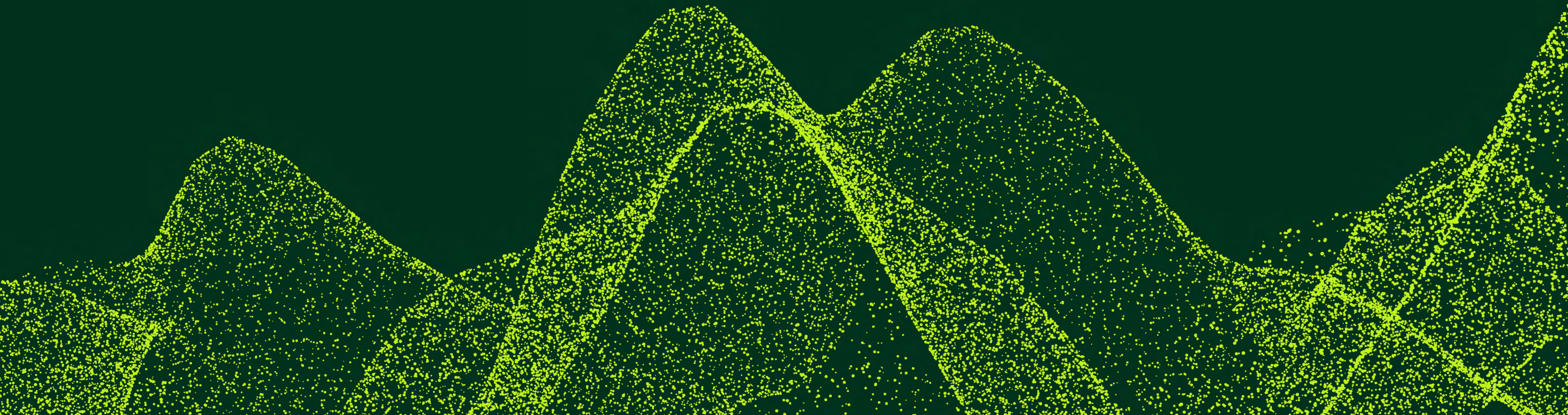


Navigating the Carbon Removal Landscape:

Understanding Tech-based CDR



Overview of the Landscape

As of February 2024, investment in the Carbon Dioxide Removal (CDR) market has surged to a staggering \$2.1 billion—a monumental rise that underscores the immense opportunity of the space. Half of this, \$1.25 billion, was invested in 2023. Tech-based CDR purchases grew 7.3x in 2023 to 4.5 megatonnes, up from 0.615 megatonnes in 2022. This exponential growth trajectory shows no signs of slowing in 2024.

Investment in CDR is crucial. As the Intergovernmental Panel on Climate Change (IPCC) emphasizes, CDR plays a pivotal role in global net zero emissions. Global imperatives demand ever greater volumes of CO₂ removal—2.3 gigatonnes per year by 2030 and 10.8 gigatonnes per year by 2050—so effective implementation of CDR technologies is paramount. Investments in CDR present a compelling opportunity, but meticulous execution and thorough scrutiny are crucial to ensuring that CDR projects deliver the anticipated and critical results.

CDR technologies play a central role in achieving three primary objectives:

- Providing short-term mitigation alongside traditional emission reduction strategies.
- Offsetting hard-to-abate emissions, thereby contributing to net-zero targets.
- Facilitating net-negative emissions in the future to actively contribute to the reduction of global temperatures.

While CDR technologies hold potential, they must not overshadow immediate decarbonization and emission reduction efforts. They serve as a tool for offsetting residual emissions, especially in hard-to-abate sectors. Amidst this surge in CDR investment, ensuring quality is paramount. The market is flooded with new entrants and technologies, yet the effectiveness of these investments remains largely unproven. Investors must understand how to assess CDR projects to drive investments towards quality. This briefing provides guidance based on our research in the CDR space.

Three Key Developments Shaping the CDR Landscape

Regulatory Framework Development

The European Carbon Removal Certification Framework (CRCF), currently under development, is one of the EU's efforts toward reaching its goal of climate neutrality in 2050 and negative emissions thereafter. The voluntary regulatory framework aims to boost the evolution of quality removals across the EU by creating a unified certification scheme for CDR. It is unprecedented, will serve as an inspiration to other regulatory frameworks, and expected to guide best practices across the VCM.

Government Support and Industry Initiatives

Governments actively promote CDR technologies through different approaches. For example, the US government is set to contribute \$1.2 billion in direct funding for the development of two commercial DAC facilities (Project Cypress and South Texas DAC Hub) and provides financial incentives for CDR activities through its 45Q tax credit. Also, the US is considering public procurement of CDR credits as a tool to

scale supply through the CDR Purchase Pilot Prize. Private initiatives like the Science Based Targets initiative (SBTi) and the Oxford Principles drive CDR recommendations and advocate for increased carbon removals.

CDR Discussions on a Global Stage

At COP28, the spotlight shifted to carbon removals, especially DAC, marking a change from previous years. The global stocktake text acknowledged carbon removals and their role in reaching climate targets. In the context of Article 6, finalizing the carbon removal recommendations in Article 6.4 was deferred at COP28, causing some disappointment. But this delay could allow for further refinement of discussions and present an opportunity to highlight the potential of technology-based CDR before COP29. Also, CORSIA's carbon credits eligibility list allows airlines to use carbon removals to meet their obligations under the scheme.

What Investors Need to Know

Although there is high demand for innovative CDR technologies, the supply of viable and scalable solutions remains relatively low, creating an environment ripe for investment opportunities. Offtake contracts, which define the terms for the purchase of carbon removal services, are pivotal in securing revenue streams for CDR projects and project developers. As the sector matures, investors can expect increasing scrutiny from regulatory bodies and stakeholders, necessitating robust risk management strategies and transparent reporting practices. In the meantime, investors must closely scrutinize the terms and conditions of these agreements and the quality and design of the project, as they can significantly impact project profitability and long-term success.

Tech-based solutions hold immense potential. The CDR industry's trajectory is poised for growth, offering lucrative opportunities for those who carefully navigate its evolving dynamics. With the right disclosures around financials and carbon accounting to assess, it's possible that many of these innovative technologies, like direct air capture, are a surefire means for robustly removing carbon from the atmosphere than any of the solutions available.

Sylvera's innovative approach to assessing quality can help organizations make sense of the range of projects in this space, from corporates looking to invest in these projects to standards bodies working to ensure integrity in the market. Here, we show you how to evaluate projects, what to look for, and how to invest in the right projects at the right time to maximize your returns – and maximize overall climate impact.

Defining CDR: Types, Technologies, and Critical Distinctions

In the complex realm of carbon credits, understanding the nuanced difference between removals and avoidance is crucial. A removal credit signifies the removal of one metric ton of CO₂ or its equivalent, achievable through various CDR methods. An avoided emissions credit, also representing one metric ton of CO₂e, involves projects that prevent emissions that would have occurred without intervention.

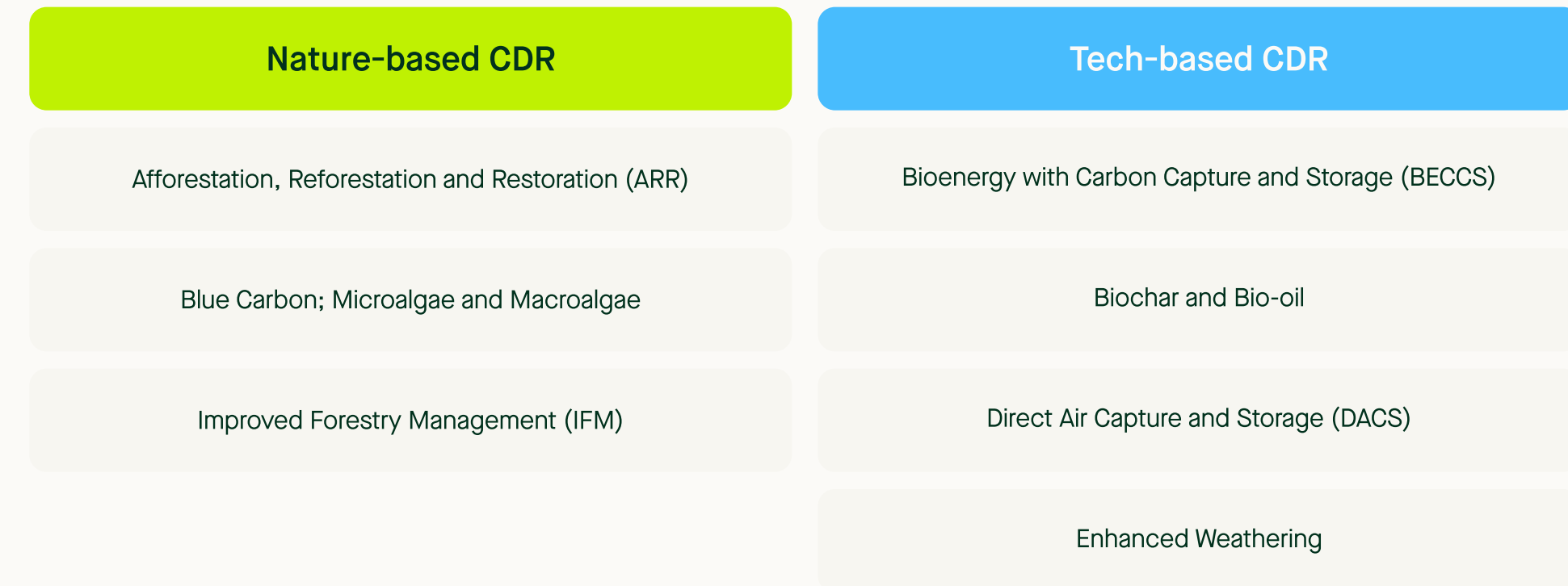
Carbon removals are not inherently a superior version of carbon avoidance. In-depth analyses of prominent projects have revealed both removal credits with serious flaws and exceptionally high-quality avoidance credits. This perception that removal credits have higher "environmental integrity" oversimplifies the intricate reality. Tech-based

CDRs like DACS offer significant benefits, such as high permanence, but banking exclusively on them is impractical. Challenges, including the lack of scalability, high costs, high energy consumption, scientific uncertainties, and the potential lack of co-benefits, necessitate a diversified approach incorporating both removals and avoidance projects. The key lies in acknowledging the unique strengths and limitations of each approach. Investors need to scrutinize projects individually to comprehensively understand their effectiveness.

Defining CDR Types

There is a spectrum of CDR activities that extract carbon dioxide from the atmosphere or ocean and store it in Earth's biosphere or lithosphere. The methods show diversity across their removal processes, storage timescales, technological maturity, mitigation potential, cost and co-benefits.

The Rocky Mountain Institute (RMI) is currently tracking 32 distinct CDR approaches, although new approaches are expected to emerge. CDR activities can be differentiated into nature-based and technology-based categories. Nature-based solutions currently account for 99.9% of the annual 2 Gt CO₂ removal, and tech-based solutions contribute only 0.002 gigatonnes annually. However, projections suggest that novel tech-based CDR methods could increase by a factor of 30 (potentially reaching 540) by 2030.



We categorize Biochar and BECCS as technology-based CDR due to their engineered removal mechanisms. In contrast, nature-based solutions, such as ARR, rely on natural processes, where trees naturally absorb CO₂ and maintain the carbon pool. While Biochar and BECCS utilize living biomass for removal, the biomass undergoes conversion into a removal pool through technology and human intervention, so we classify them as technology-based solutions.

Defining CDR Types

While nature-based approaches currently provide cost-effective removals and long-term co-benefits such as biodiversity protection, they may not alone suffice to offset hard-to-abate emissions. Gradually transitioning to tech-based CDR solutions can enhance durability, complementing the benefits of nature-based methods. As we anticipate a decrease in tech-based removal costs, it becomes crucial to invest

in accelerating their scale-up to ensure lasting carbon storage. This comprehensive portfolio approach ensures both short-term capacity and long-term flexibility, addressing the evolving costs and requirements of effective carbon removal.

Tech-Based CDR

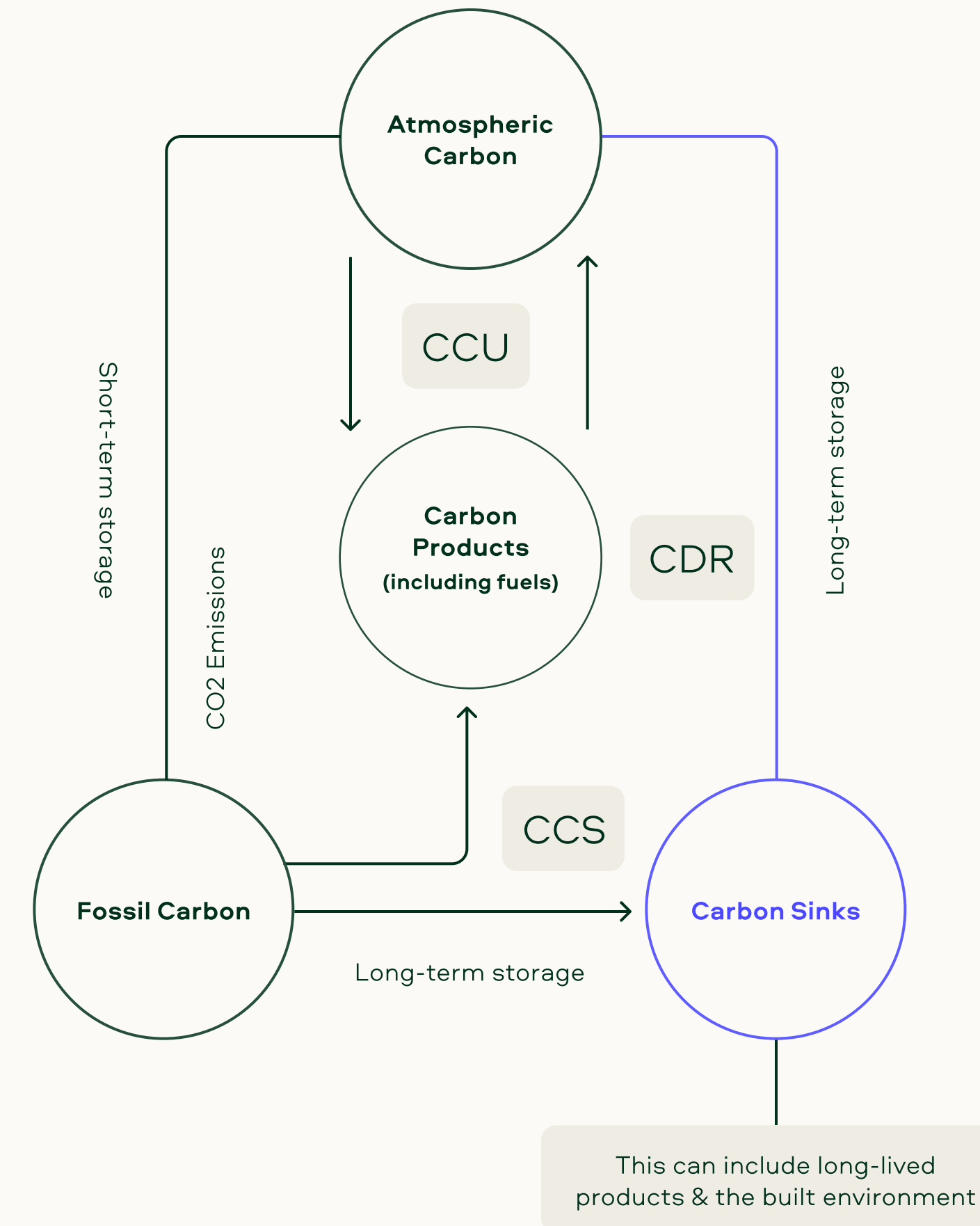
Core method	Biochar	BECCS	DACS	Enhanced Weathering
Definition	Biochar is a soil-enhancing material made from heating organic matter without oxygen. It's produced from biomass, improves soil quality by adding nutrients to the soil, and stores carbon in open or controlled environments.	BECCS turns biomass into electricity or fuels while capturing and storing the resulting CO2 emissions. It involves converting sustainably sourced biomass, such as feedstock or waste, to generate biofuels, electricity, heat, or pulp. The key is to capture and store the CO2 emissions produced during these processes.	DACS is a technology that directly captures carbon dioxide (CO2) from the atmosphere through various methods. The captured CO2 is then either mineralized, regenerated, or separated from the capturing medium using different processes, such as high or low-grade heat.	Enhanced Weathering is a method that speeds up the natural process of rocks and minerals capturing carbon from the atmosphere. Terrestrial enhanced weathering involves spreading finely ground alkaline materials in soil. Coastal enhanced weathering distributes crushed alkaline minerals in coastal areas.
Storage Timescale	Centuries to millennia	10,000+ years	10,000+ years	10,000+ years
Financial Cost (per ton)	\$10-\$345	\$50-\$270	\$100-\$1,000	\$50-\$800
Risks	Increased demand for biomass if not sustainably sourced; uncertain degree of soil permanence; and land use, and water requirements from scale up.	Energy requirements across the full life cycle, land use, and water requirements from scale up, limited waste biomass supply, CCS technology challenges, and cost.	High water and energy usage, high energy requirement could lead to growing competition for low-carbon energy or increase GHG emissions, environmental impacts, and cost.	Environmental and social effects; effects of trace metals in local ecosystem, measurement at scale to validate net CO2 removals and impacts of mining.
Stage	Projects ranging from pilot to commercial stage 6 companies with <\$15M in funding each	Projects ranging from pilot to commercial stage BECCS electricity - 4 companies at pilot stage BECCS fuel - several companies at commercial stage	Over the 10 different DACS methodologies, there are 36 companies across concept, pilot, demo, lab and commercial stage, with funding ranging from \$0.1-100M The most advanced DACS are at commercial stages with funding ranging from \$1m to \$1b	Projects ranging from pilot to lab and demo stage Terrestrial - 6 companies at lab to demo stages with <\$50M in funding each Coastal - 2 companies at pilot stage with <\$5M in funding each
Success is Contingent on:	Improvements in carbon efficiency of biochar formation and supply of sustainable biomass feedstock.	Breakthroughs in CCS technologies and sustainable biomass feedstock supply.	Breakthroughs in materials, process design, and equipment, and increased cost effectiveness.	Methodology cost effectiveness, environmental safety, and wide deployment across multiple continents
Funding needed for success	\$450-650M over 10-12 years	\$300M-\$1.5B over 5-15 years	\$400M to \$3B over 13-20 years	\$250-700M over 7-20 years

Table References: https://www.ipcc.ch/report/ar6/wg3/downloads/outreach/IPCC_AR6_WGIII_Factsheet_CDR.pdf and <https://rmi.org/insight/the-applied-innovation-roadmap-for-cdr/>

Carbon Removals vs Carbon Capture Storage/Utilization

There is often a misconception that Carbon Capture for Storage (CCS) or Utilization (CCU) are types of Carbon Dioxide Removal (CDR). CCU and CCS technologies serve to either recycle or store fossil CO₂ emissions that would otherwise be released into the atmosphere. However, they do not remove carbon from the atmosphere.

CDR methods, such as DACS, may share common capture processes or long-term storage infrastructure with conventional CCS. But the pivotal difference lies in the origin of the captured CO₂. In CDR, carbon has been actively removed from the atmosphere, while CCS involves storing carbon from fossil sources, which has not yet been emitted and therefore cannot be counted as a removal credit. It is important to recognize that even though CCU methods may capture atmospheric carbon, the captured carbon is not durably stored, and CCU is not considered a removal.



CDR Market Dynamics and Insights

CDR has become a prominent subject, but it only recently developed into a robust pipeline, attracting substantial participation from major stakeholders. Because CDR is a novel technology, investors primarily channel their investment through advanced market commitments, ensuring adequate funding for the development of new technologies. The CDR market is nascent, so understanding the underlying dynamics at play is crucial.

Early-stage projects (pre-issuance) predominantly drive CDR market activity, with only 3.8% of purchases having been delivered so far. Realizing the necessary CDR capacities to attain net-zero targets is no small feat and demands substantial financial commitment. Successfully meeting the needs for a net zero economy could lead to an industry worth \$0.3 - \$1.2 trillion annually by 2050.

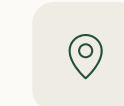
CDR Market Potential

Delivering six to ten metric gigatons of carbon removals could create an industry worth \$0.3 trillion to \$1.2 trillion annually by 2050.



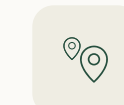
2050 climatic-need market size

\$0.3 trillion-\$1.2 trillion



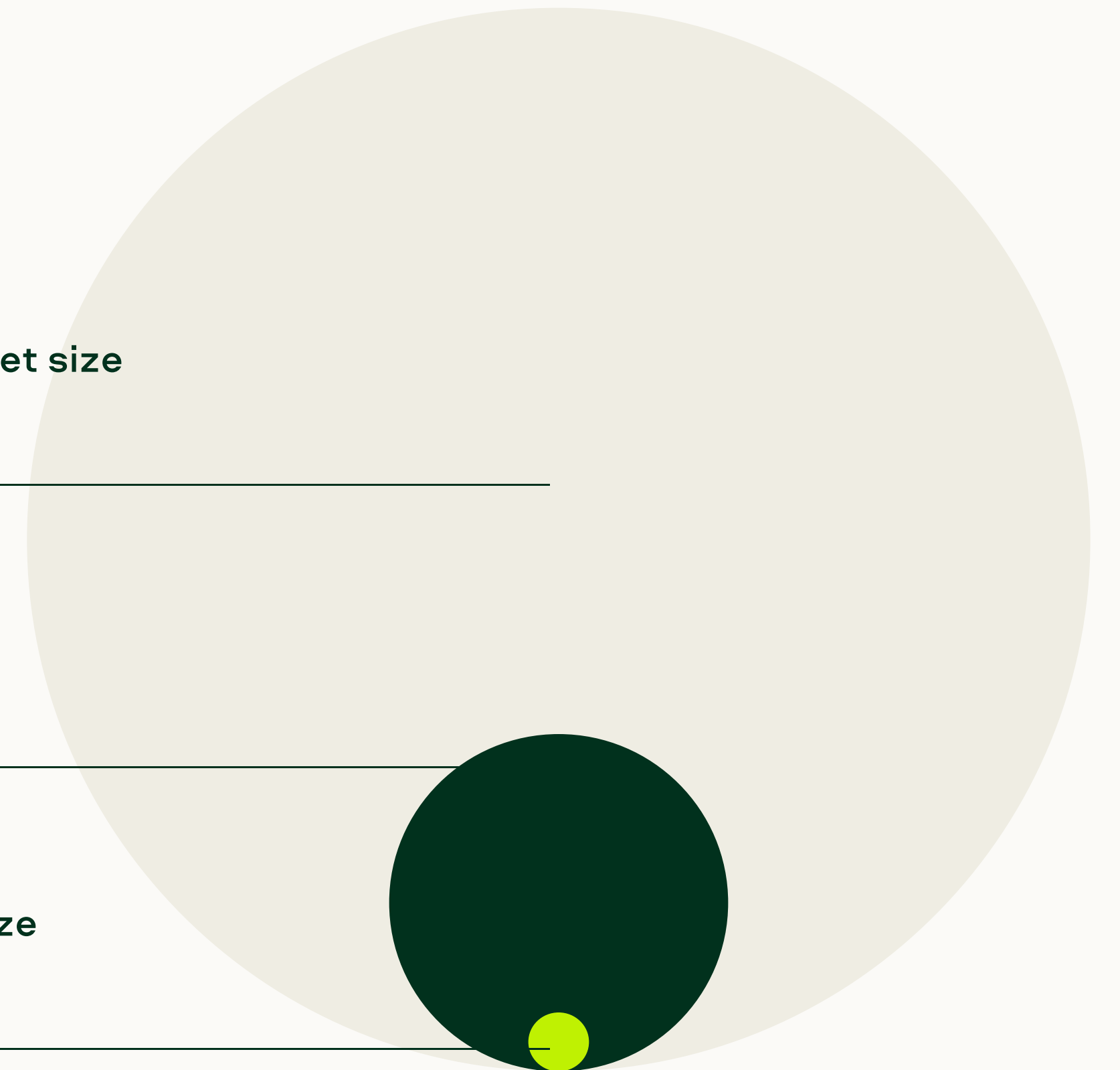
Current market

\$0.8 trillion-\$2.1 trillion



2030 expected market size

\$40 billion-\$80 billion

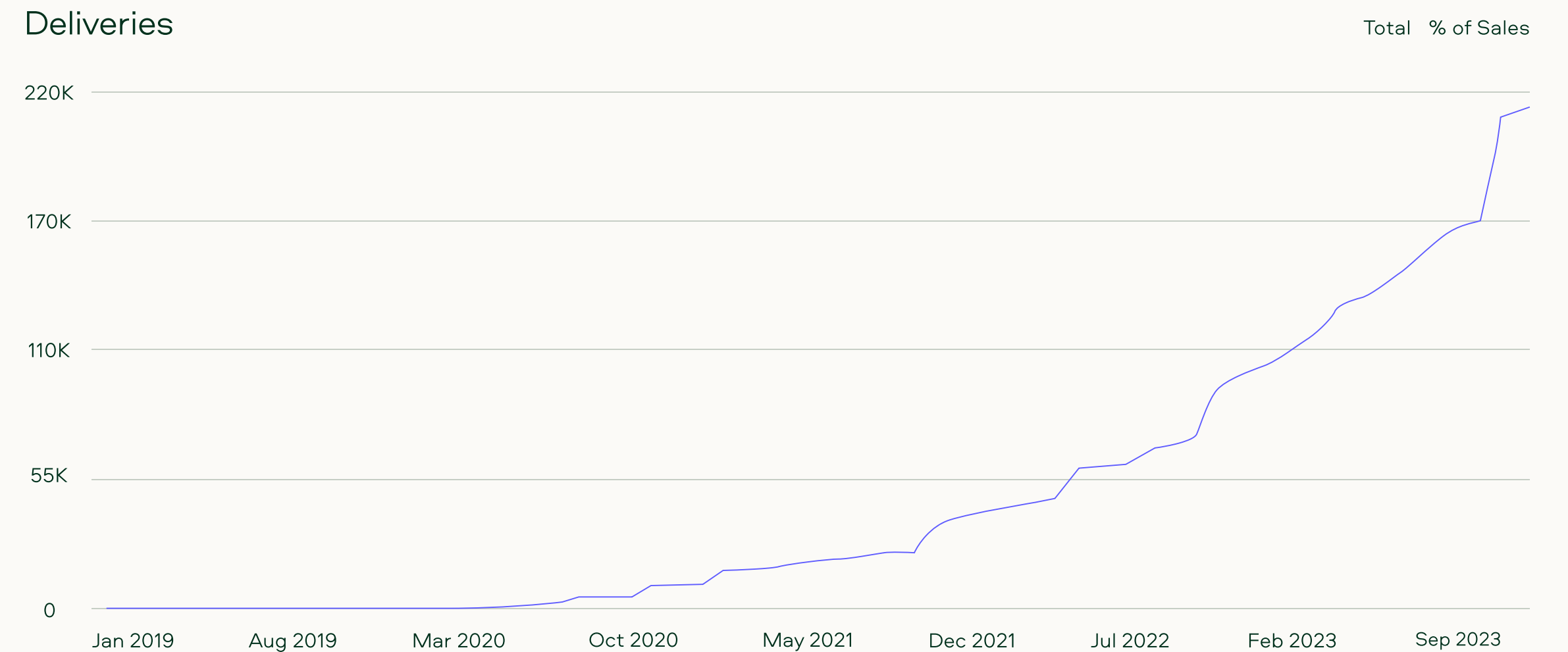
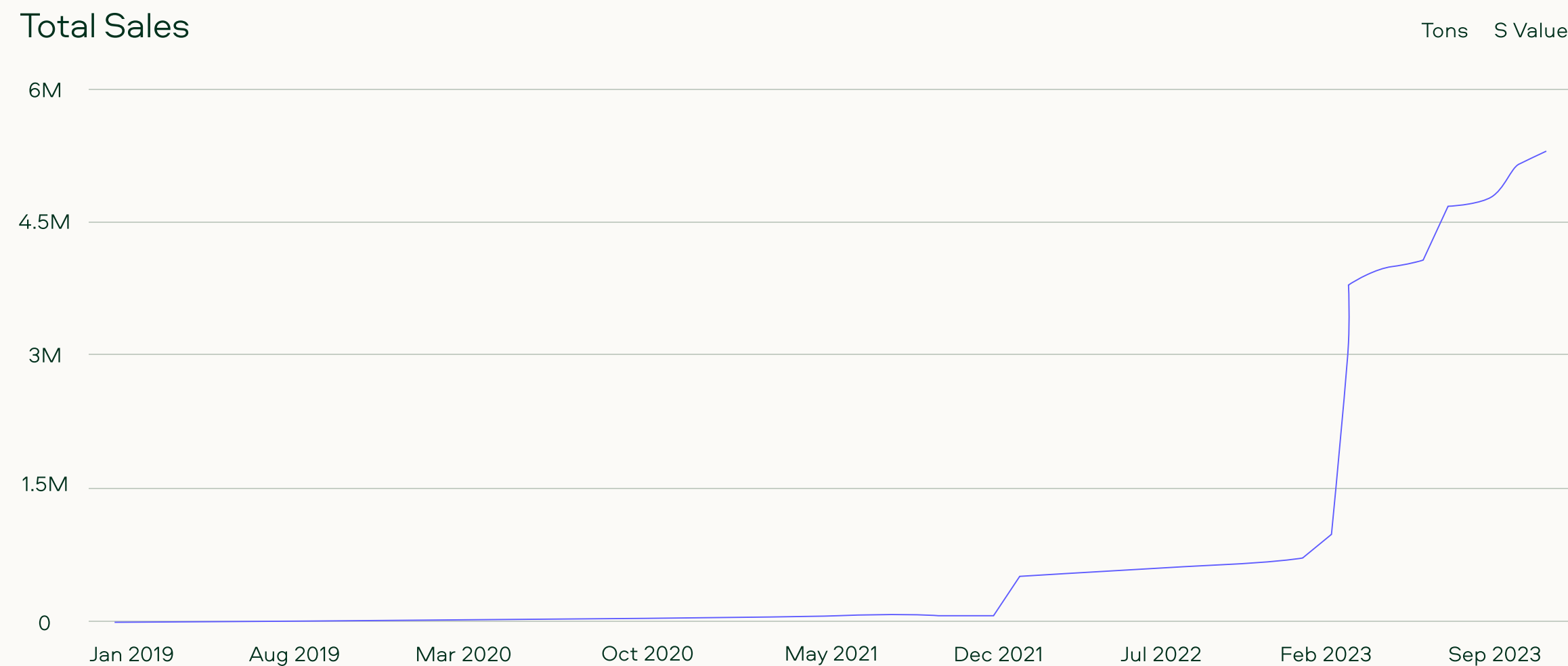


Reference: <https://www.mckinsey.com/capabilities/sustainability/our-insights/carbon-removals-how-to-scale-a-new-gigaton-industry>

CDR Purchased and Delivered

According to [CDR.fyi](https://www.cdr.fyi), as of January 2024, purchasers have bought 5,496,541 metric tons of CO2, with only 3.8% of these purchases delivered. That's 5.5 million metric tons of CO2 purchases (cumulatively), compared with 750k in Jan 2023.

In 2023, deliveries continued to increase, although at a slower rate compared to purchases. The Annual Delivery Capacity rose from 25.6 kilotonnes in 2021 to 61.4kt in 2022 and then to 125.1kt in 2023. Still just a fraction of the 10 gigatonnes of CO2 removals needed for global net zero.

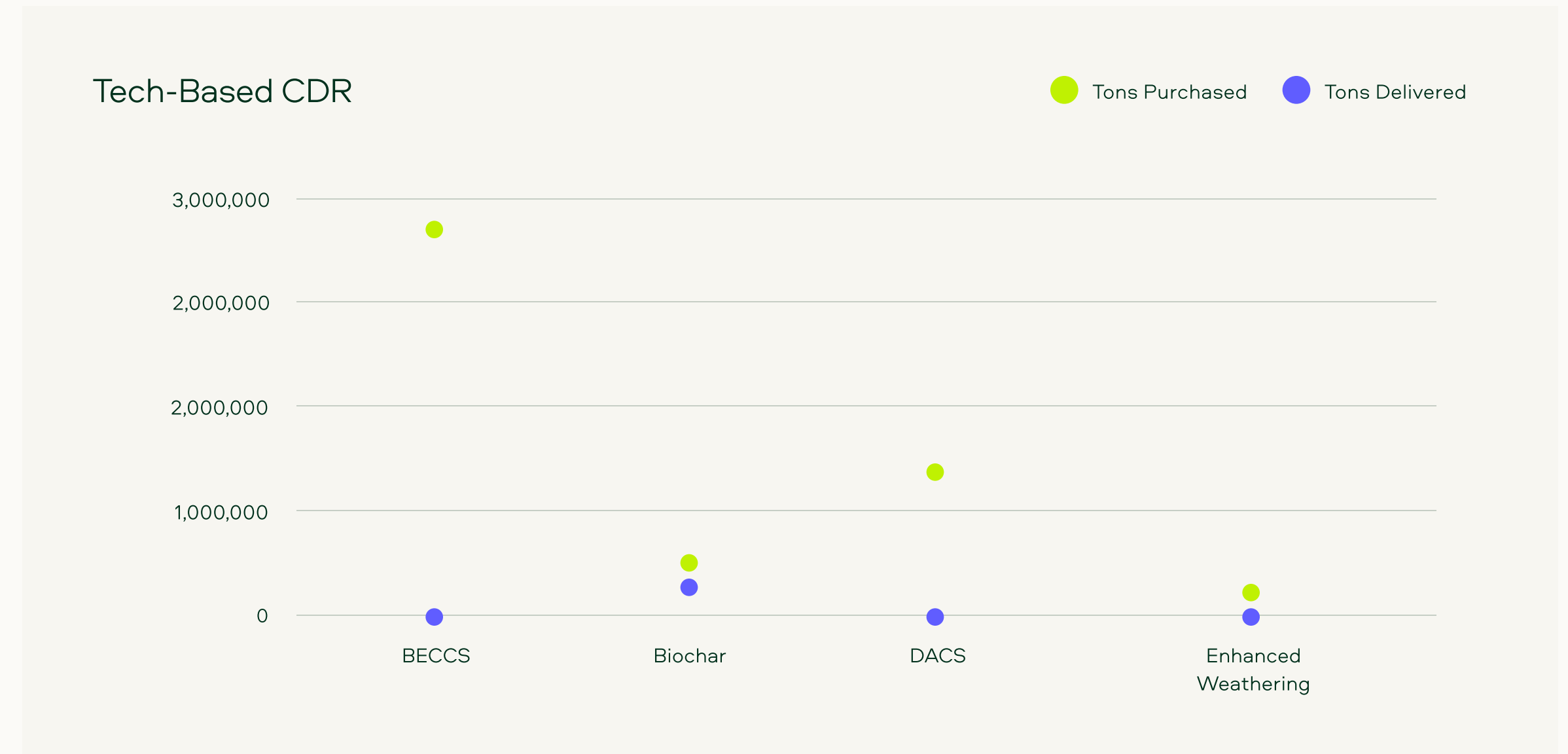


Reference: <https://www.cdr.fyi/>

Tech-Based CDR

Approach	No. of Suppliers	Tons Delivered	Tons Purchased
BECCS	3	0	2,781,800
Biochar	51	199,774	448,693
DACS	24	100	1,323,487
Enhanced Weathering	11	3,369	156,637

Data Reference: <https://www.cdr.fyi/>



Average Price per Ton Comparison

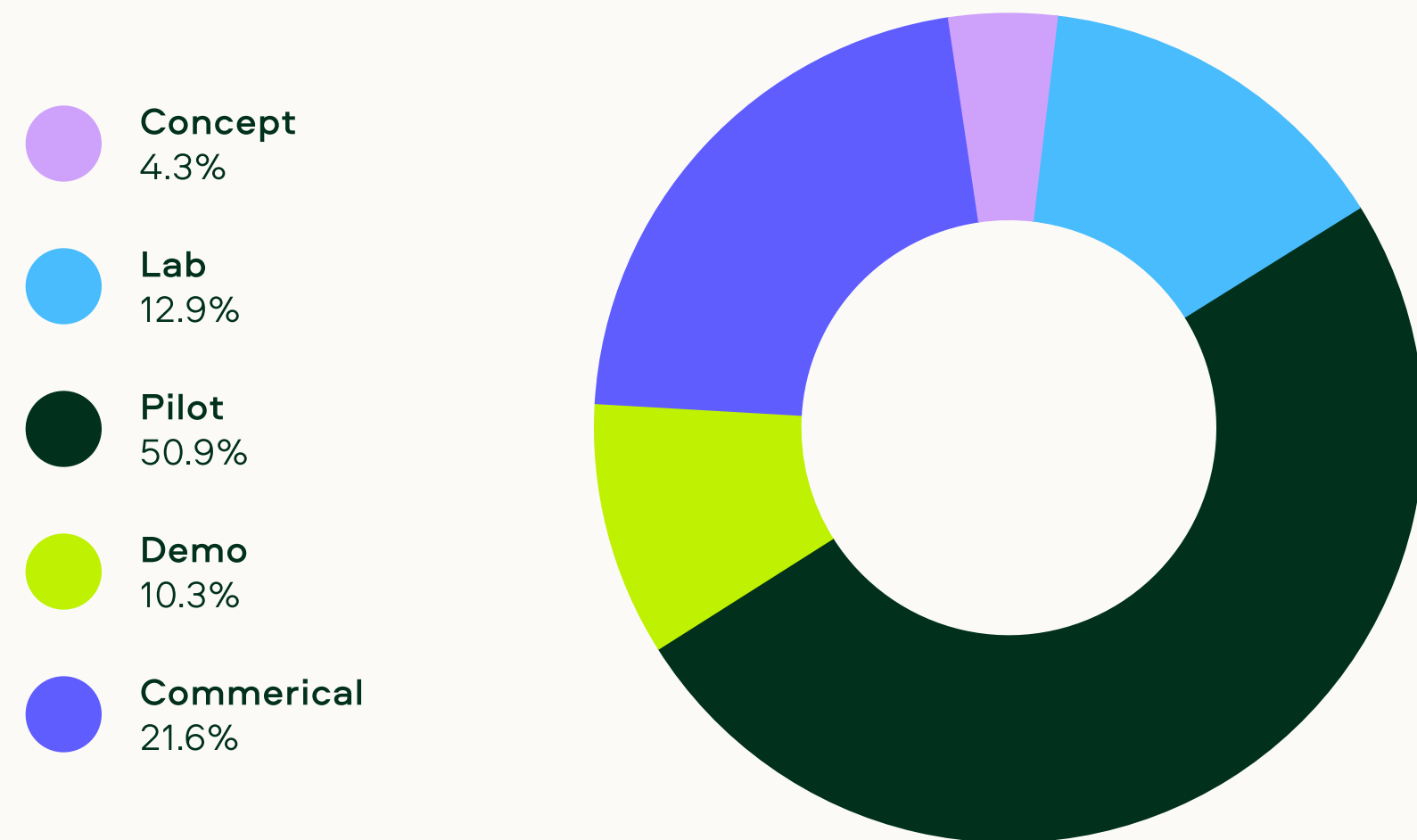
Average price by method between 2022 & 2023

	2022	2023	↓ % Change
Enhanced Weathering	\$434	\$371	-15%
Biooil	\$600	\$505	-16%
Biochar	\$212	\$131	-38%
DAC	\$1,261	\$715	-43%
BECCS	n/a	\$300	n/a

Reference: <https://www.cdr.fyi/blog/2023-year-in-review>

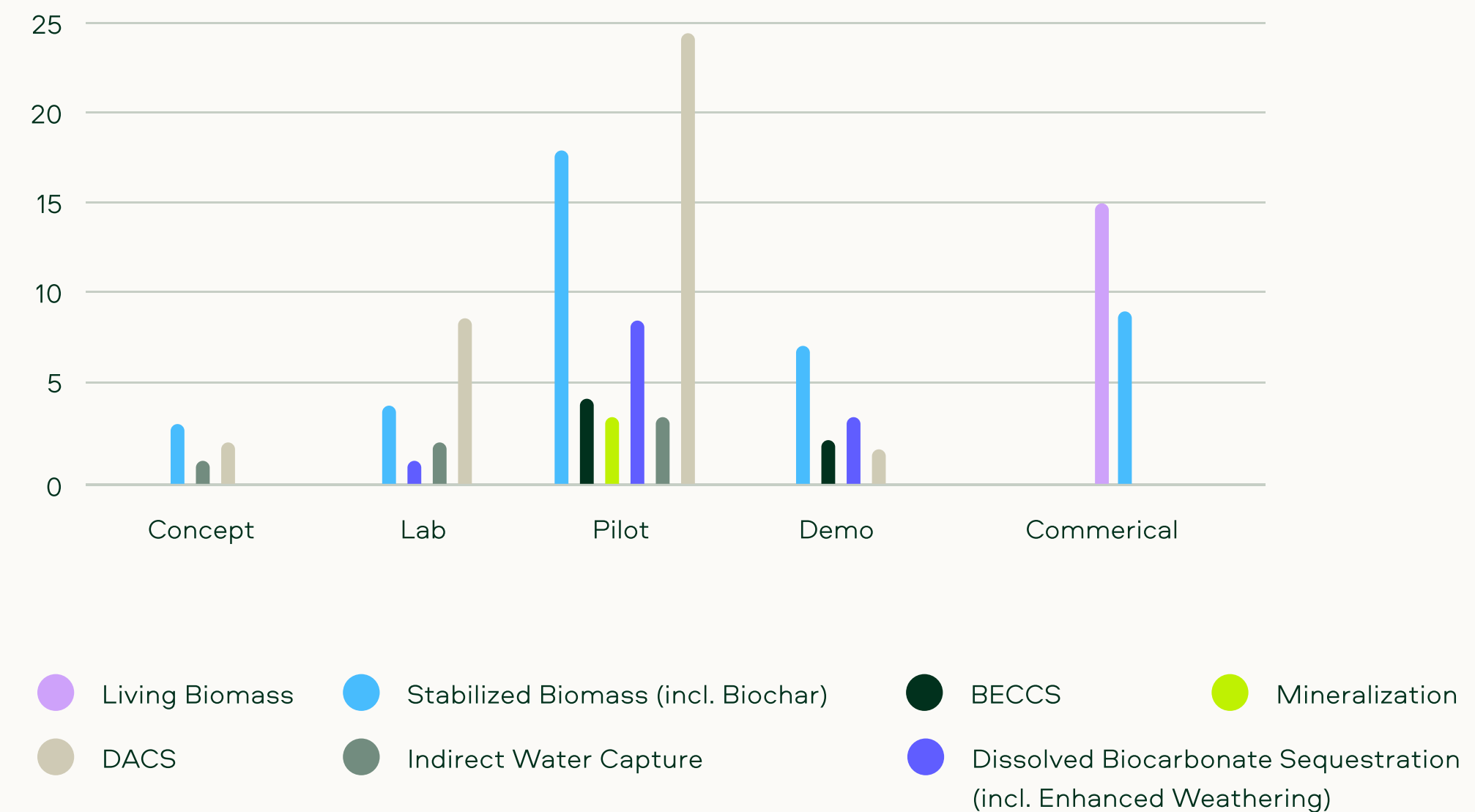
Tech-Based CDR

The RMI is tracking 189 projects across different stages of project development, from concept stage, lab stage, pilot, demo and commercial stage. 118 projects are in the pre-demo stage (concept, lab or pilot) and 71 in the demo stage (demo or commercial), highlighting the considerable number of projects still in development.



Data Reference: <https://rmi.org/insight/the-applied-innovation-roadmap-for-cdr/>

The surge in demand for CDR has led to a scramble to meet it, revealing a substantial variation in technological readiness among different CDR project types. This huge variation in technological readiness for different CDR project types also brings variation in the development of projects and their relevant standards.



Navigating the CDR Market: A Strategic Approach

To channel funds towards impactful climate action, investors need to optimize their CDR investment strategies and make informed decisions. Despite promising attention and rapid expansion, navigating the risks in CDR requires careful consideration.

Seven Key Challenges to Navigate

Investment flowing into CDR is gaining momentum, yet significant challenges persist due to the industry's early development stage. Investors need to understand and address these challenges to make informed choices.

1. Robust Data and Transparency

As the CDR sector transitions from labs to real-world applications, there is a pressing need for robust data in order to scale the solutions. Transparent practices are needed to ensure effective industry growth. CDR's novelty compared to other carbon credit projects gives it the unique potential to learn from past errors. Recent legislation, such as California AB 1305, mandates annual reporting for carbon credit buyers in the state, enhancing transparency in climate claims. This exemplifies the trend towards stricter standards and the government's role in fostering transparent markets.

2. Lack of Universal Methodology

The industry's novelty is underscored by the absence of a universal methodology. The Monitoring, Reporting, and Verification (MRV) of CDR plays a pivotal role in creating standardized guidelines and defining high-quality standards. Many companies are also developing their own MRV systems, which results in a multitude of methodologies available on the market. Establishing clear definitions and criteria like durability, additionality, and measurability is crucial before the industry can scale significantly.

3. Baselines and Reference Scales

A prominent hurdle lies in the absence of established baselines. Alongside this, the absence of universal methodology creates a lack of standardized reference points to assess project quality and progress against. This makes it difficult to discern high-quality projects, creating a complex landscape for stakeholders to navigate.

4. Regulatory Complexities

The regulatory landscape for carbon removal is in flux, lacking well-defined and universal definitions. Regulatory actors face the challenge of setting universal standards and benchmarks amidst the vast and varied nature of the CDR industry and its intersections with other sectors.

5. Complexity Around Stakeholders

There is an intricate interplay between regulatory policies, project developers, investors, and CDR companies. The industry's substantial demand, coupled with numerous new entrants, adds complexity and requires a concerted effort for effective collaboration—all actors must evolve in tandem.

6. Pricing Volatility

Carbon credit pricing in the CDR industry is in flux due to varying levels of project maturity. Pricing changes can be influenced by regulatory shifts, market demand, and technological innovations. Differing levels of maturity across various CDR technologies lead to discrepancies in pricing across the projects, which can add complexity for those looking to invest. Despite facing challenges typical of emerging sectors, the industry holds significant economic promise with substantial growth potential.

7. Confidence in Future Deliveries

Securing trust and assurance regarding future deliveries poses a significant challenge, particularly in contexts where purchases primarily rely on Advanced Market Commitments (AMCs) and offtake agreements. This confidence in forthcoming deliveries holds immense importance as these AMCs serve as pivotal instruments in market expansion. Employing insurance mechanisms such as Puro's CORC Offtake Allocation service bolsters confidence in future deliveries and enhances reliability.

Confidently Investing in CDR

Drawing from our ongoing observations, here are critical steps to enhance investment efficacy and confidently drive capital towards tangible environmental outcomes.

Prioritize Due Diligence

Some perceive tech-based CDR as automatically meeting the highest standards due to its potential. However, the evolving nature of the CDR landscape demands rigorous due diligence. Understanding potential risks and opportunities is foundational to informed decision-making. Due diligence for CDR requires project-type specific frameworks, as this is the only way to accurately assess quality across fundamentally different activities. At Sylvera, our team has assessed the quality of the major non-forestry CDR methodologies used in the market based on their requirements across carbon performance, additionality and permanence. Although not project-specific, assessing methodologies is fundamental to developing appropriate ratings frameworks and helps identify projects' potential red flags and inform areas of improvements.

Invest in Quality CDR

In addition to identifying high-quality CDR investments, investors should advocate for global standards that promote transparency and quality in carbon removal projects. Leveraging tools and partnerships to stay ahead of evolving guidelines is key. Sylvera's methodologies assessments and ratings approach emphasize meticulous evaluation to find the highest quality projects, going beyond certifications and acknowledging the reputational stakes involved.

Stay Proactive and Informed

In addition to identifying high-quality CDR investments, investors should advocate for global standards that promote transparency and quality in CDR projects. Clarity on policy frameworks and keeping up with government signals that can bolster demand is also essential for aligning CDR investments with regulatory trends. Sylvera has a team dedicated to unraveling the intricacies of the market, along with a specialized policy team to navigate the regulatory landscape, ready to assist investors in making well-informed decisions.

Invest Early and Collaborate

Investors engaging early in CDR can build market-leading capabilities and establish themselves as industry leaders. By developing relationships with key stakeholders now, investors can position themselves for significant revenue opportunities as the market matures. Encouraging innovation through collaborative efforts is key to reducing CDR solutions costs. As the market matures, Sylvera's ongoing work, collaborations, and dedication to quality will continue to position us as a trusted partner in evaluating and identifying CDR investment opportunities. Additionally, the Sylvera pre-issuance team and relationship with project developers and carbon standards make us adeptly positioned to assist investors in making crucial decisions and accessing essential data.

Diversify Investments

Investors can manage risks by diversifying their investments across different CDR solution types. The varied returns profile in the CDR market enables investors to balance risks according to their risk appetite.

Investors who actively engage in these actions stand to not only navigate the complexities of the CDR market but also position themselves strategically for long-term success. Sylvera's commitment to transparency, innovation, and comprehensive assessment underscores our role as a trusted partner in this journey, ensuring the integrity of CDR projects as the market progresses.

Future Evolutions of CDR

The rapidly evolving Carbon Dioxide Removal (CDR) landscape demands a strategic investment approach. Allocating resources to CDR technologies requires a nuanced understanding of risks and opportunities. Whether you're just starting to explore CDR investments or are already involved, maintaining a balanced portfolio is key.

The CDR market is experiencing substantial growth, driven by technological advancements, increasing demand, and policy incentives. However, the lack of data and the absence of universal methodologies and clear guidelines pose significant challenges for investors. Digital Monitoring, Reporting, and Verification (DMRV) plays a pivotal role in

amplifying CDR scalability and facilitating data accessibility. To navigate this evolving landscape effectively, investors must draw from past experiences in carbon markets, implementing lessons learned to establish robust frameworks that prioritize integrity and transparency.

Looking ahead, the CDR sector will evolve towards greater transparency, energy efficiency, and cost-effectiveness. Investors must conduct thorough due diligence to grasp the current uncertainties, challenges, and opportunities within this expanding market. Sylvera remains a trusted partner, equipped to guide clients in making informed investment decisions in this dynamic field.