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CDR 2.0: Five Pillars of Successful Project Deployment and Delivery

February 19, 2026

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Acronyms and abbreviations

BECCS: bioenergy with carbon capture and storage
BiCRS: biomass carbon removal and storage
CDR: carbon dioxide removal
CFO: Chief Financial Officer
DAC: direct air capture
ERW: enhanced rock weathering
FEL: front-end loading
FEED: front-end engineering design
FID: final investment decision
FOAK: first-of-a-kind
ICVCM: Integrity Council for the Voluntary Carbon Market
IPCC: Intergovernmental Panel on Climate Change
ISO: International Organization for Standardization
LCA: life cycle assessment
LOI: letter of intent
mCDR: marine carbon dioxide removal (abiotic)
MMRV: measurement, monitoring, reporting, and validation
NDC: nationally determined contribution
SAF: sustainable aviation fuel
SBTi: Science Based Targets initiative
TECOP: technical, economic, commercial, organizational, and political
TRL: technology readiness level
VCM: voluntary carbon market

Executive summary

The carbon dioxide removal (CDR) industry is offtrack—both for the world's climate needs and self-declared corporate commitments. Despite the last several years spent developing standards, establishing criteria for project quality,[1] and educating buyers, the market is not scaling quickly enough to meet corporate climate commitments, much less global climate goals. Buyers hesitate, projects fail to reach the final investment decision (FID) stage, and capital sits on the sidelines. Credibility issues within the voluntary carbon market (VCM) have affected the CDR industry by association, dampening buyers' appetite for risk. Well-meaning responses—more working groups, principles, and frameworks—have not spurred needed action. To move the CDR industry forward and encourage scaling at the necessary speed, we outline a vision for CDR 2.0 here.

This whitepaper addresses engineered and hybrid pathways that provide high-durability CDR and require large amounts of capital investment, such as abiotic marine CDR (mCDR), bioenergy with carbon capture and storage (BECCS), biomass carbon removal and storage (BiCRS),[2] carbon mineralization, direct air capture (DAC), and enhanced rock weathering (ERW). These pathways share common challenges—the need for large upfront investment, complex project execution, and significant delivery risk. To successfully deploy these projects, we recommend building up five pillars for CDR 2.0. While these pillars can also be used to support nature-based CDR projects, or projects in adjacent markets like sustainable aviation fuel (SAF)[3] and low-carbon building materials,[4] the stakes are highest for hybrid and engineered CDR projects. These categories are the bedrock of market expansion. While the cost of failure is high, these risks are manageable and preventable.

To move off the sidelines and secure the high-quality tonnes required for future compliance and net-zero goals, corporate leaders should help build the pillars of CDR 2.0. A shift from CDR 1.0 to CDR 2.0 represents a fundamental change in corporate strategy: moving from the purchase of promises to the procurement of performance.

For CDR projects to reach a FID and reliably deliver credits, they must meet five conditions, or **the five pillars of CDR 2.0:**

1. **Technical readiness:** A commercial-scale project's core technology must be at a high technology readiness level (TRL), ideally TRL 8 or above.
2. **Project assurance:** Developers must be able to manage and execute a project's front-end engineering design (FEED) stages, construction, and operations with discipline—or be willing to bring in external specialists where they lack expertise. Declaration of offtake does not guarantee a FID, sound construction, operation, or delivery.
3. **Standardization:** Methodologies for measurement, monitoring, reporting, and validation (MMRV), crediting, and environmental accounting must converge and provide

[1] Carbon Direct and Microsoft. 2025. 2025 Criteria for High-Quality Carbon Dioxide Removal. [accessed 2026 Jan 23]. https://www.carbon-direct.com/criteria/2025-edition
[2] Carbon Direct. 2025. 2025 Guide to Sustainable Biomass Sourcing. [accessed 2026 Jan 23]. https://www.carbon-direct.com/research-and-reports/2025-guide-to-sustainable-biomass-sourcing
[3] Carbon Direct. 2023. Sustainable Aviation Fuels Primer. [accessed 2026 Feb 5]. https://insights.carbon-direct.com/hubfs/Sustainable%20Aviation%20Fuels%20(SAF)%20Primer%20Report.pdf
[4] Carbon Direct. 2025. Criteria for High-Quality Environmental Attribute Certificates. [accessed 2026 Jan 23]. https://www.carbon-direct.com/research-and-reports/criteria-for-high-quality-environmental-attribute-certificates

standardization that buyers, investors, and regulators uniformly see as both rigorous and investment worthy.

4. **Bankable contracting:** Capital stacks must be structured to allocate risk appropriately, with binding offtakes signed in advance that can support a FID.
5. **Transactional ease:** Contracts and syndication structures must be simplified, allowing buyers to easily assess and commit to projects with predictable terms, conditions, and structure. Buyers should aim to crowd in future demand by carefully considering the impact of terms such as credit shortfall recovery and rights of first refusal.

The five pillars of CDR 2.0 are entirely attainable; global energy markets have a long history of overcoming hurdles of this magnitude. Current market participants must activate these levers now to ensure every dollar of demand is maximized. While the efforts of early movers are vital, the ultimate goal is to attract a much broader base of buyers. By standardizing these five pillars, we create a market so robust that remaining on the sidelines becomes inexcusable. Ultimately, more buyers are needed, and CDR 2.0 addresses key needs of buyers: to manage risk and achieve commercial results.

Why CDR 1.0 stalled

The 2018 report from the Intergovernmental Panel on Climate Change (IPCC)[5] made the math unambiguously clear: limiting global warming to 1.5°C will require 100–1,000 billion tonnes of CDR by 2100. The question is no longer whether CDR is necessary, but whether the industry can deliver it on the necessary scale and timeline.

So far, the industry has not met this challenge. This is partly because the VCM was largely built on the incorrect premise that all carbon credits are interchangeable. Avoidance, reduction, and removal credits were lumped together and collectively described as "carbon offsets," creating a faulty impression that they are equivalent and fungible—or, is often said in our industry "a tonne is a tonne is a tonne." This categorical error has damaged the VCM's credibility and, by association, the credibility of CDR.

Between 2020 and 2024, exposés revealed overcrediting, environmental damage, and outright fraud across high-profile "carbon offset" projects.[6, 7, 8] Governance bodies scrambled to respond. Ratings agencies emerged. Buyers' clubs formed. Carbon Direct and Microsoft established a floor for defining high-quality CDR credits.[9] This was CDR 1.0: to accept the premise of CDR, to define quality, and to work to separate projects that met the criteria for high-quality CDR from those that did not.

This was not enough. Today, the CDR industry is populated with developers, registries, and ratings agencies, with some buyers, buyers' clubs, and standard-setting bodies. *What it lacks is deal flow.* Many buyers and investors chose to wait rather than move from expressions of interest to firm commitments. Signals from the Science Based Targets initiative (SBTi) and the European Union's Green Claims Directive, which might have spurred demand, did not actuate. This was due, in part, to uncertainty and long time lines.

Key technologies and projects have also underperformed, especially on cost reductions and scale-up. The industry has at times been poorly served by unrealistic cost reduction and scale-up estimates. Project developers cannot secure the binding offtakes they need to reach a FID. Capital sits on the sidelines waiting for absent demand signals. While the potential and interest for a robust CDR market exists, momentum and concrete action has lagged.

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[5] Intergovernmental Panel on Climate Change. 2018. Global Warming of 1.5 °C. [accessed 2026 Jan 23]. https://www.ipcc.ch/sr15/download/

[6] Trendafilova P. 2023 Mar 27. South Pole Faces Accusations Due To Exaggerated Carbon Offsets Claims. Carbon Herald. [accessed 2026 Feb 4]. https://carbonherald.com/south-pole-faces-accusations-due-to-exaggerated-carbon-offsets-claims-bloomberg/

[7] Carboncredits.com. 2024 Oct 7. Former C-Quest Capital CEO Accused of $100M Carbon Credit Fraud Scheme. [accessed 2026 Feb 4]. https://carboncredits.com/former-c-quest-capital-ceo-accused-of-100m-carbon-credit-fraud-scheme/

[8] Gill-Wiehl A, Kammen DM, Haya BK. 2024. Pervasive over-crediting from cookstove offset methodologies. Nat Sustain. 7(2):191–202 [accessed 2026 Feb 4]. https://doi.org/10.1038/s41893-023-01259-6

[9] Carbon Direct and Microsoft. 2025. 2025 Criteria for High-Quality Carbon Dioxide Removal. [accessed 2026 Jan 23]. https://www.carbon-direct.com/criteria/2025-edition

Delivery risk

All forms of forward demand signal serve a real and important purpose: they signal demand, unlock early-stage project development and give companies a basis for raising capital. However, they do not guarantee credit delivery. Projects backed by various forward commitments have missed deadlines, exceeded budgets, and failed to produce credits. Many forward demand portfolios are designed like venture portfolios (i.e., numerous small bets, most expected to fail), while the next phase of CDR requires infrastructure-building outcomes (i.e., a smaller number of large assets that must reliably deliver).

Similarly, buyers should not expect registries to do more than they are capable of. Well-functioning registries report data relative to the guidelines that they write. A project can commit to adhering to those guidelines without fully understanding the likelihood of delivery. This problem is exacerbated by a short-term tendency in some demand cycles. While short-term cycles are easier to get stakeholders to approve, these cycles are misaligned with project timelines. Brief contracting windows risk leaving projects well short of requirements for a FID.

The problem is structural. In today's market there are many early-stage projects, most of which carry a high risk of non-delivery, supported by a handful of large buyers who absorb most of the projected credit volume. There is no "like-for-like" delivery available—unlike in a mature commodity market where you can easily substitute one supplier for another, when a CDR project fails there is no ready credit replacement. The supply of high-quality, delivery-ready projects is too scarce.

To stabilize the sector, CDR 2.0 commitments must be paired with rigorous TECOP diligence, active project assurance during execution, and sophisticated contracting that allocates risk to the parties best equipped to manage it.

TECOP: Managing technical, economic, commercial, organizational, and political dimensions
To deliver credits to the CDR market, projects must succeed on all merits: technical, economic, commercial, organizational, and political (TECOP). When a project fails in any one of these dimensions, time, capital, and trust will be spent in return for limited gains or even failure. Success across all of these dimensions requires a high level of sophistication on the part of CDR project developers, investors, and buyers. This is particularly true for projects leveraging emerging technologies or for new project developers.

The five pillars of CDR 2.0

The next few years will determine whether the CDR industry meets its potential or remains a niche market. This is not about principles or frameworks. It is about ensuring contracting and delivery of key, early projects over the next several years. This is the necessary step to take before building and operating the thousands of projects and facilities needed to reach gigatonne-scale. To achieve this, the industry must be supported by the five pillars of CDR 2.0, all built upon a foundation of scientific and technical rigor (**figure 1**).

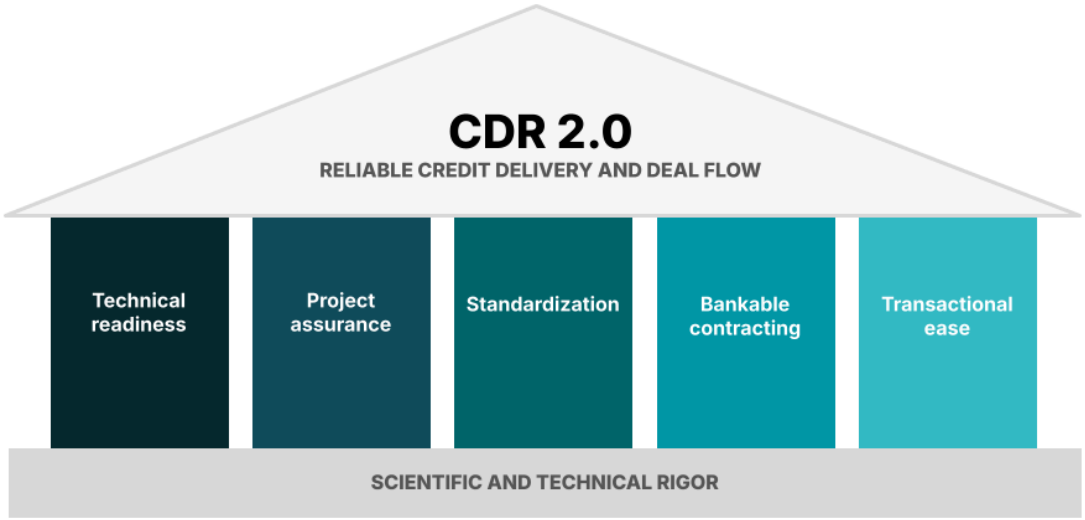

Figure 1: The five pillars of CDR 2.0. Source: Carbon Direct.

Foundation: Scientific and technical rigor

Carbon Direct and Microsoft's *Criteria for High-Quality Carbon Dioxide Removal* remain the industry's baselines.[10] Projects are analyzed against both broad principles and specific criteria that cover additionality, durability, leakage, MMRV, and net-carbon accounting grounded in life cycle assessments (LCAs) and direct measurement. Projects must also demonstrate environmental and social integrity—that they provide benefits to communities and cause minimal harms. As the market moves from theoretical build out and baseline requirements to actualized projects that put steel in the ground, a gap has emerged between public certification and technical reality.

Buyers and investors sometimes assume, based on product ratings or registry approval alone, that a project will perform like a traditional industrial asset. In practice, ratings and registry approvals are rarely designed to fully underwrite engineering execution risk, integration risk, and schedule realism. The emergence of higher-quality registries and the growth of independent ratings agencies represent genuine progress—they bring greater standardization and help buyers compare projects at a glance. That said, they do not address many key issues, nor is that their intended role. Registries and raters can tell you whether a project's paper plan represents notional high-quality CDR; derisking tells you if a project developer can actually construct, operate, and meet a project's specifications. Buyers who treat registries and ratings agencies as the primary gatekeepers for project quality *and* delivery risk may find themselves overpaying for an assurance that does not fully address the range of risks determining project failure or success.

Pillar 1: Technical readiness

Pilot programs and demonstration projects serve a purpose: they give emerging technologies a runway to mature. CDR 2.0 must stand on high technical readiness. Projects built on technologies with a low TRL can help companies mature and may deliver small volumes of credits to forward-looking buyers. They also carry delivery risks that conventional project finance cannot absorb. Risk is magnified for first-of-a-kind (FOAK) deployments, where even proven technologies

[10] Carbon Direct and Microsoft. 2025. 2025 Criteria for High-Quality Carbon Dioxide Removal. [accessed 2026 Jan 23]. https://www.carbon-direct.com/criteria/2025-edition

face integration challenges at scale. Buyers and investors must assess a project's technology readiness as it stands, not as developers project it will be in the future. If a project's core technology has a low TRL, it belongs in a pilot portfolio, not a bankable capital stack. Such projects may merit support, but they must not be misclassified.

Pillar 2: Project assurance

CDR facilities are heavy industrial assets. They are designed to provide 50,000–5,000,000 tonnes of CDR per year, with carbon dioxide captured, concentrated, and transported to permanent storage. These facilities require the same level of project management discipline as energy infrastructure or chemicals manufacturing.

That discipline starts with front-end loading (FEL). Concept development, FEED, and pre-FEED stages of project development exist to identify and resolve technical, commercial, and integration risks before capital is committed. Developers face constant pressure to compress these stages—to reach a FID faster, to satisfy impatient investors, to beat competitors to market. It is important to resist this pressure. When stage-gate reviews become mere formalities, unresolved issues can migrate into construction and operations, where they become real problems that cost time and money.

Beyond assessing TRL level, technology selection during concept development deserves particular attention. Core technology (e.g., gasifiers, capture units), component technology (e.g., sorbents, solvents), and balance of system (e.g., compressors, chillers) must be matched to a project's operating climate, local environment, and system integration requirements. Even established technology, if misapplied, represents risk.

For buyers and investors, a project that conducts all stages for FEL and thoroughly executes FEED provides a strong signal that the development team knows what it takes to reliably deliver. If a developer cannot walk an investor or buyer through their stage-gate process and the decisions made at each gate, one should treat that as a red flag.

Pillar 3: Standardization

The CDR community faces a standards gap. While specific methodologies and protocols for various CDR pathways exist, standards do not—at least not in the form buyers and investors need. Registries and standard-setting bodies such as the European Commission, the Integrity Council for the Voluntary Carbon Market (ICVCM), the International Organization for Standardization (ISO), Isometric, Puro.earth, and Verra all have published frameworks in the form of principles or protocols. While helpful, these do not substitute for the kind of clear, technical specifications common to large capital investments, commercial underwriters, and regulations. Risk reduction will occur only when we migrate from principles to specifications.

A higher degree of clarity and fidelity is essential. Today, first-mover projects are left to fill this gap on their own. Developers and buyers must negotiate project-specific MMRV requirements, co-develop verification protocols, and accept that FOAK projects carry risks that cannot be shifted to a standards body. This is the cost of being an early mover. It is also an opportunity: the specifications written into today's contracts will shape the standards that govern tomorrow's market, giving early investors a chance to create large impacts and drive market outcomes. A

dynamic approach is required, where learnings from early projects and actions can fold into evolving regulations and standards that will likely tighten over time.

Pillar 4: Bankable contracting

CDR projects need investment that is structured similarly to other high-capital infrastructure with project equity for risk-tolerant investors, senior debt for those who need security, as well as mezzanine debt and preferred equity to bridge the gap. Government incentives—such as 45Q tax credits, federal grants, and state auction revenues in the United States—add non-dilutive capital that reduces risk for private investors. None of this is novel, the project finance playbook exists and is well understood.

The missing element for CDR projects is reliable execution. Most CDR developers lack experience structuring bankable deals, and most investors lack fluency in CDR-specific technical risks. This creates friction: deals that take too long, fall apart over misunderstood risks, or never reach term sheets at all. Early failures due to misallocation or miscategorization of risk slow bankable contracting, burn money, and stall deployment.

To accelerate bankable contracting for CDR projects, we need three things:

- **Milestone-based deployment:** Capital is released against verified progress, not promises. This protects investors and disciplines developers.
- **Risk-matched tranches:** Equity absorbs technology and execution risk. Debt comes in after a FID when construction risk is quantifiable. This distinction supports viable deals.
- **Technical-financial translation:** Developers speak in engineering terms, while capital providers speak in financial terms. Deals require both sides to understand each other—converting technical performance into bankable assumptions, and financial requirements into actionable project specs. This translation function is often missing, and its absence creates a bottleneck.

Pillar 5: Transactional ease

Every CDR deal made in today's market is bespoke. Buyers and suppliers often negotiate terms from scratch, spending months on contracts. Aggregated demand for pilot-stage projects does not deliver the standardized, bankable contracts or repeatable deal structures required for a mature market. Fortunately, many of these deal structures exist in other industries and can be applied to CDR. Chief Financial Officers (CFOs) must not be held back by fear of contractual complexities:

To enable greater transactional ease, the CDR market needs four things:

- **Standardized contracts:** Simplified contracts for CDR credit delivery would provide base terms for offtake agreements that don't require reinvention for every deal. Negotiation should then focus on project-specific variables including timelines, risks of contract breach, and underdelivery.
- **Syndication infrastructure:** While buyers should leverage shared data to scale efficiently, they must account for the competing interests and divergent views inherent in large-scale corporate collaborations. While this infrastructure can accelerate timelines, CFOs should not expect syndication forums to handle all complexities of the final contracting process.
- **Universal quality benchmarks:** Buyers need to be able to assess a project against published criteria, not proprietary methodologies that differ by intermediary.

- **First-mover discipline:** Early offtakers will predictably seek preferential terms, but those terms must be structured to encourage future buyers, not lock them out. Buyers should carefully weigh well-warranted incentives for early action with the reality that the project must sell additional volumes to succeed and receive financing.

CDR 2.0 success

A variety of roles to play

Carbon credits are not fungible commodities. They represent environmental services—delivered through project operation and verification and differentiated by durability, geography, and community impact. To date, the largest CDR deals have been negotiated directly between buyers and suppliers. This is likely to remain true for the foreseeable future. The CDR market is not a spot market. It is a business-to-business contracting environment where relationships and diligence determine project outcomes.

In such an environment, project success cannot be ensured by developers alone. Buyers, investors, and third-party experts all have roles to play—not as passive observers, but as active participants in getting projects to a FID and into operation. Participants can engage in portfolio selection, offtake agreements, and project assurance to support the success of CDR 2.0. Someone must take responsibility for project success.

- **Portfolio selection:** Buyers should approach CDR procurement the way institutional investors approach private equity: with rigorous, structured diligence across a portfolio of opportunities. This requires a full TECOP assessment across all five dimensions of every project under consideration. It also means understanding not just the technology, but the developer's execution capability, management depth, and operational track record. Selecting projects by going through this disciplined process greatly improves the likelihood that buyers will make commitments to projects that deliver.
- **Offtake agreements:** Binding offtakes are the cornerstone of bankable CDR projects. Without contracted revenue, developers cannot secure a FID or build their project. Letters of intent (LOIs) are helpful but not adequate substitutes. While LOIs express an intention to negotiate, they do not guarantee a purchase. CDR buyers would be better served to adopt the contracting structures commonly used in other capital-intensive industries: take-or-pay agreements with predetermined price, volume, and schedule. These instruments—not expressions of interest or aspirational commitments—are what underwrite project finance.
- **Project assurance:** Most CDR developers lack the in-house expertise needed to manage large, complex, FOAK projects. Municipal utilities, pulp and paper companies, industrial gas firms—many are venturing outside their core competencies to enter the CDR market. By the time these actors recognize the expertise gap, they have already burned through valuable time and money, risking schedules and budgets. Project assurance—engaging external specialists who monitor execution, flag risks early, and support course correction—costs less than 1% of a project's budget. For FOAK projects, projects with government grants or subsidized capital, or projects that represent a meaningful share of a country's nationally determined contribution (NDC), project assurance is essential. Stakeholders should fund project assurance directly and explicitly. Most developers will not do it on their own. Project assurance can mean the difference between project failure and successful delivery.

An action agenda

Five key actions, related to the five pillars of CDR 2.0, will determine whether the CDR industry scales or stalls:

1. **Verify technical readiness before committing capital.** Buyers that focus on scaling technologies with a high TRL for bankable projects, are more likely to see reliable delivery. If a buyer is willing to accept higher risk to catalyze emerging pathways, they must do so knowingly and structure contracts that reflect that risk. Developers must be transparent about where a project's technology actually stands. Overpromising today results in non-delivery tomorrow, while transparency begets success.
2. **Fund project assurance directly.** For any project where the developer lacks deep execution experience, require independent project oversight as a condition of investment or offtake. This is particularly applicable to FOAK projects and those receiving government support.
3. **Drive standardization through practice.** Standards will not emerge from committees alone, but from the specifications written into early contracts. Buyers and developers must document a project's MMRV approaches, additionality methodologies, and verification protocols, then share what works. This will contribute to building standards from the ground up.
4. **Structure bankable deals.** Match capital tranches to risk profiles. Secure binding offtakes before a FID. Use conventional project finance structures that are adapted to the risks specific to CDR projects. If a deal cannot be structured to close, it is not a deal—it is a conversation.
5. **Reduce transaction friction.** Standardize base contract terms. Build a syndication infrastructure that enables multiple buyers to participate without duplicating diligence efforts. Create quality benchmarks that allow new entrants to transact with confidence.

The bottom line

The CDR market needs more than principles and frameworks to scale. It requires the same commercial discipline as other capital-intensive industries. The five pillars of CDR 2.0 outlined here provide the structure for the "steel-in-the-ground" era of carbon removal. For the corporate buyers and commercial leaders who will rely on CDR in the future, the path forward is straightforward. Progress does not have to mean accepting higher risk. By applying the rigorous structure of CDR 2.0, executives can transform intention into industrial performance.

Acknowledgements

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