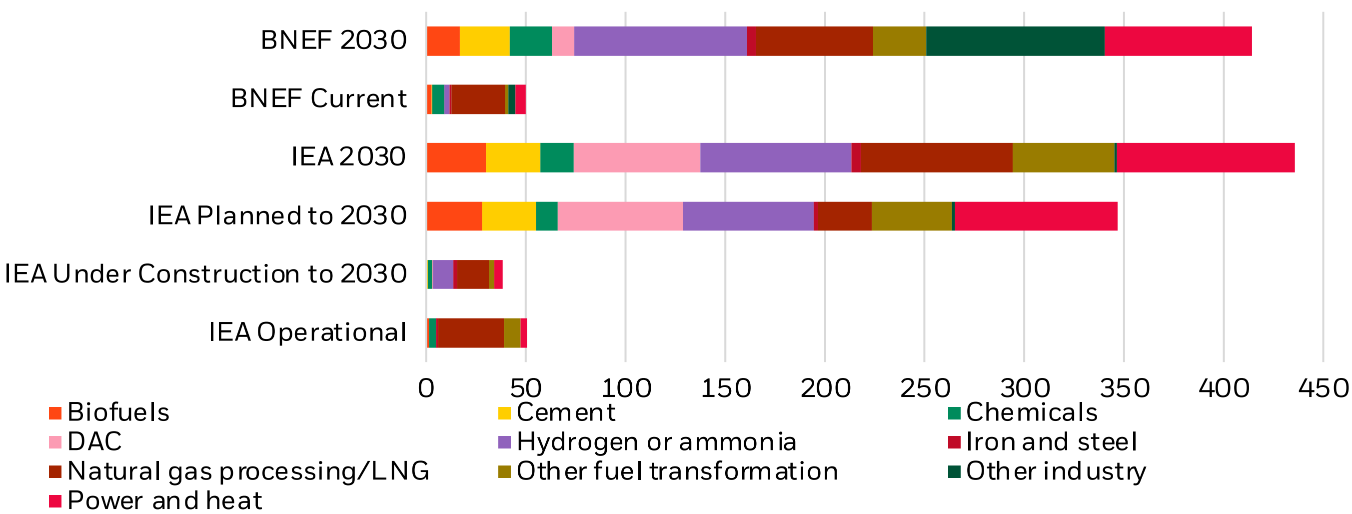
D.V.: Direct subsidies currently exist for these businesses, which could be cash-based or credit-based. Generally, the credit-based subsidies are more complex because they can require the recipient to finance a tax credit.

There are also market incentives. The voluntary market for carbon credits allows large multinationals to buy and sell carbon removal credits to meet their climate goals.

There are also compliance markets emerging in various parts of the world for trading carbon credits. These can be quite effective in catalyzing activity around industries like

Growing demand

The number of carbon-management projects is expected to rise considerably in the next few years.



Source: BNEF, IEA, CCUS Projects Database. December 2023.

shipping, electric vehicles, and aviation that require end-users to decarbonize, stimulating the demand for low-carbon products.

Then there are grants, which while helpful, usually need to exist in conjunction with one of the other incentives. Generally, revenue-based incentives that come from a credit-based system or through a compliance market are most effective in allowing businesses to scale.

W.S.: Yes, there are a lot of policies out there, and the companies who have moved forward with carbon-management projects have structured them to capture as many buckets of incentives as possible. They are setting the assets up to enjoy multiple streams of subsidies to overcome the underlying financial investment hurdles.

D.V.: And the landscape is evolving. The technology is coming to scale and being used in new ways. For example, as the aviation industry strives for lower emissions, carriers are looking beyond sustainable aviation fuel to alternate solutions, such as using fossil-based jet fuel along with direct air capture to vacuum up the emissions.

Where do you see growth in carbon management today?

P.H.: We spend a lot of time looking at various technologies across different sectors, and there are a couple carbon removal technologies that break the mold, and fit between what people call nature-based solutions versus engineered, as well as between direct-air versus point-source capture. Those are the ones that are interesting, where you're working with the laws of nature or with thermodynamics and what you end up with are pathways that are low-energy, low-cost and effective at producing a durable credit.

For example, we just invested in a mineralization-based technology out of Europe that uses recycled concrete to absorb CO2 from biogenic sources. The company works with biogas plants, where there's a fairly concentrated CO2 stream you can get access to. This generates a credit that's interesting to the corporate buyers in the voluntary market.

D.V.: We see opportunities to partner with large companies on carbon-management projects across the world for a few reasons. Public shareholders expect energy companies to prioritize returning capital to shareholders. At the same time, carbon-management projects are typically very capital-intensive, with returns that are more similar to traditional infrastructure.

So these companies want partners to share the risk, share capital, and to collaborate. Large companies like Occidental Petroleum for example, our partner in the STRATOS carbon capture facility, have the technical and operational expertise to develop, build, operate, and commercialize large projects in this space. And for an investor that provides a real competitive advantage.

Snapshot—carbon markets

The market for carbon dioxide removal credits, or CDRs, is an important consideration when investing in carbon management.

Explosive growth: Purchases in the durable CDR market have grown more than sevenfold, to 4.5 million tonnes in 2023, up from 615,000 tonnes in 2022. From 2020 to 2023, the space has seen a CAGR of roughly 500%.[1]

Rising costs: The CDR price index has increased to US$444 per tonne. This indicates that while the market is growing, the costs associated with managing carbon are also increasing, which could pose challenges for scalability and widespread adoption.[1]

Limited technology transfer: Despite the growth and potential of the CDR market, there is still limited technology transfer from project to project. This may be due to the unique nature of each project, which involve different technologies, methodologies and local conditions. This could slow down new projects and reduce the overall efficiency of the CDR industry.[2]

Sources: 1. CDR. 2023 Year in Review, Feb 2024; 2. McKinsey, Scaling Carbon Removals and Voluntary Carbon Markets, Dec 2023.

They require knowledge to operate those assets and commercialize them. It's a very different value proposition to enter the direct-air capture space, which is incredibly nascent, with a 30-employee startup than with the second-largest chemical company who has been handling CO2 for 50 years.

As an investor, you want a partner who's capable of managing large construction projects. When you think about the investment, it's probably more in the mold of co-creating a business with a corporate partner or doing something structured more like a joint venture.

W.S.: You're seeing big U.S. names invest more aggressively in carbon capture assets, building out CO2 pipelines, making venture investments into direct air capture technologies, and setting up better-defined carbon-sink areas in the Gulf of Mexico.

While public shareholders are generally pretty allergic to long-duration and loss-leading investments, more companies are viewing carbon-related investments at this stage as R&D - a portfolio of options that could have asymmetric payoffs down the road.

I think investors today are more accepting of these investments when the expenditures are ratable, contained, and do not detract from the key proposition of returning significant cash to shareholders.

Companies are looking for lower-cost funding as well as very patient private capital in a joint-venture structure to underwrite this research spend in exchange for long-term, infrastructure-like returns. Eventually, the companies would like to control the molecules and electrons from these assets and integrate them into their trading operations. This has been the key for large, integrated energy companies to justify financing low-carbon investments from a returns perspective.

I also wouldn't count out many of the world's largest national oil companies, especially in Asia and the Middle East. They're making some very impressive and scaled-up investments in their regions. One key advantage they have is greater speed and fewer roadblocks to investment decision-making, because they don't have to get approvals from public shareholders or a board. It's a top-down directive from the government owners.

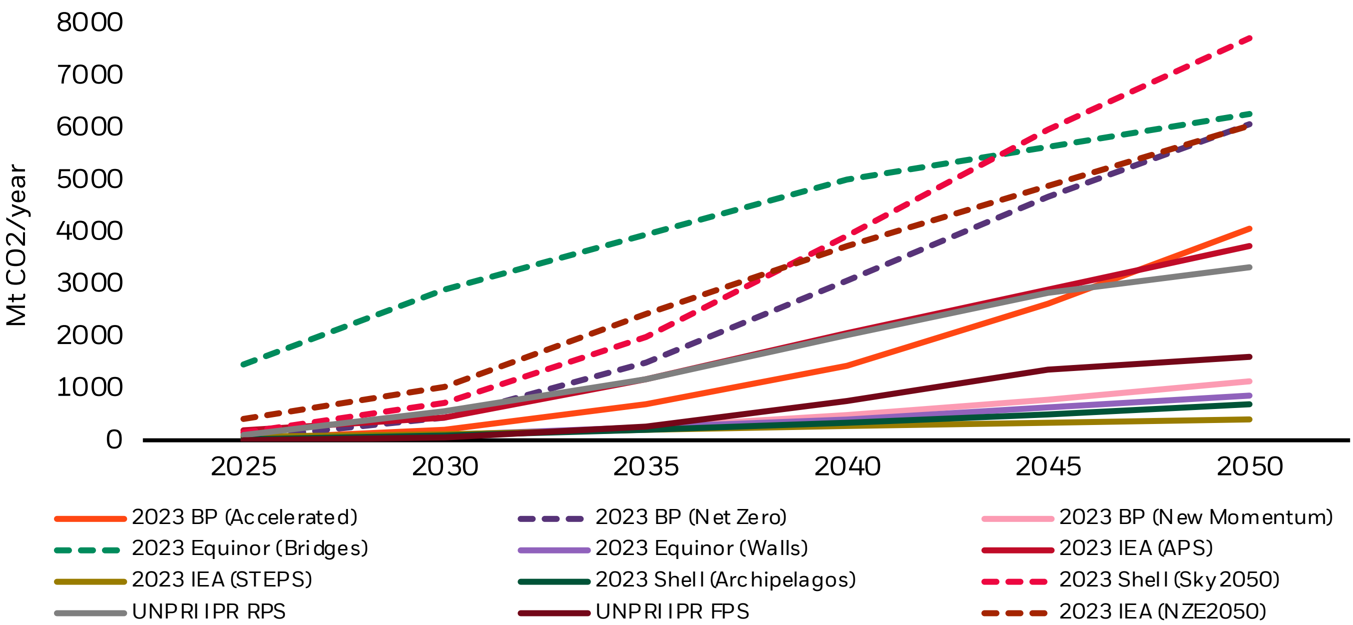
What are the biggest question marks right now?

P.H.: What gets lost in the public discourse is the significant differences by industry. People talk about cement, where there are emissions all the way across the lifecycle of the product.

There are steps you can take from an abatement perspective or a removals perspective that make economic sense, and then there are steps that are cost prohibitive.

Outlooks and outcomes

Different scenarios show different futures for carbon management.



Sources: BP, "BP's Energy Outlook 2023," Equinor, "Energy Perspectives 2023," IEA, "World Energy Outlook 2023," Shell, "Energy Security Scenarios 2023," UN PRI, "Inevitable Policy Response 2021." There is no guarantee that any forecasts made will come to pass.

Reference to the names of each company mentioned in this communication is merely for explaining the investment strategy, and should not be construed as investment advice or investment recommendation of those companies.

The cost of reducing emissions is different across industries, and so the role of carbon capture will also be different for different industries.

D.V.: There's an interplay - the cost of carbon-management solutions is evolving at the same time as the policy incentives. We expect the solutions that work well today and are economical within the confines of existing policies to be the ones deployed.

The more expensive solutions that also rely on the voluntary market will have a harder time scaling up and achieving their ultimate cost targets in the absence of incremental policy.

Another key obstacle will continue to be permitting, which is a key issue in the deployment of many other decarbonization projects. Carbon-management solutions that involve pipelines or the storage of CO2 underground continue to face local challenges in the form of permitting, which has chilled investment in certain regions.

W.S.: Given the importance of policy incentives, regulation is a major factor, and these frameworks are constantly evolving; some of them have proven quite expensive from a taxpayer-burden perspective.

Around the world, people expect these policies to ramp up over time. For example, the sustainable aviation fuel standards in the EU are quite aggressive. It's forcing many European refiners to basically shut down their refineries, retool the kits, and basically produce clean fuel that's just a small fraction of the volume they were producing before the retrofit. But because the margins are so massive with subsidies, it makes economic sense for them to do so.

These things will have a phase with a lot of incentives to catalyze initial investments, which will hopefully drive down costs through a learning curve, and eventually give way to needing fewer incentives after, say, the first 10 years. They might then migrate afterwards to variable incentives, and could eventually become competitive in a free market. But we are, I'd say, at least two decades away from that stage.

Looking out, where do you see carbon management headed?

P.H.: We're still in the early days. One of our portfolio companies is active in the carbon markets as an advisor and supplier of high-quality removals credits. The team includes about 60 world-class climate scientists, and it provides companies with advisory services on reducing their CO2 footprints, and as part of that conversation, where carbon removals credits can fit in for that given player.

By virtue of having run RFPs for carbon removals for large corporations, it has a broad set of relationships with developers of carbon removal projects and can structure unique and proprietary, high-quality portfolios.

Last year, the broader market woke up to the need for more stringent quality of credits. And this investment gives us a perspective across the whole carbon market.

W.S.: We see opportunities arising in the broader economy. Everyone's talking about AI-enabled data centers now, and I think it's just amplifying the dilemma of how you meet society's demand for growing energy while lowering emissions.

The fast-growing energy needs of AI and other digital technologies may require constant, carbon-emitting energy sources like natural gas plants for power. And the only way you can do that while limiting carbon emissions, let alone reducing them, is through investments that accelerate the technology curve in carbon capture.

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