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Barriers to scaling the long-duration carbon dioxide removal industry

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Executive summary

To reach net-zero targets and stabilize global temperatures, we will need to dramatically cut emissions and remove large quantities of carbon dioxide from the atmosphere. Awareness is growing around the need for long-duration carbon dioxide removal (CDR) — a suite of largely nascent approaches to removing CO₂ from the atmosphere and storing it for hundreds of years or more. To date, private sector investment in long-duration CDR via the purchase of carbon credits has largely happened outside of the conventional offsets system and in the absence of established third party standards.

We conducted this assessment to explore whether the general lack of third-party standards for long-duration CDR currently presents a barrier to its growth, as well as how critical of a factor that is relative to other market barriers. Through the course of our interviews, we found that the lack of standards is not considered a main barrier to scaling up long-duration CDR today, but is expected to grow in importance as initial markets expand to reach a broader set of buyers.

We executed this assessment in four stages. First, we set out to understand how existing third-party standards in the conventional offsets market are poised to interact with long-duration CDR approaches, today and in the future. Second, we identified a set of key stakeholders involved in the current long-duration CDR ecosystem, and grouped them according to their role

(CDR Providers, Buyers, Brokers, and System Actors; see Table 1). Third, we developed surveys to gather stakeholder perspectives on third-party standards and other potential barriers to long-duration CDR. Finally, we conducted 37 virtual interviews, synthesized survey input, and identified convergent and divergent stakeholder perspectives on the barriers to scaling long-duration CDR. These perspectives are summarized below.

Convergent perspectives

We identified three perspectives that were commonly shared across stakeholders.

First, stakeholders commonly expressed their view that the lack of third-party standards does not present a major barrier to scaling long-duration CDR approaches in the short term. However, most interviewees also recognized that standards could play an increasingly important role as the market for long-duration CDR grows. Views largely converged around the notion that trusted third-party standards may be needed to attract the next wave of buyers, who will likely be more risk averse or have less internal capacity and expertise than today's buyers.

Second, stakeholder perspectives also converged around the view that public sector support is the most important factor for scaling up long-duration CDR. Stakeholders acknowledged that voluntary private sector demand has played an important and catalytic role to date, but expressed the view that the public sector will play a larger role than the private sector in enabling long-term growth.

Finally, many stakeholders stated that successfully scaling up long-duration CDR will require costs to fall, with a common benchmark suggestion of \$100 per ton. Despite many interviewees anchoring to this number, there was a lack of consistency on how stakeholders interpreted it: some framed it as a break-even point for the provider, others as a post-incentive price to the buyer, and others still as a full cost net of government incentives and producer margins. The lack of clarity highlights the need for more modeling and analysis around target costs, as well as greater clarity on how the CDR community defines its long-term goals.

Divergent perspectives

We also identified four topics on which stakeholder perspectives split into two or three distinct points of view.

First, although stakeholders converged on the importance of public sector involvement to scale long-duration CDR, they expressed different views on the specific role the public sector should

play. One view was that governments should set standards and technology-neutral policy signals, and then “get out of the way.” A second view preferred a more catalytic role in which proactive policies would serve to “crowd-in” investment, support research and development, and streamline deployment. A third view imagined governments acting as large-scale buyers and directly procuring long-duration CDR. While these views were not mutually exclusive and some stakeholders indicated a preference for combining multiple approaches, the diversity of views signaled the need for more discussion within the CDR community about the appropriate policy levers for scaling up long-duration CDR.

Second, stakeholders expressed divergent perspectives on the role of conventional carbon offset registries in developing third-party standards for long-duration CDR. Some providers and brokers shared that they are already working with conventional offset registries to establish standards, despite encountering logistical challenges with respect to the speed and cost of this approach. Other providers indicated that they are avoiding conventional registries altogether based on fundamental critiques of the conventional offset registry system.

Third, views also diverged around the importance of brokers, advisors, and marketplaces for scaling long-duration CDR. Some stakeholders expressed the view that brokers add tremendous value to the market, providing much-needed transparency and scrutiny for novel projects that most buyers cannot provide in house. Others expressed the opinion

that brokers have a less important role to play in helping to scale long-duration CDR because they are subject to significant price and supply constraints over which they have little influence.

Finally, while buyers ranked cost as the most important barrier to scaling up CDR, providers were generally sanguine about reducing costs over time and did not see it as a major barrier. Providers suggested that current high prices do not appear to be stifling near-term demand, and many expressed confidence that costs will come down as CDR technologies mature. (Because our survey only included buyers who have made long-duration CDR purchases, our results do not incorporate perspectives expressed by those who either did not consider or did not choose long-duration CDR on the basis of current costs.)

Other notable stakeholder views

In addition to the convergent and divergent perspectives summarized above, interviewees also identified two significant issues.

First, stakeholders expressed dissatisfaction about how two major standard-setting initiatives address long-duration CDR approaches — namely the European Commission’s CDR certification framework consultation and the Science Based Targets initiative (SBTi). Our survey included a question about the European Commission’s consultation. Although relatively few stakeholders indicated they were

familiar with the details, those who were expressed concern that the framework does not adequately identify or prioritize long-duration CDR in comparison to short-duration carbon removal approaches involving forests and soils. Without any prompt from our survey questions, many stakeholders also expressed concern about the SBTi’s corporate net-zero standard, specifically that the guidelines set forth do not send a clear message about how corporations should plan to incorporate long-duration CDR into their net-zero strategies. These statements highlight the need for greater participation from long-duration CDR stakeholders in both public and private sector standard-setting initiatives.

Second, many stakeholders identified infrastructure challenges as an emerging area of concern and potential supply bottleneck, especially the lack of safe and effective CO₂ storage and transportation infrastructure. Stakeholders perceived a lack of resources being directed toward the infrastructure needed to support future deployment of long-duration CDR.

As public interest grows and new policies and financing mechanisms take shape to help scale up long-duration CDR, it is more important than ever to address the institutional barriers that could limit its responsible growth. We learned that the barriers to scaling up long-duration CDR are complex and that the opportunities to address areas of divergence and confusion are numerous. Greater stakeholder engagement is needed to explore the different roles the public sector could play in scaling long-duration CDR, create alignment on how costs

are defined, and clarify the implications of emerging supply and infrastructure concerns. Although stakeholders did not identify the lack of coherent third-party standards as the most pressing concern today, there was a general consensus that the absence of credible standards is a significant risk to market

growth in the years ahead. We believe that deeper stakeholder engagement and more research and analysis on the topics covered in this assessment are critical prerequisites to building a mature CDR industry that is effective in helping achieve global climate goals this century.

Background and context

Reaching global net-zero emissions will likely require gigaton-scale carbon dioxide removal (CDR) by sometime later this century. In order for CDR to effectively mitigate the climate impacts of CO₂ emissions, the duration of carbon storage must match the timescale of fossil CO₂ emissions' impacts — what we call long-duration CDR.¹

Most long-duration CDR approaches are in the early stages of development and commercialization, including direct air capture (DAC), enhanced mineralization, biochar, and various carbon removal pathways involving the oceans. Their prospects for maturation are supported by a number of relevant developments. Several companies have recently provided grants, [advance market commitments](#),² and [outright purchases](#)

of long-duration CDR. Prominent private sector standards, such as the Science Based Targets initiative, have [identified](#) permanent CDR as a prerequisite for companies' long-term net-zero goals. Leading [governments](#) have also supported research, development, and deployment of long-duration CDR projects and technologies.

The early development of the long-duration CDR industry coincides with an explosion of interest in voluntary carbon markets and conventional offset credits. [Most carbon offset credits](#) claim benefits from avoiding climate emissions, rather than removing CO₂ from the atmosphere. However, a small and growing premium market for nature-based carbon removal credits has emerged. These credits make carbon removal claims of storing carbon for as little as one year to as long as 100 years.³ Although these short-duration credits dominate the market on volumetric terms, they offer distinct climate services that are [not comparable](#) with the essentially permanent impacts of fossil CO₂ emissions.

1 For the purposes of this report, we define long-duration CDR as achieving carbon storage on the order of hundreds of years or more. This definition is intentionally broader than one that focuses exclusively on geologic carbon storage timeframes, which are the only horizons over which one can make accurate comparisons with the impacts of fossil CO₂ emissions. Our definition includes multiple ocean-based and biochar approaches, but excludes most conventional strategies involving the forest and soil sectors. This inclusive definition was chosen not to determine what CDR pathways are appropriate for addressing the permanent consequences of fossil CO₂ emissions, but for exploring the barriers facing CDR approaches that store carbon for considerably longer than conventional forest and soil carbon pathways.

2 Disclosure: one of the authors (Jeremy) serves as an unpaid advisor to Frontier.

3 For example, [NCX](#) offers offset credits based on harvest delays as short as one year. The longest duration nature-based projects of which we are aware are subject to a 100-year permanence requirement in [California's forest offset program](#).

The relationship between long-duration CDR's nascent stage and growing demand for carbon removal in voluntary carbon markets raises a number of questions about the institutional barriers that might constrain the potential for long-duration CDR to scale to appropriate levels in the decades ahead. While a few early corporate actors have stepped forward with purchase commitments for long-duration CDR providers, these initiatives require significant effort and rely primarily on internal due diligence processes to manage technology and execution risks.

In contrast, buyers in conventional voluntary carbon markets primarily rely on formal standards and third-party verification processes that have developed over the course of decades. Critics point out myriad conflicts of interest in the operation of these systems, as well as documented

challenges achieving conventional offset programs' stated goals. But there is no question that the incumbent voluntary carbon markets have a comparably more mature governance ecosystem — whatever its performance.

As companies and governments put forward net-zero climate targets and plans, many actors are likely to expect a robust governance ecosystem to emerge for carbon removal as well. If third-party standards for long-duration CDR are needed now or in the future, it will be important to think carefully about how they are developed. Standards for long-duration CDR will need to grapple with a different set of challenges than existing standards have, including navigating fundamental, unanswered questions about the science and practice of a wide variety of approaches with rigor and transparency.

Our approach

We set out to determine whether the lack of established third-party standards represents an important barrier to growing the long-duration CDR market, and if so, how important that need is relative to other prominent market barriers. This report was developed in four stages.

The first stage involved learning about existing third party certification and verification systems. The aim of this exercise was to establish a baseline understanding of how existing standards systems operate within voluntary carbon markets, and how they are positioned to support the growing long-duration CDR market.

The second stage involved establishing the landscape of key stakeholders using a standardized template. Stakeholders were grouped into one of the four categories described below.

Providers — Companies developing long-duration CDR solutions and engaged in selling CDR credits. CDR pathways represented included direct air capture (DAC), biomass, oceans, and mineralization. These providers were selected from applicants to recent CDR RFPs included in the [CarbonPlan CDR Database](#). We interviewed sixteen stakeholders in this category.

Buyers — Companies currently purchasing or planning the purchase of CDR credits. This group consists of buyers who have publicly engaged in

early-stage CDR purchases, as well as companies who are actively exploring making CDR purchases in the near future. We interviewed eight stakeholders in this category.

Brokers — Companies maintaining online marketplaces for individuals or companies to buy CDR credits, some of which also advise buyers on credit purchases. Only brokers who currently or plan to include long-duration CDR as part of their offerings were included in the survey. We interviewed six stakeholders in this category.

System Actors — NGOs, philanthropies, and investors who support the CDR market, but are not involved in CDR credit transactions. We interviewed seven stakeholders in this category.

These categories were designed to represent specific stakeholder groups while being broad enough to ensure the views shared within each group could not be attributed back to individual stakeholders. In total, 37 stakeholders were interviewed (see Table 1).

The third stage involved developing surveys to gather input on institutional barriers generally, and third-party certification and verification specifically. The surveys used a combination of questions tailored to individual stakeholder groups and questions consistent across groups. Most of the surveys consisted of qualitative questions meant to generate discussion,

Table 1. List of stakeholders interviewed for this report.

PROVIDERS	Carbon Engineering, Heirloom, Mission Zero Technologies, Climeworks, Noya, Charm Industrial, Carbo Culture, Carbofex, Running Tide, Climate Foundation, Ocean-Based Climate Solutions, CarbonCure, Carbon Built, FutureForest, Neustark, Carbix
BUYERS	Stripe, Shopify, Microsoft, Swiss Re, Autodesk, BCG, LGT, Milkywire
BROKERS	Patch, Puro, Supercritical, Joro, Wren, Nori
SYSTEM ACTORS	Carbon180, Carbon Gap, ClimateWorks, Breakthrough Energy Ventures, Grantham Foundation, Additional Ventures, Lowercarbon Capital

highlight salient concerns, and surface convergent and divergent perspectives across stakeholders. Before requesting survey input, a confidentiality guarantee was provided to the respondent to help them feel comfortable sharing their perspectives knowing that nothing would be attributed back to them on an individual basis.

The final stage involved data collection and analysis. Stakeholders were contacted directly, and 45-minute interviews were scheduled with the stakeholders identified in Table 1. Altogether, 37 survey interviews were conducted via Zoom over a six-week period. We then compiled over 100 pages of interview notes and synthesized insights to identify the key themes reported below.

This approach was designed to gather perspectives across the CDR field. It

comes with important caveats. First, the results presented here are a reflection of the interviews conducted and our best efforts to synthesize insights without editorial interference. They are not assertions about objective truths. Second, the interviews also reflect the composition of the parties interviewed. By design, participant selection was limited to CDR stakeholders who had made their role public, who we were able to contact, and who were available and willing to participate in the survey and interview process. As a result, while the survey gathered input from different parts of the CDR field, this report is not based on a representative sample of actors in the space. Buyers who were “on the fence” about buying CDR, as opposed to buyers that have publicly supported CDR, were particularly difficult to identify given the lack of information about companies at this exploratory stage.

An overview of existing voluntary carbon market standards

Third-party standards play an important role in the voluntary carbon market. Buyers of conventional carbon credits generally rely on these standards to assure quality outcomes. These standards are intended to provide assurances about what a carbon credit represents, thereby enabling buyers to participate in the market with less effort and exposure.

Most of the third-party standards used in the voluntary carbon market today were developed by carbon offset registries, which also track trading and retirement of carbon credits issued under their standards. Today, there are five prominent registries in the voluntary carbon market: [Verra](#), [Gold Standard](#), [Climate Action Reserve \(CAR\)](#), [American Carbon Registry \(ACR\)](#), and [Plan Vivo](#). According to the [UC Berkeley Carbon Trading Project](#), Verra has issued more than two-thirds of credits in the voluntary market as of April 2022, with the other registries playing significantly smaller roles.

Most carbon offset registries operate as nonprofits with fee-based revenue models, although some for-profit approaches also exist. Project developers pay to participate with a registry via one-time and volume-based

fees, such as for listing a project on the registry and issuing credits.

Registries employ a wide variety of standards to issue carbon credits, often with at least some public engagement opportunities. Some registries develop protocols themselves, appointing expert workgroups to engage with registry staff and protocol proponents. Others allow protocol proponents to submit their own methodologies for review and registry approval. A few registries, including Verra, even issue credits to projects that follow legacy methodologies from older carbon offset programs, such as the 1997 Kyoto Protocol's Clean Development Mechanism. All of the major registries employ some form of third-party verification of offset projects, although verification ranges from desk reviews of project paperwork to extensive site visits to confirm on-the-ground conditions.

The concept behind third-party standards is that someone other than the carbon offset project itself stands behind the project's claims. By following a standard issued by a registry organization or that was developed with public input from an expert workgroup, projects aim to assure buyers that their climate claims are reliable. Similarly, the idea of having some kind of third party

verify that projects have complied with applicable standards is also meant to assure buyers that everything is in order.

Nevertheless, critics have pointed out that the financial and working relationships between offset projects, project developers, and third-party registries replicate many of the conflicts of interest that third-party standards are meant to address. For example, some registries allow companies to pay for the development of standards that they both help write and later use for project development. And although registries often employ third-party verification, the offset projects typically pay the verifiers and verification is generally limited to compliance with the applicable standards. Thus, while third-party verification can help provide some assurance that projects are undertaking the promised activities, it does not address potential weaknesses in the standards applied.

While carbon offset registries are the primary source of credit supply, voluntary carbon markets also involve a number of important brokers and secondary marketplaces. These entities generally do not issue credits themselves, but rather re-market credits issued by the registries. Many of these actors claim to provide an extra layer of diligence or screening, such that the products they offer are selected from the broader market to address specific buyer interests or to deliver higher levels of quality than are found on the mass market. Paradoxically, some of these entities advertise their private diligence processes while simultaneously pointing

to the registries' third-party standards as an assurance of credit quality.⁴

Across the voluntary carbon market, most registries, brokers, and marketplaces focus on carbon credits that reflect avoided emission claims, rather than CDR projects of any duration. Very few carbon market actors have a direct focus on CDR projects or standards.

A few new entrants, like Nori and Puro, are developing registry services specifically for CDR projects.⁵ To the best of our knowledge, however, only Puro has developed standards for approaches that match our definition of long-duration CDR. For most long-duration CDR approaches, few third-party standards and registries exist.

4 Adding to the complexity, many industry stakeholders are backing a self-regulatory body called the Integrity Council for the Voluntary Carbon Markets (IC-VCM). As of this writing, the IC-VCM is developing a set of "core carbon principles" that it will use to screen the voluntary market, with the goal of identifying the subset of credits on offer that meet its standards. To the extent such an effort is needed or publicly embraced by the industry suggests that the registries, brokers, and marketplaces are not adequately resolving these issues on their own.

5 Disclosure: one of the authors (Na'im) serves as a co-host of a CDR podcast published by Nori.

Survey findings — Key themes

A number of themes surfaced from stakeholder surveys regarding the barriers to scaling the long-duration CDR market. A few convergent themes emerged where most stakeholders expressed similar perspectives on scaling up long-duration CDR, as did tensions where stakeholder perspectives diverged across two or three key points of view. These views were synthesized into the themes set out in the following sections. Perspectives that did not come up in enough interviews to be categorized as convergent or divergent are described separately.

The themes below are intended to offer insights about how key stakeholders perceive the barriers to scaling up long-duration CDR. By design they do not capture all feedback received during the interview process, nor are they purely objective assertions, but rather reflect our judgment and effort to synthesize. Nevertheless we hope this analysis will provide the carbon removal community with a useful snapshot of stakeholder perspectives.

For brevity and consistency in the following description of the survey findings, we refer to long-duration CDR simply as CDR.

Convergent perspectives

Voluntary private sector demand has helped catalyze the CDR industry, but most stakeholders see a bigger role for the public sector going forward

Across stakeholder groups, voluntary private sector purchases were viewed to have played an important role in catalyzing the CDR industry to date. Most respondents did not see private sector buyer interest and education as a major barrier to scale moving forward. This is because stakeholders perceive private sector buyers as increasingly knowledgeable and interested in CDR, and more agile than the public sector in supporting the industry by purchasing CDR credits. Some stakeholders suggested that demand is vastly outstripping the supply of CDR credits today. Others noted that what barriers do exist around private sector CDR knowledge are solvable. Stakeholders widely acknowledged the contribution of private sector procurement to scaling up CDR to date, and the importance of voluntary procurement to continue to catalyze the industry in the short-term. However, many stakeholders pointed out that voluntary private sector

Box 1. Convergent responses on the role of public sector support.

PROVIDERS

“Public sector support is more important than private sector demand because the private sector will never get as big. Private markets are buying \$10-20M [in] CDR every year. [California’s Low Carbon Fuel Standard] has [an] offset market trading at a billion or two.”

“Private companies can help bridge to reduce cost, but there’s no more brand lift to buy high-cost removals right now. We need to get to a world where the public sector requires removals.”

“I don’t see CDR scaling to gigaton level from voluntary purchases. It’s good for early adopters.”

BUYERS

“The public sector is so important because the private sector can’t buy it all.”

“Private sector has the ability to move more quickly, get [long-duration CDR] to first base. Public sector support gets it to fourth base.”

“The private sector can set the table for the public sector. Then the public sector needs to pick it up.”

BROKERS

“The public sector role is very important. It’s hard to imagine the private sector ever getting as big as the public sector, though the private sector is faster.”

“I’m worried about using the same mechanisms that got us into this crisis to get us out of it. Just a few buyers that have a lot of the power, a few companies that decide how we draw down carbon. I’m concerned about that and the strange incentives it could create and inequalities it could perpetuate for those who have access.”

SYSTEM ACTORS

“There’s a lot of existing interest at high-dollar amounts, but higher volume is going to be hard for the private sector. They are not going to help the \$50-100M projects.”

“There’s enough private sector demand. There’s actually a huge shortage of credits.”

“Private sector buying is already happening. It’s not much of a barrier.”

procurement will be insufficient to scale the CDR industry over the long-term.

Most stakeholders viewed the public sector playing a larger role than the private sector in enabling long-term growth of CDR. The need for public sector support was rated the largest barrier to scaling up CDR across all stakeholder groups except buyers. However, perspectives on what exactly public sector support for the CDR market should look like varied. As detailed below in the section on divergent perspectives, respondents referenced different potential roles for the public sector, including direct procurement of CDR, expanding targeted incentives, and setting standards and definitions. Despite these differences, almost all respondents saw a bigger role for the public sector to play in growing the CDR market.

Third-party standards will be increasingly important as the market for CDR grows, but their absence is not a major barrier today

Most respondents did not consider third-party certification and verification a significant barrier to scaling up CDR in the near term. A consistent view emerged that the lack of clear CDR standards is not currently holding the market back, but may become a problem in the coming years as the market grows. This temporal shift in the perceived importance of standards was consistent across stakeholders, but was justified on different grounds across different stakeholder groups.

Providers expressed the importance of third-party certification and verification, but did not rank it a major barrier to scale since most either had a certification process underway or completed.

Buyers rated third-party certification as one of the least important criteria in making CDR purchases today — especially if they were primarily focused on supporting early-stage CDR companies, rather than meeting a net-zero commitment.

Buyers and **Brokers** expressed willingness to continue buying and selling CDR in the short term without third-party standards in place, but emphasized they could not continue doing so for long.

System Actors acknowledged the general lack of formal standards as a natural feature of the industry's early stage, though many are concerned about the need to create a trusted and credible system over the long term.

Views ultimately converged around the need for a trusted system to attract the next wave of buyers. Providers and system actors overwhelmingly indicated that third-party standards would build trust in the CDR market, reduce market friction, and attract new buyers. Many buyers and brokers noted the difficulty of engaging in the in-depth, project-level due diligence that is required in the absence of third party standards. Although some buyers and brokers have invested in developing internal capacity for vetting projects, they expressed concerns that similar efforts may prove untenable for them in the long term as the market grows. They also

Box 2. Convergent responses on third-party certification and verification.

PROVIDERS

“It’s doable. Not difficult. Especially for engineered solutions.”

“[Third-party certification and verification] is something that’s on our OKRs. Right now, it doesn’t seem like something that’s absolutely needed. But when less sophisticated buyers get in, it’s going to be incredibly important.”

“Third-party certification and verification is really, really important. We don’t have certification in hand, but we made a lot of progress in the last six to twelve months. We have clarity on how we’re going to get there.”

BUYERS

“Third-party certification and verification is a concern for the long term. Right now we can tolerate the lack of standards. Pretty soon it’s going to become a problem.”

“As you go to mass market, you’re going to need trust and visibility in the marketplace.”

“Early buyers don’t care much about third-party certification and verification, but later ones might. Especially if they can’t do the research themselves.”

BROKERS

“Not having standardized third-party verifications means a lot of effort to do additional verification and evaluation ourselves. We’re willing to do that for mission-driven reasons.”

“Third-party certification and verification will eventually be a massive barrier.”

SYSTEM ACTORS

“Third-party certification and verification is a larger issue in the future. I’ve already seen multiple groups try to correct this.”

“Third-party certification and verification will be a major issue a year from now.”

“Right now it doesn’t matter as buyers know suppliers, but this is going to be a big lift.”

acknowledged that the lack of widely accepted standards could discourage more risk-averse corporate buyers with less internal expertise and capacity.

Some stakeholders expressed concern about the credibility and fraud risk to the CDR market that could emerge in the absence of robust, third-party standards. Whether or not respondents highlighted these particular concerns, a general consensus emerged around the need for

robust third-party standards — despite the initial success many actors have found with more resources-intensive diligence processes in operation today.

A \$100/ton is a sweet spot for cost

Stakeholders expressed widespread agreement that costs for CDR need to fall significantly in the long term. Interestingly, many stakeholders anchored to \$100/ton as an ideal cost

Box 3. Convergent responses on costs as a barrier.

PROVIDERS

“If cost were \$100/ton, demand would be practically unlimited.”

“Addressing the cost barrier means people see CDR as a waste fee that people are responsible for, for ... less than [about] \$100/ton.”

“Cost is king. We have a long-term target of \$100/ton.”

BUYERS

“Success means willingness to pay can be met. Everyone knows their willingness to pay. Ours is \$100/ton. Everyone has their own.”

“We want costs to be sub \$100, or \$100-\$140 per ton.”

“Bringing down cost to \$100/ton for CDR would be the sweet spot.”

BROKERS

“Successfully addressing the cost barrier means bringing down the cost to \$100/ton, higher is untenable.”

SYSTEM ACTORS

“Successfully addressing the cost barrier means cost gets below \$100/ton for CDR that lasts 1,000 years.”

“Cost needs to get to the holy grail of \$100/ton.”

target for long-duration CDR. There was some variability, however, with suggested targets ranging from \$50–200/ton. Some stakeholders went as far as saying that at \$100/ton, other barriers to scale — like third-party standards and public sector support — no longer mattered. Nonetheless, it was interesting that despite limited economic research on costs necessary to scale CDR to meet climate goals, many stakeholders anchored to \$100/ton as a benchmark for determining whether CDR’s cost barrier had been successfully addressed. (One possible explanation is that stakeholders took cues from a November 2021 [Carbon Negative Earthshot announcement](#) from the U.S. Department of Energy, which seeks to bring down the cost of CDR and durable storage to less than \$100/ton).

Although respondents generally agreed on a target for costs, there was no consistent definition on how to interpret it. Does \$100/ton represent the total cost for a project, or the final cost to the buyer after tax credits and other government support policies? To the extent this target relies on government policy intervention, what effect would stacking multiple revenue streams have on a buyer’s ability to make a claim towards net-zero emissions? While our survey was not designed to answer these questions, there appears to be space for discussion and alignment across stakeholders on these cost targets and associated policy questions.

Divergent perspectives

Diverging views on what a larger role for the public sector should be

Most stakeholders considered public sector support the most important barrier to scale, but respondents expressed very different views on the specific role that the public sector should play. Stakeholders referenced three potentially overlapping roles the public sector could play to support the CDR market.

First, some suggested the public sector should play the role of standard setter responsible for developing clear definitions and requirements for what constitutes high-quality CDR. This group identified an important role for the government, and often expressed concern about the government being ineffective at “picking winners” or frustration with the government “moving too slowly.” Many respondents in this group also thought the government should develop compliance markets or a carbon tax to stimulate the private sector to engage in the regulated CDR market.

Second, others suggested the public sector should play a more proactive, catalytic role. Respondents in this group expressed interest in seeing a significant expansion of existing policies to fund and encourage the scale-up of CDR. Example policies mentioned by this group included the expansion of the 45Q tax credit, increased RD&D investments, streamlining siting and permitting

Box 4. Divergent responses on the role of the public sector.

PROVIDERS

“The government can spend hundreds of millions of dollars on really bad technology. The best thing the public sector can do is write really strong, clear carbon standards, and let the market buy and sell from there.”

“I’m not a big fan of government tampering with these systems. They should just apply a carbon price.”

“The public sector should provide a predictable, rising price on carbon. Ultimately, you should have to pay to pollute.”

“The role we need is either procurement directly, or creating a mechanism for private procurement to happen.”

BUYERS

“The public sector can create a compliance market. That is going to have the scale we need. More R&D funds, permitting, and infrastructure.”

“The public sector is important but I’m a believer in capitalism being focused on this problem ... It would be a heck of a lot faster if 45Q was sorted and the public sector invested in this, but that’s complementary, not primary.”

“Just having literacy [in CDR] from policy makers, and then incentives to grow the marketplace.”

BROKERS

“Companies should be regulated around emissions and net-zero claims; we should have priced-in externalities like a carbon takeback obligation or tax on carbon.”

“Government is important because R&D funding and public sector capital is needed to crowd in private sector investment, de-risk private investment.”

“Public sector needs to get its act together and we need universal criteria as to what qualifies as carbon removal.”

Box 4 (continued). Divergent responses on the role of the public sector.

SYSTEM ACTORS

“Permitting and siting is really hard. It takes years to get Class VI wells online, same with ocean siting and permitting. 45Q will matter a lot for stimulating work in the field.”

“45Q and infrastructure investments would change things.”

“The government needs to have a stated ambition to advance CDR, develop standards, invest in basic research, and talent development in CDR.”

“Direct government procurement is a big lever to solve demand pull. We still need R&D dollars.”

processes, and guaranteed loans for providers. This group was less concerned about the government “picking winners” and perceived a hands-on, catalytic role for the government to “crowd in and de-risk” investment.

Finally, some believe the public sector should directly procure long-duration CDR. Many in this group viewed government procurement as the highest leverage opportunity to scale the CDR market.

Although most stakeholders primarily indexed on one of these three potential roles for the public sector, these roles were generally not seen as mutually exclusive. We did not observe stakeholder groups expressing consistent views about what the most promising role for the public sector would be. That said, system actors were generally inclined to see a more hands-on role for government intervention in CDR markets relative to providers.

Ultimately, whether stakeholders preferred a more limited or hands-on role for government, all stakeholders envision governments taking actions beyond what is widely seen in CDR policy today.

Technical vs. structural challenges with registry systems

Many respondents cited challenges with existing carbon registries, but the challenges raised were fundamentally different in nature and diverged across two views. The first view focused on technical or procedural challenges with existing registries, whereas the second view identified underlying structural or incentive-based issues with registry systems. The divergence between these two perspectives partially aligned with stakeholder groups.

Most brokers and those providers that are currently working with registries were more likely to express concerns about delays or logistical challenges

 Box 5. Divergent responses on challenges with existing registries.

PROVIDERS

“A big problem is the lack of standards and protocols ... everything in the voluntary space is done on an ad hoc basis. Players are making up their own terminology and accounting schemes ... would love to see a new sheriff in town on what counts and what doesn't ...”

“[The registries] don't understand CDR. They don't understand there's a problem with offsets ... the process is too clunky, and no one has picked up the mantle successfully.”

“There's a conflict of interest. Standards like [a carbon offset registry] and others don't understand CDR. They don't get the importance of it. They have such a bad brand for those buying high quality removals, they made their living on really cheap, dumb stuff.”

“We need third-party certification and verification. We're putting time into [a registry standards process] but don't know how it's going to turn out ... Frankly, it's a gong show. Total chaos. It's been frankly dismaying.”

“It can take up to six months after submitting a monitoring report to have it verified so then we can deliver certificates in our registry for customers ... we want this process to move faster.”

“What's not working well? Timescale and cost for standard methodologies [from the existing registry system].”

“I don't trust previous players in the [standards] space. They gamed the market.”

BUYERS

“The problem is the race to the bottom. It's not what we should be incentivizing. We need to get a clearer understanding of what's good and what's bad.”

“The standards are conflicted — we need an actual third party that doesn't make money from verifying more projects. Changing standards is a problem! If we take a position today, in two years it could turn out bad. It's better not to do anything than do the wrong thing. We don't want to take the risk.”

“Companies that are aware of CDR don't trust the registries, and companies that are not aware of CDR do trust them. Registries need to up their game for the benefit of companies already involved in CDR.”

“There's a sell-side focus on volume. Existing systems are paid per certification, driven to do more volume. The frameworks and protocols are often very esoteric, or labyrinthine.”

Box 5 (continued). Divergent responses on challenges with existing registries.

BROKERS

“Huge limitations in the current system. The field is growing fast and we’re using old tech and ideas ... if you have one massive f***-up ... you’ll blow a hole in this market for a long time. Trust is hard to rebuild once you’ve lost it.”

“[Verifiers] are not as agile as we’d like them to be. It takes months to arrange an audit and months for documentation.”

“It’s really challenging to create an account to become a buyer. There’s months of back and forth. It’s really expensive, and it takes a really long time for projects to get verified.”

“What’s not working well? Speed of protocol development – not broken but could be improved.”

“There’s lots of friction in getting certified.”

SYSTEM ACTORS

“There’s a lack of trust in the market system. People perceive the voluntary carbon market as another format for greenwashing. Trust between stakeholders is not high enough and it’s hard to create a new system because everyone is suspicious of everyone else.”

“We’re worried about public perception... groups are interested in scaling up CDR for their own bottom line that can create a crisis of legitimacy.”

“Is anything working well? I can’t think of any aspect of standards that are moving the market forward in a justifiable way.”

“[A new entrant registry] is probably the smartest and most forward looking but their model isn’t different from traditional registries. You can’t have projects paying you. The whole ‘project pays for protocol’ – people need to stop doing that.”

associated with getting methodologies approved or verifications underway. Most providers shared that they have some form of third-party certification process planned, in place, or underway with an existing registry (including Puro, Verra, and Gold Standard). Many brokers cited challenges with creating accounts with existing registries, the speed of protocol development, and the time required to arrange audits with verifiers. Respondents in this group indicated that they expend significant time and resources working with existing systems, and appear more concerned with practical limitations of these systems and less interested in their wholesale reform.

Buyers, providers without certification processes underway, and system actors were more likely to raise concerns about flawed incentive structures and potential conflicts of interest associated with the existing standards system. Across these stakeholders, three specifically expressed concern that existing certification and verification systems are paid for by project developers and are incentivized towards selling a higher volume of credits — a practice they believed should end. A few stakeholders who were skeptical of existing systems cited challenges existing registries had with establishing baselines and counterfactuals associated with nature-based projects. Other stakeholders used terms like “legitimacy crisis” and “industry death knell” to describe the implications of continuing with potentially compromised standards systems. Stakeholders concerned about flawed incentive structures and potential conflicts of interest were more likely to recommend that financially disinterested, non-biased parties establish standards

instead. Most identified a role for the public sector to get involved, either by establishing a new standards system or coordinating a coalition of nonprofits and scientists to do so, as a potential alternative to the status quo.

Finally, in response to questions about what is working well or not with existing standards, a number of stakeholders responded that they did not know enough to comment. This may be due to an unwillingness to discuss sensitivities associated with existing systems, or the need for more education around how incumbent systems operate.

The importance and incentives of brokers, advisors, and marketplaces in the CDR market

There was some divergence between how stakeholders described the role of brokers in shaping the CDR marketplace. The first view was that brokers play an essential and influential educational role, while the second view was that brokers are “facilitators” who simply connect supply and demand. This divergence did not align to specific stakeholder groups.

Some stakeholders expressed the perspective that brokers add value to the CDR space by providing greater scrutiny and due diligence to CDR projects that exceed the in-house capabilities of many buyers today. Respondents indicated that brokers provide vital education, transparency, and independent analysis to prospective buyers of CDR credits, and are therefore very impactful in determining which CDR projects get funding. Some stakeholders aligned with this view also expressed concern that brokers do not have a financial incentive

Box 6. Divergent responses on the role of brokers.

PROVIDERS

“Brokers need to push for high integrity, have a race to the top, not to the bottom. If removals become the next offsets, we lose license for public support, and license for government funding.”

“Education sits with them. It’s a really important role.”

“As a DAC company, since there are so few of us and supply is so low, I have the privilege of going direct to consumers instead of marketplaces.”

BUYERS

“Marketplaces aren’t going to help you choose the best projects - they might be more interested in selling volume.”

“[C]onnecting suppliers to buyers feels really early at this stage given that supply is so constrained.”

“If we have more brokers, we have more scrutiny. Not everyone can deploy dozens of scientists like [a large buyer]. They can go to [a reputable broker] or a marketplace.”

“We work with brokers, but for frontier solutions, we do the work on our own.”

SYSTEM ACTORS

“Brokers are scrambling for supply, so they’re not playing much of a role.”

“[The role of brokers] doesn’t matter much. There’s no supply so what are you going to do? ... They just have the worst pick of supply.”

“Brokers are immensely influential. They will have a big impact, but incentives aren’t necessarily aligned to do the really good thing.”

to recommend high-quality projects because their business models depend on meeting customer needs on price and volume, sometimes leading to the sale of low-quality CDR credits.

Other stakeholders saw brokers as “facilitators” who play a less important role, primarily because they are subject to price and supply constraints in the market. These stakeholders observed that the lack of available CDR supply today might diminish brokers’ influence as CDR “supply is already spoken for.” Some stakeholders suggested that it would be easier and preferable for providers to sell directly to buyers.

Brokers saw themselves playing an important role as educators, providing much-needed information and transparency to customers (as well as data and insights to other stakeholders). Interestingly, brokers expressed mixed responses about how much customer needs and perceptions influence which projects they include on their platform. Some brokers stated that customer perceptions and needs were less crucial to influencing project selection because customers “don’t want too many options.” One broker mentioned that customers are “swayed” by what’s in the news, but are ultimately constrained by budgets. Other brokers described customers’ needs and perceptions as a very important factor and that they want to be “customer driven” in curating their platform.

Among brokers that suggested customer needs and perceptions did not significantly impact their portfolios, one broker described picking projects that had compelling stories that they could

communicate to customers, and another mentioned the importance of storytelling and selecting projects that resonate with customers on an emotional level. Some brokers described anticipating customer perceptions and selecting projects accordingly, while others described modifying project selection in response to customer reactions.

Finally, brokers echoed challenges cited by other stakeholders on supply limitations and the extent to which that disrupts their ability to meet customer demands.

Buyers care most about cost, while providers are generally sanguine about their ability to reduce costs over time

Buyers rated cost as the single most important market barrier to scaling up CDR, but providers expressed the view that cost is only a moderate barrier. This divergence was notably aligned by stakeholder group.

Some buyers involved in supporting early-stage providers rated cost as having a low level of importance in making their procurement decisions today, but ranked cost a major concern to be addressed for the scale-up of the broader CDR market. While these buyers are accustomed to paying premium prices for supporting early-stage projects, they ranked cost as a major concern because their strategy centers around long-term cost reduction. These particular buyers entered the CDR market to have a catalytic effect on its scale, and at some point will need to point to cost-reduction as a metric for success that the strategy is paying off.

Box 7. Divergent responses on the importance of cost.

PROVIDERS

“Cost is not a concern. More of an investment of time right now. There’s lots of money out there, and we can access a lot of it at low interest rates.”

“Cost is not a problem. As you scale, costs come down.”

“If cost is cheap, none of this other stuff matters.”

“Cost doesn’t have to be a problem. There are lots of ways to lower the cost over time.”

BUYERS

“Cost is most important because success is defined by moving down the cost curve.”

“Buying [long-duration] CDR creates a liability on the books because what you bought can’t deliver in 4 years, even though the money is gone. Public companies have to disclose that and shareholders have concerns. Cheap forest offsets avoid that whole problem.”

“We are buying Tesla Roadsters, if there’s a path to a Model 3.”

“When quality is equal, we’ll take the lowest cost.”

Buyers that were exploring the potential of CDR purchases to meet a net-zero commitment, or who were accustomed to buying cheaper offsets instead of CDR, expressed particular concern about the current cost of CDR. These buyers also highlighted the importance of cost as a barrier to scaling up the broader CDR market. They expressed that individuals in charge of procurement decisions must justify the expense associated with CDR to a number of stakeholders within their organization, including executive leadership and finance departments that might be less interested in CDR and

do not understand why the higher cost is justified in the context of net-zero commitments. They also highlighted the challenge of explaining why buying traditional offsets in the past might not have been the right decision. Buyers sometimes face an additional step to justify the cost of CDR purchases to shareholders, especially if expensive CDR purchases impact corporate financial statements in advance of carbon removal deliveries. Individual respondents in this group of buyers expressed that the high cost of CDR today has introduced challenges in advocating for CDR

purchases within their organizations, leading them to rate the high cost of CDR as an important and urgent barrier to scale.

Most buyers indicated that their executive leadership has a good or very good understanding of CDR. Because our survey focused on knowledgeable buyers, it is reasonable to expect that advocating for long-duration CDR internally would be more challenging for companies that start with lower levels of executive buy-in or understanding.

Compared to buyers, providers appeared less concerned about cost, for two main reasons. First, some providers pointed out that current high costs do not appear to be stifling near-term demand, which is outstripping supply even at present costs. Second, many providers expressed confidence that costs will come down as CDR technology matures. They were either confident in their own cost roadmap, or discussed this in abstract ways like “as you scale, costs come down.” Despite concerns from buyers about the sensitivity of prices — either as a barrier to interest today, or a barometer for interest in the future — providers do not appear to feel the same sense of pressure or apprehension about costs coming come down.

Other notable stakeholder views

Absence of long-duration CDR representation in the European Commission’s CDR Framework

In the last year, the European Commission initiated a process to develop a certification framework for CDR projects. Respondents were asked if they were aware of this development, and what effect they thought it would have on the long-duration CDR field in particular. Most respondents were unaware or only vaguely aware of the European Commission’s efforts. Many of those with limited awareness held generally positive views and indicated that the EU’s efforts could serve as a blueprint for improved standards for CDR that could be adopted by other jurisdictions. Others identified the EU’s process as a potential wake-up call for other governments to take a more systemic approach to supporting long-duration CDR.

In contrast, respondents that indicated a closer familiarity with the European Commission’s process expressed concerns. Some pointed to lobbying from large environmental NGOs, point-source capture interests, or entrenched interests from the forestry and agriculture industries that could distort priorities or policies affecting the Commission’s CDR efforts. Some expressed concern at the lack of long-duration CDR representation in consultative processes associated with this initiative.

Box 8. Responses on the European Commission's CDR Framework.

PROVIDERS

“If they do a good job of it, it could serve as a gold standard. But powerful ag/forestry stakeholders can push to define a lot.”

“I’ve heard about it, I think it would be great. It would solve the whole thing about standardization.”

“I’m aware of it. I think it’s good and will have a massive impact.”

BUYERS

“Moderately aware. When the EU does something they are often the leader. If done properly, we’ll have a larger scope of adoption [of CDR] as we go forward.”

“I’m aware of it – I hope good stuff comes out and they don’t reinvent the wheel.”

BROKERS

“I haven’t looked into it. The EU leads on all things climate. Where the EU goes, the world eventually follows.”

“It can show that it’s possible to use CDR as an instrument in emissions trading systems around the world. This reliance on soil organic carbon may lead to a disaster ... (it) could threaten the whole CDR sector ... we should rely on things that are measurable and we know the permanence.”

SYSTEM ACTORS

“No one is talking about long-duration CDR, [the process] is heavily lobbied by traditional [environmental] NGOs, and it’s just going to be forests. People with experience in the frontier stuff are not at the table.”

“There are lots of entrenched interests during the consultation period. Particularly the temporary removals and carbon capture crowd – they will try to obfuscate what [CDR’s] definition is and try to redefine permanence ...”

Box 9. Responses on the Science Based Targets initiative.

PROVIDERS

“SBTi supports DAC and long-duration CDR, but also says CDR is not necessary today and can’t be counted in net-zero standards. So the commercial sector postpones CDR.”

“SBTi does not have offsets in their framework. That will work against us.”

BUYERS

“SBTi released guidance without saying anything clear on removals.”

“How do we fix net-zero SBTi stuff in a way that could be unlocking for CDR?”

“SBTi demands long-duration CDR.”

BROKERS

“SBTi is making a bit of a disservice to CDR, basically saying ‘don’t worry about CDR today.’”

“SBTi did CDR a disservice [telling companies to cut emissions] until you’ve reduced down to 10%, then you can use CDR for the remaining. That’s not a helpful guideline.”

SYSTEM ACTORS

“SBTi is right to have a decarbonization-first approach, but SBTi is not interested in CDR at all. The CDR industry can’t conform to these standards even if they wanted to.”

Confusion about guidance from the Science Based Targets initiative and implications for long-duration CDR

The Science Based Targets initiative (SBTi) is a net-zero standard setting initiative formed in partnership by a number of prominent institutions including the United Nations Global Compact, World Resources Institute, and the World Wide Fund for Nature. SBTi is generally recognized as a preeminent initiative to guide private sector climate action, and is the basis for net-zero commitments for over 1,000 companies as of writing.

Although our survey did not mention SBTi, several respondents raised it on their own initiative. SBTi was generally viewed in stark terms, with many respondents indicating their view that SBTi does not care about CDR. Some respondents expressed frustration that SBTi did not recognize CDR in their guidelines,⁶ or that SBTi would not allow inclusion of CDR in meeting net-zero commitments until after most emissions reductions targets were met. A few respondents described this as a “disservice” to CDR and “not a helpful guideline.” Providers and brokers were

concerned that disinterest from SBTi could dry up private sector interest and investment in the CDR market. Others expressed frustration that it was unrealistic to expect companies to ignore CDR for years as they pursued their emission reduction targets, and then expect developed CDR solutions to be available when needed decades later.

Stakeholders did not view SBTi as sending a clear message on the use of CDR, and expressed frustration at the lack of near-term standards on the use of CDR and conventional carbon offsets. Given SBTi’s importance in guiding corporate net-zero commitments, this ambiguity could have serious implications for the CDR market. Respondents indicated a sense that they have had little agency in addressing this challenge so far.

Supply and infrastructure concerns

Without prompting, many system actors and a few buyers referenced the lack of supply as a constraint or a concern to scaling up CDR. Specifically, few CDR options are available today because so much of the limited existing and planned project capacity has been procured by a small group of buyers. The lack of currently-available supply could serve as a significant barrier that discourages new buyers from entering the market. When providers were asked what they thought buyers considered a constraint for scaling up CDR, only three providers mentioned the lack of supply. However, many system actors, buyers, and brokers reported the lack of supply as a current challenge in the CDR market, despite the lack of attention this issue has received to date.

6 [SBTi Corporate Net-Zero Standard \(Version 1.0\)](#) (October 2021) at 9 (Figure 2). The SBTi standard identifies two roles for carbon removal. First, the standard recommends “beyond value chain mitigation” efforts that can include conventional carbon offsets and carbon removal of any duration, but requires that companies not count these efforts toward their own emission mitigation pathways. Second, the standard eventually requires that companies “neutralize” any remaining emissions with “permanent” carbon removal. However, the standard provides very little guidance on a timeline for when permanent carbon removal must occur, nor what steps companies should take to prepare.

Box 10. Responses on supply and infrastructure concerns.

PROVIDERS

“We’re in a supply-constrained market.”

“Sequestration is the biggest barrier I’m worried about. I don’t think we’ll have enough places to put CO₂.”

“We are racing against the clock. All the infrastructure for this stuff takes a long time after it gets passed, then you have states and localities that can block stuff, then permitting is difficult.”

BUYERS

“The market is short-supplied for quality tons, we need to develop projects that will bring supply online in the decade.”

“Government procurement and government funding in terms of infrastructure — that looks like success to me.”

“What’s the biggest barrier to scaling up CDR? There’s no supply.”

BROKERS

“Supply constraints can wreck the market, or lack of infrastructure to meet future-dated CDR commitments can halt market growth.”

SYSTEM ACTORS

“Lots of work is being done on market infrastructure, but there’s no supply.”

“Demand has outstripped supply if you want to buy quality removals today ... we need to start sending demand signals now to pull that supply forward.”

“Transportation and infrastructure are barriers. There’s not enough capacity being planned for carbon management needs.”

Another emerging challenge raised was the lack of CDR infrastructure. A number of respondents noted that the lack of necessary CO₂ transportation and storage infrastructure was going to be a significant bottleneck to scaling up CDR, as is the social license and

public acceptance of deploying that infrastructure. Respondents identified the general public and individual communities in proximity to CDR installations or related infrastructure as important stakeholders.

Conclusion

This assessment was designed to provide insight on whether the general lack of third-party standards presents an important or immediate barrier to long-duration CDR market growth, as well as how critical of a factor that was relative to other market barriers. Interviews with CDR Providers, Buyers, Brokers, and System Actors suggest that third-party standards are not the main barrier to scaling up CDR today, but are growing in importance. In particular, standards are likely to be especially important as new corporate buyers with limited knowledge about long-duration CDR or less of a desire to play a catalytic role enter the market, or if the public sector gets involved by setting formal standards for private markets' use, for including CDR in compliance trading systems, or in direct CDR procurement.

Third-party certification and verification was widely seen as a means to establish greater trust in providers and the CDR market more broadly. Nevertheless, interviewees did not express consensus on how to develop standards going forward, nor how providers should work with the legacy carbon offset registry system. Many stakeholders, including some providers and brokers, have decided to work with existing carbon offset registries, despite some citing logistical challenges and other process frustrations. Other stakeholders expressed fundamental concern with existing carbon offset registries. Some providers who hold this view

have decided to directly market their products without engaging a third-party standards-setting organization. Other providers have decided to work with a small number of new entrant companies that are setting up registry services focused more specifically on carbon removal. The diversity of approaches on display calls for additional discussion and analysis as the long-duration CDR community contemplates its future.

Across the board, interviewees identified the importance of public sector support in scaling the long-duration CDR market, though views about the government's proper role diverged without any strong alignment across stakeholder groups. One view is that governments should set meaningful standards to define long-duration carbon removal and then provide technology-neutral policy signals, such as carbon pricing or tax incentives. Another view prefers more proactive policy engagement, such as direct policy incentives designed to "crowd in and de-risk" investments, support RD&D, and streamline private projects' siting and permitting. Another view focused on governments directly procuring long-duration CDR. While these views are not meant to be mutually exclusive — and indeed, respondents articulating one position often referenced the policy positions of the others supportively — they illustrate a significant diversity of perspectives about how government policy should evolve.

Long-duration CDR stakeholders also expressed views about two critical standards processes, one public and the other private. We asked respondents to share their reaction to the European Commission's ongoing CDR certification framework consultation. Although awareness of and engagement with the Commission's work varied, responses indicate a concern that long-duration CDR stakeholders appear to be underrepresented in Commission discussions, which many perceived to be dominated by short-duration CDR in forests and agricultural applications. Unprompted, many respondents also gave their views on a prominent corporate net-zero standard developed by the Science Based Targets initiative. Although SBTi identifies a long-term role for "permanent" CDR in corporate net-zero targets, many respondents expressed concerns that SBTi has downplayed the role of long-duration CDR and is not prioritizing the need for corporations to prepare for a transition to long-duration CDR. Respondents indicated concern that ambiguity on these key points is leading to confusion about the role of conventional offsets and long-duration CDR among participating corporations and regulators.

Many stakeholders expressed a view that long-duration CDR costs need to fall and were generally anchored to a target of about \$100 per ton or less in order to scale successfully. However, it was not clear how consistently stakeholders interpreted this cost target: as a break-even point for the provider, a full cost to the buyer, or a cost to the buyer net of government incentives. Cost discussions surfaced the need for consistent

language around how cost targets are defined in market conversations, as well as more analyses and models for scaling up CDR at different cost levels. Clarity is particularly important because buyers reported much more significant and specific concerns relative to providers, who were generally more sanguine about the ability to find markets for their products today and the prospects for cost declines in the future.

Finally, long-duration CDR supply and infrastructure challenges appeared to be emerging concerns for a number of stakeholders. The implications are particularly uncertain for brokers, which have proliferated significantly over the last few years as supply has thinned out. What does this mean for their business model? How do they remain relevant to buyers? What alternatives or incentives emerge if brokers are unable to sell long-duration CDR credits? How providers, buyers, and system actors navigate the reality of low supply over the near term becomes increasingly important as long-duration CDR gains awareness faster than supply grows. The lack of safe and effective CO₂ storage and transportation infrastructure is a concern among stakeholders, as is the time, cost, social consequences, and political considerations associated with infrastructure development. There appear to be few actors dedicated to resolving the unknowns and charting a path forward for responsible deployment of the necessary infrastructure.

The CDR market has come a long way over the last two years. Catalytic buyers have entered the market, new companies have formed, and investment has grown across the private and

public sectors. A once-obscure tool for addressing climate change has gained a new spotlight. Nevertheless, key institutional gaps remain barriers to the responsible growth of the long-duration CDR market. The lack of coherent standards is arguably leading to greater fragmentation and confusion, while limited alignment on the role of the public sector engagement could present a barrier for effective policy engagement. The lack of a common language to discuss cost expectations obscures the different roles stakeholders assume

government policy will play, and could also distract from a fuller discussion of emerging supply and infrastructure challenges in the years ahead.

We hope this assessment has unveiled valuable insights, perspectives, and opinions that can inform new work across the CDR community. Our collective next step is to leverage those insights and expertise to address these institutional barriers and allow long-duration CDR to proceed to the next stage in its development.

Credits

All authors helped design the project and interview questions. Na'im led project implementation, conducted the interviews, and synthesized stakeholder responses. Freya, Danny, and Jeremy helped interpret findings and edit the final report. Jeremy developed the web and print formats for the report with help from Kata Martin.

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Terms

CarbonPlan received a grant from Additional Ventures to support this work and hired Na'im Merchant as an expert consultant. CarbonPlan and Na'im Merchant are solely responsible for the content of this project, which does not represent the views of Additional Ventures or any other other organizations.

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