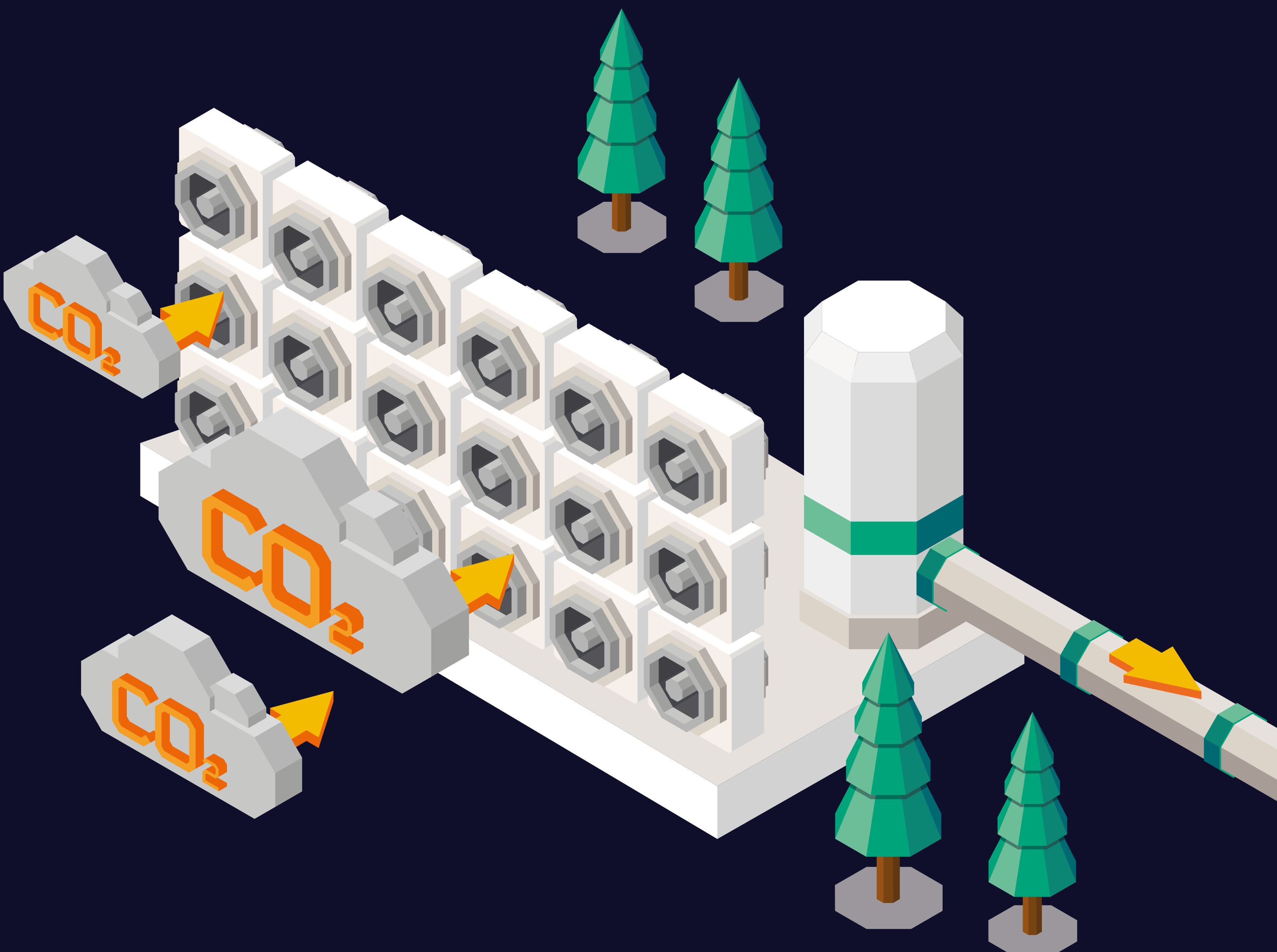

NEGATIVE EMISSIONS TECHNOLOGIES, POSITIVE IMPACT

Carbon Removal Catalyst

The role of strategic financing
in accelerating carbon capture and storage technologies

SIEMENS

How strategic financing with industrial expertise can be the growth catalyst for early-stage companies building carbon capture and storage solutions, nurturing the technological readiness of negative emissions technologies, and propelling decarbonization efforts forward.

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1 The **need for diverse innovation** in accelerating climate action

The world's race to net zero requires multiple decarbonization pathways. These need to be enabled by a diverse range of innovation that accelerate climate action simultaneously – be it in critical or complementary capacities. With predictions indicating less than a decade remaining to prevent irreversible climate change damages[1], strategic financing can play a pivotal role in accelerating the adoption of technologies that maximize the world's chance to fight climate crisis. These range from renewable power generation that cuts carbon footprint at the source, to emerging technologies that could upscale climate change mitigation efforts.

Among the relatively nascent technologies aiming to scale decarbonization are Negative Emissions Technologies (NET) – a set of methods that remove greenhouse gases from the atmosphere. Their evolution has sparked discussions about achieving net-zero not only through reducing carbon emissions but also through capturing and storing emissions.

This white paper explores the technological prospect of NET, as well as challenges specific to relatively young technologies led by early-stage companies, such as technological readiness and scalability. Altogether this underscores how strategic investors with long-term visions and industrial expertise can play a uniquely critical role in enabling NET companies on their development and business journeys, thus helping to grow an emerging field that could boost decarbonization efforts.

The urgent need for **new decarbonization pathways**

Since the adoption of the Paris Agreement in 2015, the United Nations global framework has been one of the most effective initiatives to date in propelling international actions in greenhouse gas (GHGs) emissions reduction. These actions aim to prevent intolerable impacts from climate change, such as sea-level rise and extreme weather events, that would devastate our agricultural and natural ecosystems beyond a point of no return. In the years following the Paris Agreement, more than 70 countries, including China, the United States, and countries in the European Union, have set a net-zero target, covering about 76% of global emissions.[2]

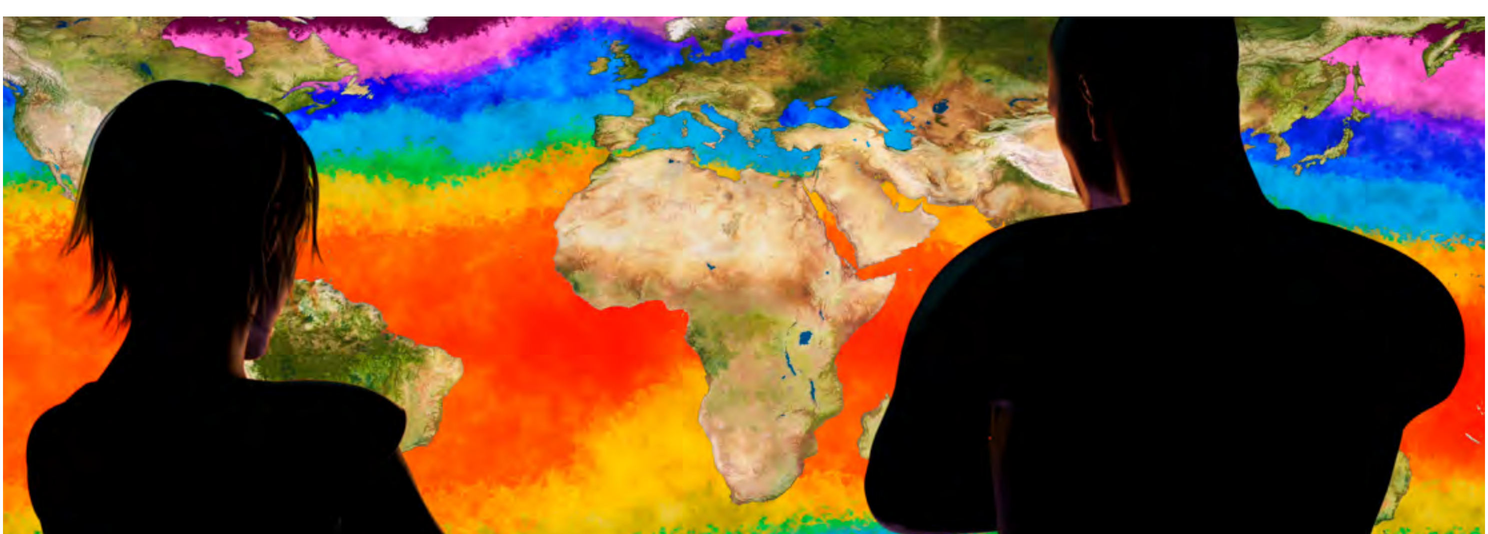
However, not only that many net-zero initiatives target a timeframe until 2050 or beyond[3], but the United Nations also predicts that the current national climate plans among the 193 signed parties would still lead to an increase of almost 11% in global GHG emissions by 2030, compared to 2010 levels[4].

Altogether, a **hollowing climate future** remains, suggesting that current actions still fall short of what is urgently required, despite the adoption of the Paris Agreement.

This urgency has spurred growing investments in an expanding range of climate technologies around the globe, driven by both public and private sectors. For instance, while deep emissions cuts through transitioning away from fossil fuels remain a critical decarbonization pathway, governments and businesses have also raced to invest in infrastructure transformation such as improving energy efficiency of buildings, vehicles, and industrial processes, and transitioning to electric vehicles. In many cases, specialized financing that closely connects with technology value chains has been integral to alleviating financial barriers and speeding up technological adoption. For example, Siemens Financial Services (SFS), the financing arm of Siemens, has enabled energy infrastructure projects worldwide for a wide range of sectors along their decarbonization journeys. Through creating business models that are weaved into technological features, SFS has been facilitating the adoption of decarbonization technologies for buildings, industries, and cities by tailoring financing solutions to both business and environmental needs.

Meanwhile, many of these energy transition technologies target the point of energy generation, such as switching to solar and wind power, or target the transmission and consumption points along intricate energy supply chains, such as integrating smart grids and energy storage that improve flexibility and efficiency. While this underscores the multi-dimensional facets of climate technologies, the slower-than-expected progress towards net-zero (or the likelihood of climate overshoot as some have predicted) has intensified discussions around new technologies that target beyond the focal points of generation and efficiency: capturing and storing carbon emissions.

This is where **discussions around NET**, and the specific **challenges faced by early-stage companies**, come into the picture.



2 **The vision is here:** the potential of Negative Emissions Technologies

NET, or Greenhouse Gas Removal (GGR) technologies, refer to a set of technologies that focus on removing emissions from the atmosphere. While energy efficiency and renewables remain as the "central pillars" in the world's race to net-zero emissions[5], the impact of offsetting carbon footprint in innovative ways should not be overlooked.

As early as 2018, the Intergovernmental Panel on Climate Change (IPCC) highlighted that relying on renewable energy would not be enough and recommended global societies to strike different balances between "lowering energy and resource intensity, rate of decarbonization, and the reliance on carbon dioxide removal"[6]. While there has been a rise of data-driven innovation to propel energy transition – with Siemens spearheading technologies such as the Industrial Internet of Things (IIoT) that transforms energy consumption across industrial processes, along with smart infrastructure technologies like energy-efficient building systems powered by predictive analytics – the road to decarbonization remains multifaceted. It is a comprehensive challenge that requires the collaboration of various pathways to upscale the collective impact.

Specifically, NET could emerge as a supporting decarbonization pathway with their potential in upscaling industry-scale carbon offset practices, particularly concerning residual emissions. When deployed alongside the other critical pillars of decarbonization, NET could be instrumental in preventing the worst effects of climate change.

For interested stakeholders, a deeper look into NET shall consider both their technological prospect and near-term challenges such as technological readiness and commercial scalability. Therefore, the role of patient capital and ecosystem support is crucial in nurturing its steady development.

Capturing carbon emissions to **abate climate overshoot**

Among various methods of carbon dioxide removal, such as reforestation and ocean fertilization, Carbon Capture and Storage (CCS) refers to the process of reducing GHG emissions by capturing carbon dioxide (CO_2). The technology typically involves capturing emissions through various methods such as absorption, then transporting them to a storage site, such as underground formations, or storing the CO_2 in a permanent form that prevents it from being released into the atmosphere.

In terms of impacts on decarbonization, CCS technologies could play a particularly relevant role in capturing residual emissions, which are the remaining emissions that are difficult to be fully eliminated through implementing low-carbon technologies or practices. These emissions often derive from activities that are hard to achieve net-zero, such as heavy industries, long-haul transport, and agriculture.

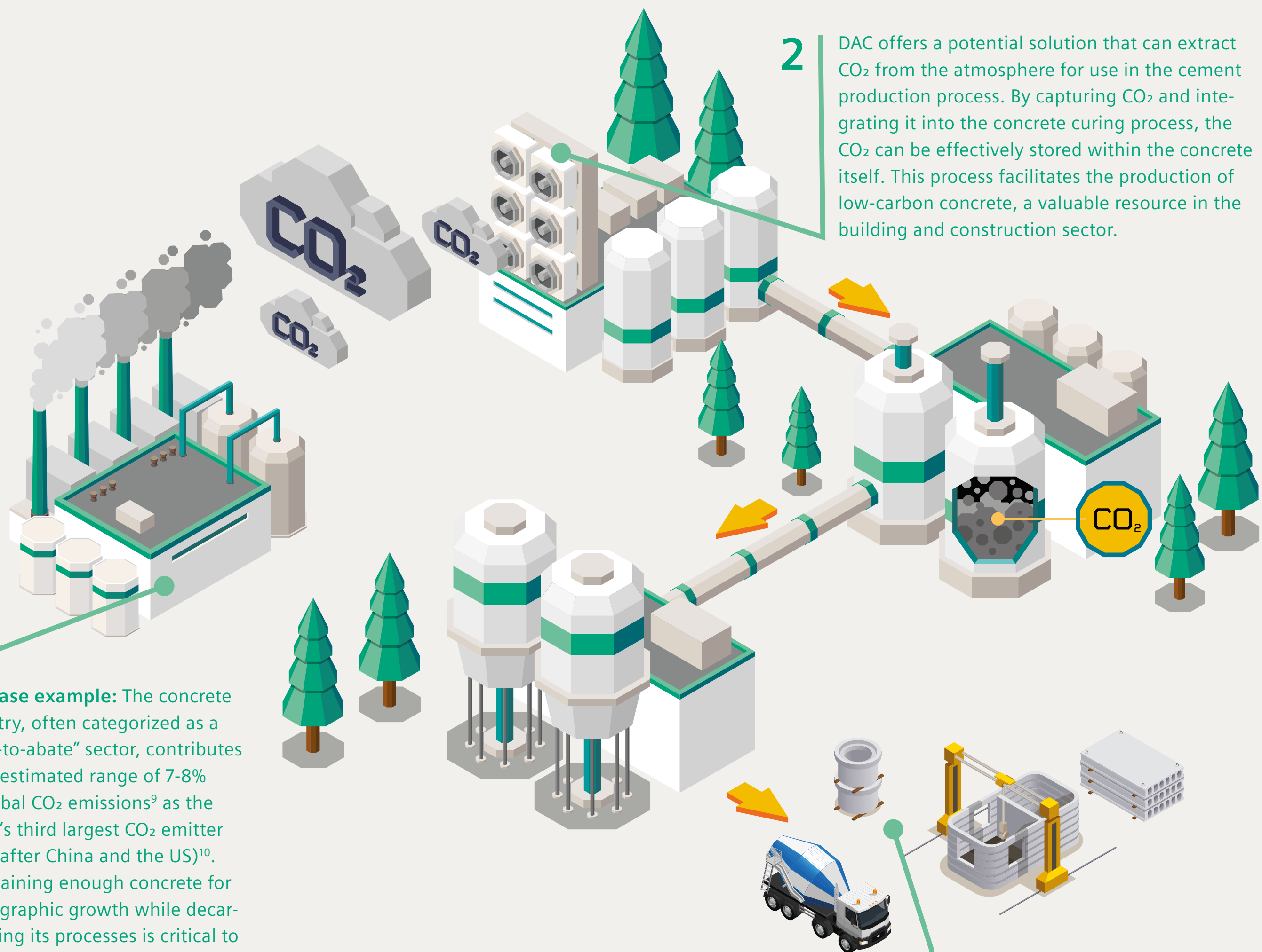
While it is critical to lower these emissions through transitioning to renewable sources and lowering energy intensity, a certain scale of residual emissions will still likely exist. In one comprehensive report, the IPCC estimated that all forecast scenarios of climate action that could **limit global warming to 1.5°C** with limited or no overshoot would require the use of carbon dioxide removal (CDR) to actively offset carbon footprint, including residual emissions[7] from, for instance, agriculture, industry and various value and supply chains.

A report by Wood Mackenzie estimates substantial potential for CCS in helping to deliver at least 15% of the global carbon emission reduction under its scenario whereby global warming is kept below 1.5°C.[8] These analyses point to the notion that deployment of CO_2 removal technologies, such as CCS technologies, could be indispensable to a net-zero future and is needed with great urgency.

A closer look into one NET method: Direct Air Capture (DAC) and use case in concrete production

DAC captures CO_2 directly from the air using special equipment that uses chemicals or filters to absorb CO_2. The captured CO_2 can be used in various applications or stored in long-term storage.

Main advantage: capture CO_2 emissions from any source, e.g. mobile sources such as cars and airplanes, not necessarily tied to industrial processes.



1 **Use case example:** The concrete industry, often categorized as a "hard-to-abate" sector, contributes to an estimated range of 7-8% of global CO_2 emissions[9] as the world's third largest CO_2 emitter (only after China and the US)[10]. Maintaining enough concrete for demographic growth while decarbonizing its processes is critical to climate action.

2 DAC offers a potential solution that can extract CO_2 from the atmosphere for use in the cement production process. By capturing CO_2 and integrating it into the concrete curing process, the CO_2 can be effectively stored within the concrete itself. This process facilitates the production of low-carbon concrete, a valuable resource in the building and construction sector.

3 Furthermore, once the concrete reaches its end-of-life stage – typically after about 60 years – the captured CO_2 from the production process can be utilized to enhance the properties of recycled concrete aggregate. This not only promotes the upscaling of recycled materials but also supports a circular economic model in concrete production.

In a 2022 tracking report, the International Energy Agency (IEA) underscored the critical role of Carbon Capture and Storage (CCS) in decarbonizing the cement industry. The report emphasized that technologies enabling net-zero emissions in cement production should be commercialized to a scale capable of capturing nearly 180 Mt of emissions by 2030, a significant increase from the 0.1 Mt captured in 2022[11].

3 The market is forming – A look into policy and commercial trends

Policymakers and corporations are increasingly recognizing the potential of NET. For instance, the United States and the European Union are accelerating policies that support Carbon Capture and Storage technologies. Meanwhile, large corporations, increasingly aware of their emission footprints, are also driving the demand for innovative practices that can help them decarbonize in multiple ways. These overall trends are propelling public- and private-sector investments in CCS projects. In an estimate by Wood Mackenzie, the **world's carbon capture capacity is expected to increase more than sevenfold to around 370 metric tonnes per annum (Mtpa) by 2033**, with the initial growth mainly observed in North America and the UK, while Asia starting commercial operations towards the end of the decade[12].

New governmental funds across multiple countries

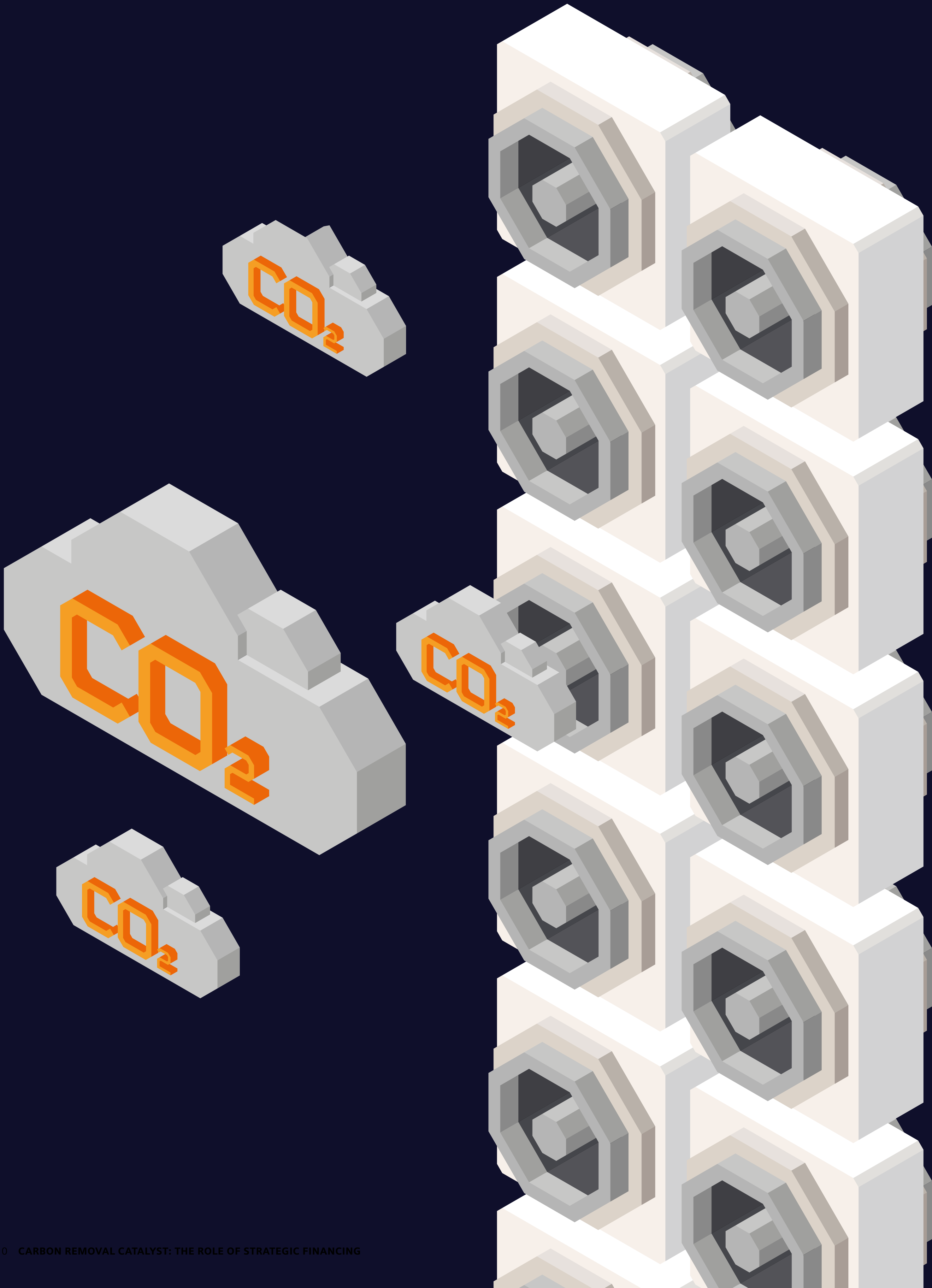
According to data compiled by the IEA, governments have committed almost USD 4 billion in funding specifically for DAC development and deployment since the start of 2020. This includes, for example, investment amounting to USD 3.5 billion to develop four DAC hubs and a USD 115 million DAC Prize program.[13] The European Commission, through its EU Innovation Fund, has also awarded over €1 billion to innovative climate projects, including projects deploying CCS technologies in Belgium and Sweden[14]. Meanwhile, countries such as Australia, Canada, and the U.K. are also announcing new R&D funding [15], while countries in Asia such as Malaysia, Indonesia, India, Japan, Thailand, and China are expected to formulate roadmaps or finalize regulatory frameworks for CCS projects in near-term.[16]

In the US, policy measures have specifically pointed to the potential of carbon dioxide removal as a tool that can help address "hard-to-abate emissions" from industries such as aviation, shipping, and agriculture[17]. For example, the recent Inflation Reduction Act provides tax credits for CO_2 captured and stored, as well as specifically CO_2 removed through direct air capture and permanently stored.[18] This need for NET is also supported by data from the World Resources Institute, which predicts that even with rapid investment in emission reductions, the US could need to remove about two gigatons of CO_2 per year by midcentury to reach net-zero[19], which is about 30% of US 2019 greenhouse gas emissions. Similar urgency is echoed on a global scale, as scientists also predict that up to 10 gigatons of CO_2 ($GtCO_2$) will need to be removed annually from the atmosphere by 2050, while **ramping up removal capacity up to 20 $GtCO_2$ per year by 2100**[20].

Corporate sustainability trends

Policy moves are also shaping market trends. The Paris Agreement has triggered corporate commitment to carbon neutrality. With over 190 countries endorsing it, the number of companies with net-zero pledges has doubled from 500 in 2019 to more than 1,000 in 2020 according to a report by the NewClimate Institute & Data-Driven EnviroLab[21]. Growing corporate sustainability trends mean that companies are not only eyeing low-carbon infrastructure upgrades, but are also increasingly demanding technologies that can capture, measure, and report on their decarbonization progress for transparency and accountability.

Altogether, these ongoing developments paint a broad picture where the momentum for NET is gathering pace, while policy and commercial incentives are increasingly prioritizing the maturing of the field from various perspectives, underscoring its critical significance in our climate change mitigation efforts.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4 **Current gaps** in technological readiness and scalability

Despite the converging market and policy ecosystems, the potential of NET is tempered by limitations at this stage. While they hold promise in mitigating climate change, some have also warned against over-relying on them to limit warming to 1.5 °C due to current challenges in their technological readiness and scalability.

For instance, the IPCC has cautioned that while various types of CO_2 removal methods exist, all are relatively "untested in practice or not ready for deployment at the scale needed to be effective"[22]. In its 2019 Special Report, the IPCC stated that carbon dioxide removal deployed at scale is "unproven", and that "reliance on such technology is a major risk in the ability to limit warming to 1.5°C".[23]

These considerations are crucial in the broader context: rather than over-relying on NET alone, which are not ready to absorb emissions at the pace that matches the required pace of decarbonization, the world must also maintain its focus on reducing emissions through a combination of strategies, such as renewable energy and energy efficiency, to achieve the necessary emissions reductions in a timely and sustainable manner. In other words, it would be more prudent to examine NET at their current stage as technologies that will complement, rather than replace, existing decarbonization pathways.

Nonetheless, to avoid the worst scenario of climate crisis, nurturing NET in a careful manner remains a worthwhile undertaking. This endeavor would require both technological and financing expertise to help promising early-stage companies with strong technological potential overcome typical growth- and expansion-stage hurdles. The role of a strategic investor, therefore, would serve a multi-faceted function in accelerating breakthrough innovation. For instance, Direct Air Capture (DAC), which focuses on removing carbon emissions from the atmosphere, would likely benefit from strategic R&D capital as well as market-building support. This type of multi-faceted partnerships could potentially improve their feasibility and scalability, considering DAC is relatively nascent compared to more established carbon avoidance processes, such as point-source solutions that capture emissions directly from industrial processes for utilizing in the production of products[24].

5 **More than capital:** why strategic investors can be the critical catalyst

In the burgeoning world of carbon credit markets, private-sector investment is on the rise. However, the journey of young companies, particularly those developing, experimenting, pilot-testing and scaling NET, require not only capital. Supporting them effectively requires a myriad of cross-disciplinary expertise, including engineering and financing know-how, that could be rare for early-stage companies to access from a single source.

Early-stage companies need more than just financial backing before their innovations are proven ready for scaling – they also need deep industry and infrastructure expertise, strong ecosystem support, and access to market resources and commercial opportunities across diverse geographies and legal setups at a competitive speed. While there is governmental funding, such as the EU Innovation Fund, that encourage breakthrough technologies, gathering the full-force support needed to mature NET ideally requires financing expertise that connects with a constellation of energy, industry, and infrastructure technologies, along with a rich understanding of the challenges arising in each development phase.

These kinds of support could take many forms: helping early-stage companies navigate banking and capital management hurdles, offering financial consultation that suit their unique technology value chains, supporting their growth plans by holistically examining their financial and engineering needs, or offering support across global markets, to name a few.

Cross-sectoral experience is particularly crucial in fostering the growth of NET, as the technological applications, financial incentives and market dynamics associated with adopting carbon capture and storage methods can differ substantially across various industrial value chains. The reach of CCS components is expected to expand into industries such as cement and steel production, as well as the production of blue hydrogen[25], while mainstream adoption in other sectors would benefit from more robust financial and policy support, particularly in areas such as transport network and storage capacity expansion. In this context, strategic investors with a strong record of designing business models for transformative technologies across diverse sectors can provide critical support.

Siemens, a global technology company developing decarbonization projects,
has a vast track record in energy transition domains as diverse as renewables, energy-efficiency technologies for buildings and industrial decarbonization, transport, e-charging infrastructure, and through their many phases.

As its financing arm, **Siemens Financial Services (SFS)** has global experience in investing in decarbonization technologies and helping early-stage companies converge with Siemens technologies in digital industry and smart infrastructure, as well as scaling their customer base through leveraging its global networks.

Focusing not on fast profits but a long-term vision of enabling sustainability through smart business models, financing experts at SFS understand the role of patient capital and ecosystem knowledge in nurturing emerging technologies and forming new markets – and has been pioneering strategic partnerships with the purpose of accelerating sustainability. They can help early-stage companies navigate the challenges along their growth paths, such as designing models for end-companies that balance between cost and incentive, making CCS use cases viable across different industries and regions.

> "When we invest into a company, we always consider the potential in this partnership for both sides. For instance, do we believe the technology is scalable? How can this or that technology be enabled by our global network? Or how can our expertise support the management to reach that? In the next years, we anticipate a significant growth market, with a lot of dynamic interconnections."
>
> Robert Schiele, Head of Negative Emission Technologies at Siemens Financial Services

6 Case:
SFS acts as a strategic investor for 44.01

"At 44.01, we partner with strategic industrial players that have a real understanding of innovation, and who can provide us with practical support in scaling our technology quickly. We are delighted to have partnered with Siemens Financial Services and look forward to working with the Siemens group to eliminate CO_2 and fix our climate."

Talal Hasan, 44.01's CEO and Founder

Case: SFS acts as a strategic investor for 44.01

Images by courtesy of 44.01

44.01 (Oman, UAE, UK)

44.01 is the first organization to remove CO_2 permanently by mineralizing it in peridotite, an ultramafic rock found commonly in Oman as well as in America, Europe, Asia and Australasia. Unlike traditional carbon "storage", which never truly removes CO_2, mineralization eliminates CO_2 forever by turning it into rock. This minimizes the need for extensive and costly monitoring and insurance, offering a safe, permanent, scalable solution for removing captured CO_2. In 2022, 44.01 was named one of the winners of the Earthshot Prize, a global environmental prize founded by Prince William and The Royal Foundation to discover, accelerate, and scale ground-breaking solutions to repair and regenerate the planet.[26]

As a strategic investor, SFS supports 44.01's journey of international deployment as the company works with both world-leading direct air capture and point-source capture technology partners. The role of strategic financing enables the scaling of NET practices in ways that go beyond capital support, for instance:

SFS provides workshops that support 44.01 throughout their development stages, helping to gather Siemens solution architects for technical consulting and financial services tailored to each development stage.

SFS supports 44.01's efforts in building a demonstration site in the United Arab Emirates (UAE) with its measuring and steering equipment, leveraging its global presence, supporting with local market knowledge, functional expertise and capabilities to grow the organization.

7 **Conclusion:** financing as a strategic enabler of NET impact

Climate action is the colossal challenge of our time that calls for an all-hands-on-deck approach. The race to a net-zero future requires a diverse array of innovations to enable multiple pathways of decarbonization. Negative Emissions Technologies could emerge as a supporting decarbonization pathway, complementing energy efficiency, renewables, and other strategies.

At this juncture, the significance of NET lies primarily in their potential to upscale industry-scale carbon offset practice, particularly concerning residual emissions. Considering their near-term challenges, such as technological readiness and scalability, patient capital and strategic ecosystem support can play a critical enabling role in nurturing their steady development, enabling them to reach their potential in the broader climate action landscape.

Strategic investors with a focus on sustainability and long-term visions such as SFS are uniquely positioned to help NET companies. They can provide the necessary capital, industry insights, market access and guidance to navigate financial, business, and technological hurdles, catalyzing growth in an emerging field that has the potential to boost existing decarbonization efforts, ultimately strengthening our collective ability to combat the global climate crisis.

In the face of a warming planet, the stakes have never been higher. At first glance, the race to net-zero appears to be solely about reducing emissions. However, achieving this goal also necessitates a profound reimagining of the strategic interplay between financial resources, technological advancement, and environmental needs. As underscored in this paper, strategic financing will be a critical catalyst in this journey, helping to turn the promise of NET into a tangible reality.

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