Industry Analysis: Carbon Management

Idea In Short

Carbon management is consolidating around three interlocking layers: measurement software that turns emissions into an auditable ledger, markets that price the right to emit or remove a tonne and removal technology that manufactures new supply. The industry is worth well over a trillion dollars in traded compliance allowances alone, growing on the back of mandatory disclosure rules in the European Union, the United Kingdom and California. Margin is concentrating in registries, verification bodies and enterprise software vendors that own the data layer, not in commodity offset origination, which remains capital-intensive and reputationally fragile. Bargaining power is shifting toward large corporate buyers and regulators, who increasingly dictate credit quality standards and away from small-scale project developers. Executives entering this space should prioritize positions in measurement infrastructure and high-integrity removal supply and treat legacy avoidance-based offset trading as a shrinking, low-margin segment.

Carbon management has moved from a corporate social responsibility afterthought to a mainstream financial and regulatory discipline over the past five years. What began as voluntary offset purchasing by consumer brands seeking reputational credit has broadened into a full industry stack spanning emissions measurement software, compliance and voluntary trading markets and an emerging removal technology sector building the physical infrastructure to pull carbon dioxide out of the atmosphere. Understanding how this industry creates and captures value requires separating three distinct businesses that are frequently and incorrectly, treated as one.

Industry at a glance

Carbon management, as analyzed here, covers three connected but economically distinct activities. The first is carbon accounting and measurement software, which calculates an organization's greenhouse gas emissions across direct operations, purchased energy and supply chain activity and formats that data for regulatory or investor disclosure. The second is carbon markets, both compliance systems created by government mandate, such as the

European Union Emissions Trading System (EU ETS) and voluntary markets where companies purchase offset credits to counterbalance emissions they have not eliminated. The third is carbon capture and removal technology, encompassing direct air capture, bioenergy with carbon capture and storage, mineralization, biochar and nature-based removal projects that generate the physical supply of removed carbon dioxide underlying many credits. This analysis excludes the broader climate technology venture ecosystem, including clean energy generation, electric mobility and industrial decarbonization equipment, which is covered separately.

Customers span all three procurement categories. Business-to-business (B2B) demand dominates, with large corporations buying accounting software licenses and offset credits to satisfy investor expectations, customer requirements and internal net-zero commitments. Business-to-government (B2G) demand comes from regulated entities purchasing compliance allowances and from public sector procurement of removal credits for national climate targets. Business-to-consumer (B2C) activity is comparatively small, limited to niche retail offset products sold alongside flights or consumer goods. The industry depends heavily on adjacent sectors:

> energy markets set the marginal cost of abatement that determines offset demand, financial services provide the trading infrastructure and custody for carbon credits and heavy industry, aviation and shipping generate the compliance obligations that anchor the largest revenue pools

The overall compliance and voluntary credit market, taken broadly across allowances and offsets, is now valued well into the hundreds of billions of dollars annually and continues expanding as more jurisdictions adopt mandatory carbon pricing.1 Revenue models differ sharply by layer. Accounting software follows conventional software-as-a-service (SaaS) subscription pricing, typically tiered by emissions scope coverage and company size, with enterprise contracts reaching six figures annually. Carbon markets generate revenue through transaction fees, registry listing fees and bid-ask spreads captured by brokers and exchanges, alongside the underlying commodity value of the credits or allowances themselves. Removal technology companies sell forward purchase agreements and offtake contracts, often years before a facility becomes operational, a financing structure closer to

industrial project finance than typical technology sales. Capital intensity rises sharply as one moves from software toward physical removal: a measurement platform can be built with venture-scale capital, while a commercial direct air capture facility requires hundreds of millions of dollars and multi-year construction timelines. Regulatory intensity follows a similar gradient, with compliance markets entirely dependent on government rule-making and removal technology increasingly reliant on subsidy regimes and emerging measurement, reporting and verification (MRV) standards.

Industry segmentation

The industry divides into six segments defined primarily by value chain position and secondarily by customer type. Carbon accounting and measurement software forms the first segment, comprising platforms such as Persefoni, Watershed and Sweep that calculate Scope 1, Scope 2 and Scope 3 emissions and generate disclosure-ready reports.2 The second segment is compliance carbon markets, the government-mandated cap-and-trade systems including the EU ETS, the United Kingdom Emissions Trading Scheme, California's cap-and-trade program and China's national emissions trading system, where regulated emitters buy and sell allowances to meet legal caps.

The third segment is the voluntary carbon market, where corporations purchase offset credits certified by standards bodies such as Verra and Gold Standard to counterbalance emissions outside any compliance obligation. The fourth segment covers carbon removal and capture technology, split between nature-based approaches such as afforestation and soil carbon sequestration and engineered approaches such as direct air capture, bioenergy with carbon capture and storage and mineralization. The fifth segment is registry, verification and assurance services, the accreditation bodies and independent auditors that certify emissions data and credit quality, functioning as the industry's trust infrastructure. The sixth segment is carbon market infrastructure and brokerage, the exchanges, trading desks and data providers, including entities like Xpansiv and CBL, that provide price discovery and settlement for both compliance and voluntary instruments. Engineered removal specifically is projected to grow at a double-digit compound annual rate over the coming decade as corporate offtake commitments accumulate faster than commercial capacity comes online.3

These segments are dimensioned differently along the value chain. Measurement software and registries sit upstream, generating the data and certification that downstream trading

depends on. Markets and brokerage sit in the middle, converting certified data into a priced, transferable financial instrument. Removal technology sits both upstream, as a physical supply source and downstream, as a category of credit that trades within voluntary and increasingly compliance markets. A company's position along this chain determines its exposure to commodity price volatility versus recurring software revenue and this distinction matters more to profitability than company size or geography.

Market structure

Industry dynamics reflect a market still consolidating around trust and regulatory legitimacy rather than mature competitive equilibrium. Buyers, largely large corporations and regulated emitters, have grown more discerning after voluntary market credibility controversies, pushing power toward high-integrity suppliers. Suppliers of measurement data, land and verification hold increasing leverage as regulation tightens quality requirements. Rivalry is fragmented across hundreds of registries, standards bodies and software vendors, none of which yet commands durable global scale. New entrants continue to arrive in software but face steep accreditation barriers in registries and capital barriers in removal technology. Substitutes, chiefly direct operational decarbonization, compete with every layer of this industry by reducing the emissions that create demand for measurement, trading and offsetting in the first place.

- Porter's Five Forces analysis of the carbon management industry

Bargaining power of buyers

Buyer power in carbon management has strengthened considerably as the market has matured and consolidated around a smaller set of sophisticated purchasers. Large corporations with net-zero commitments, financial institutions managing portfolio emissions and compliance-obligated industrial emitters now negotiate directly with software vendors and credit originators, extracting volume discounts and quality guarantees that smaller buyers cannot command. Enterprise software buyers increasingly run competitive procurement processes across multiple carbon accounting vendors, treating the purchase as a standard enterprise technology decision rather than a sustainability donation, which compresses vendor pricing power. On the credit side, corporate sustainability teams have become more technically literate following high-profile media investigations into offset quality and they now demand independent verification, vintage transparency and

additionality proof before committing budget.

Compliance market buyers, by contrast, hold less discretionary power because participation is legally mandated rather than optional, though large emitters still negotiate favorable terms through banking allowances and hedging strategies. The concentration of corporate carbon budgets among a relatively small number of Fortune 500 and multinational buyers means that losing a single major account can materially affect a mid-sized vendor's revenue, giving these buyers outsized influence over product roadmaps and pricing structures. Consulting firms and auditors acting as intermediaries for smaller buyers further aggregate purchasing power, negotiating platform-wide licensing deals on behalf of client portfolios. This buyer sophistication has effectively bifurcated the market between vendors who can satisfy audit-grade rigor demanded by large buyers and lower-cost platforms serving smaller companies with lighter compliance obligations.

Buyer type	Source of leverage	Effect on suppliers
Multinational corporations	Large multi-year software contracts and bulk credit purchases	Price discounts, custom integration demands
Regulated industrial emitters	Legally mandated participation with hedging sophistication	Allowance banking, forward pricing pressure
Financial institutions	Portfolio-wide emissions reporting requirements	Preference for audit-grade, assurance-ready data
Consulting and audit intermediaries	Aggregated purchasing across client rosters	Platform-wide licensing negotiation
Small and mid-size enterprises	Limited individual leverage, price sensitive	Push toward lower-cost, templated offerings

Bargaining power of buyers

Bargaining power of suppliers

Suppliers in this industry include the registries and standards bodies that certify credits, the landholders and project developers who generate offset supply, the satellite and remote-sensing data providers who verify activity and the specialized engineering firms that build removal infrastructure. Registries such as Verra and Gold Standard hold outsized power because they control the accreditation gateway that determines whether a credit can be sold at all and switching a project's registry affiliation is costly and slow. This chokepoint

position lets registries set methodology requirements that ripple through the entire value chain, effectively acting as the industry's de facto regulators even though they are private organizations.

Land-based project developers hold moderate power individually but face collective competition from thousands of similar projects, limiting their ability to extract premium pricing except for scarce, high-integrity credit types. Data and remote-sensing providers, including satellite monitoring firms, have gained leverage as buyers demand independent verification rather than self-reported activity data, making these providers increasingly indispensable rather than optional. Engineering suppliers for removal technology, particularly specialized equipment manufacturers for direct air capture and mineralization, hold considerable power due to limited competition and long lead times, since only a handful of firms can supply the specialized contactors, sorbents and processing equipment these facilities require. Labor supply, particularly technical MRV specialists and carbon accounting professionals, remains tight relative to demand, pushing up compensation costs across the industry.

Supplier type	Source of leverage	Effect on the value chain
Credit registries and standards bodies	Sole accreditation gateway for tradable credits	Sets methodology, controls market access
Land-based project developers	Fragmented but essential supply of nature-based credits	Limited pricing power except for scarce credit types
Satellite and remote-sensing data firms	Independent verification increasingly required by buyers	Rising fees for monitoring services
Specialized removal equipment manufacturers	Few qualified suppliers for capture technology	Long lead times, premium equipment pricing
Technical MRV and accounting talent	Skills shortage relative to demand growth	Elevated compensation, retention pressure

Bargaining power of suppliers

Rivalry among existing competitors

Competitive intensity varies sharply by segment but is generally rising as regulatory tailwinds attract new capital and existing players race to establish scale before consolidation. In carbon accounting software, dozens of vendors, from well-funded

platforms like Watershed and Persefoni to regional specialists like Sweep and Normative, compete on breadth of emissions scope coverage, integration depth with enterprise resource planning systems and the credibility of their audit trail. None has yet achieved category-defining dominance and price competition has intensified as buyers treat these platforms as substitutable commodities for baseline compliance functionality, reserving premium pricing tolerance for differentiated Scope 3 capabilities.

In carbon markets, rivalry centers on credit quality and registry reputation rather than pure price competition, since buyers increasingly discount low-integrity credits regardless of headline price. Voluntary market participants compete to establish premium positioning around durable, verifiable removal credits, while a large tail of lower-quality avoidance credits competes purely on cost, creating a bifurcated competitive structure within the same market. Compliance markets exhibit different dynamics entirely, since the EU ETS and similar systems function more like regulated utilities than competitive markets, with price discovery driven by allowance auctions and secondary trading rather than vendor competition. Removal technology rivalry is nascent but intensifying, with direct air capture developers such as Climeworks and Heirloom competing on cost per tonne and permanence guarantees, while a broader set of engineered and nature-based approaches jockey for corporate offtake commitments ahead of proven commercial scale.

Competitive dimension	Where rivalry concentrates	Strategic response observed
Software feature breadth	Scope 3 supply chain coverage	Rapid integration partnerships, acquisitions
Credit quality perception	Durable removal versus avoidance credits	Premium pricing for verified permanence
Registry reputation	Accreditation rigor and buyer trust	Tightened methodology standards
Cost per tonne removed	Direct air capture and mineralization	Aggressive cost-curve investment
Offtake agreement volume	Long-term corporate purchase commitments	Multi-year forward contracts before scale

Rivalry among existing competitors

Threat of new entrants

New entrant threat differs enormously by segment, ranging from low barriers in basic software to near-prohibitive barriers in registries and physical removal infrastructure.

Carbon accounting software remains relatively easy to enter, since the core technical requirements, emissions factor databases and calculation logic, are increasingly well documented and cloud infrastructure lowers the capital needed to launch a minimum viable product. This has produced a steady stream of new entrants, particularly regional and industry-specific platforms targeting segments underserved by the larger generalist vendors, though customer acquisition costs and enterprise sales cycles create meaningful friction even here.

Registries and verification bodies present the opposite case, functioning as an effectively closed market protected by decades of accumulated credibility, regulatory recognition and network effects among project developers who need buyer trust. A new entrant attempting to launch a competing registry faces the near-impossible task of convincing both credit buyers and project developers to adopt an unproven standard simultaneously. Compliance market participation is similarly restricted, since entry depends entirely on government designation as a regulated entity or approved trading participant, leaving no meaningful competitive entry point for new firms. Removal technology entry requires the most capital of any segment, often hundreds of millions of dollars before a single commercial-scale facility operates, though the scarcity of proven durable removal supply relative to corporate demand continues to attract well-funded new entrants willing to accept multi-year development risk.

Entry barrier type	Segment most affected	Severity
Accreditation and trust networks	Registries and standards bodies	Very high
Government designation requirements	Compliance market participation	Very high
Capital intensity for physical infrastructure	Removal and capture technology	High
Enterprise sales cycle and integration complexity	Accounting software	Moderate
Technical talent scarcity	MRV and verification services	Moderate

Threat of new entrants

Threat of substitutes

The most significant substitute across the entire industry is direct emissions reduction, since a company that redesigns its operations to avoid generating carbon dioxide in the first place

needs no measurement software, no offset credits and no removal technology to address that particular tonne. This substitution dynamic makes carbon management structurally different from most industries, where the core product faces competition from alternative products rather than from the underlying problem simply disappearing. As energy efficiency, renewable procurement and process electrification become cheaper, the addressable market for offsetting and removal shrinks at the margin, even as total demand for measurement software continues growing because disclosure obligations persist regardless of abatement progress.

Within the software segment, generic spreadsheet-based tracking and low-cost consulting-delivered emissions inventories substitute for dedicated platforms among smaller companies with modest compliance obligations, capping the addressable premium software market until disclosure thresholds tighten further. Within carbon markets, internal carbon pricing mechanisms, where companies apply a shadow price to emissions in capital allocation decisions without ever transacting an external credit, substitute for offset purchasing by achieving similar behavioral effects without market participation. Within removal technology, cheaper nature-based approaches substitute for expensive engineered removal for buyers prioritizing volume over permanence, though this substitution runs in both directions as buyers seeking durability increasingly favor engineered removal despite the cost premium.

Substitute	What it replaces	Constraint limiting adoption
Direct operational decarbonization	Offset and removal credit purchases	Requires capital investment and time
Spreadsheet and manual tracking	Dedicated accounting software	Inadequate for complex, audited disclosures
Internal carbon pricing without transactions	External credit purchasing	Lacks external verification and market signal
Nature-based removal	Engineered removal technology	Weaker permanence guarantees
Renewable energy certificates	Scope 2 offsetting via credits	Addresses only electricity-related emissions

Threat of substitutes

Value chain and profit pools

The carbon management value chain runs through five identifiable stages. Upstream, data

generation and land or project origination anchor the chain, encompassing satellite monitoring, activity data collection and the physical land or industrial sites where emissions reduction, avoidance or removal actually occurs. This stage requires deep domain expertise in measurement science and, for nature-based projects, long-term land tenure or partnership agreements that take years to establish credibly.

The second stage is verification and certification, where independent auditors and registries confirm that reported emissions data or generated credits meet methodology standards. This stage functions as the trust chokepoint of the entire industry, since every downstream transaction depends on the credibility established here. The third stage is aggregation and market-making, performed by exchanges, brokers and trading platforms that pool supply, provide price discovery and enable transaction settlement between originators and buyers. The fourth stage is enterprise software and analytics, the measurement, reporting and decision-support layer that translates raw emissions data into usable corporate intelligence and regulatory filings. The fifth stage is the customer interface, comprising the sustainability, finance and procurement functions within buying organizations that select vendors, evaluate credit quality and integrate carbon data into broader financial and operational reporting.

Profit pool

Profit concentrates disproportionately in the verification and certification stage and in enterprise software, both of which benefit from chokepoint economics and recurring revenue structures. Registries earn fees on every credit issued and every transaction recorded, a toll-booth model that scales with market volume without requiring proportional cost increases, generating structurally higher margins than physical credit origination. Enterprise software vendors that achieve scale enjoy conventional SaaS economics, with gross margins in the range typical of business software once customer acquisition costs are amortized across a multi-year contract.

Origination, whether nature-based project development or early-stage removal technology, remains the least profitable stage today, weighed down by high upfront capital costs, long payback periods and reputational risk from quality controversies that can strand an entire project's credit inventory. This profit distribution has shifted meaningfully over the past three years: capital that once flowed toward offset origination, chasing voluntary market growth, has redirected toward measurement software and high-integrity removal

technology, as buyers grew skeptical of low-quality avoidance credits following well-documented media investigations into overstated forest conservation claims. Brokerage and trading capture moderate, spread-based margins, more resembling commodity trading desks than either software or verification economics.

Industry economics and business models

Three business models dominate the industry, each with materially different economics. The first is the subscription software model used by carbon accounting platforms, characterized by asset-light operations, high gross margins once scale is reached and revenue predictability through annual or multi-year contracts. This model rewards rapid customer acquisition and low churn and its unit economics resemble any enterprise SaaS business, with customer lifetime value needing to substantially exceed acquisition cost to justify the sales investment required for complex enterprise deals.

The second model is transaction and fee-based trading, used by exchanges, brokers and registries, where revenue scales with market volume and price rather than customer count. This model benefits from operating leverage during periods of high trading activity but suffers when volumes contract, as occurred across parts of the voluntary market following credibility concerns. The third model is asset-heavy project development and infrastructure, used by removal technology developers and large-scale nature-based project originators, which requires substantial upfront capital, generates revenue through long-term offtake agreements rather than spot sales and resembles project finance more than either software or trading. Some large players are beginning to blend these models, with software vendors adding transaction capabilities and removal developers securing forward software partnerships, suggesting the industry may consolidate toward vertically integrated players over the next decade.

Cost drivers and scalability

Cost structures differ substantially across the three business models. Software platforms carry primarily fixed costs concentrated in engineering, data infrastructure and enterprise sales, with variable costs limited mainly to cloud computing and customer support that scale sub-linearly with customer count, producing strong economies of scale once a platform passes its break-even customer threshold. Customer acquisition cost relative to lifetime value is the critical unit economic here and vendors serving large enterprise accounts face

long sales cycles that raise acquisition cost but are offset by higher contract values and lower churn than smaller accounts.

Trading and brokerage operations carry lower fixed costs but face variable costs tied to compliance, market-making capital and regulatory reporting, with scalability driven by transaction volume rather than customer count, similar to financial exchange economics. Removal technology and project development carry the heaviest fixed cost burden, dominated by capital expenditure on physical infrastructure, land and specialized equipment, with variable costs concentrated in energy consumption, particularly significant for direct air capture facilities that require substantial power inputs. Economies of scale in removal technology are still being proven, since only a small number of commercial-scale facilities exist globally, but early evidence suggests unit costs decline meaningfully as facility size and cumulative deployment increase, following a pattern common to other capital-intensive energy infrastructure.

Moats, advantages and strategic levers

Defensibility in this industry rests on four distinct sources and the strongest competitors typically combine more than one. Regulatory moats protect registries and compliance market participants most powerfully, since accreditation and legal designation cannot be replicated through capital or technology alone, only through sustained credibility built over years. Data and learning advantages accrue to software vendors and remote-sensing providers that accumulate proprietary emissions factor libraries and verification datasets, making their calculations more accurate and defensible over time in ways competitors cannot easily replicate without similar data accumulation.

Switching costs matter significantly in enterprise software, where a company that has integrated a carbon accounting platform into its financial close process, trained staff on its interface and built multi-year historical baselines faces real friction in migrating to a competitor, even one offering marginally better features. Cost advantage matters most in removal technology, where firms that move down the manufacturing learning curve fastest, through repeated facility construction and process refinement, can offer lower cost per tonne than later entrants, echoing the cost dynamics seen in solar photovoltaic and battery manufacturing. Network effects remain relatively weak across the industry compared with typical platform businesses, though registries exhibit a mild version, since buyers and project developers both gravitate toward the registry with the deepest existing participation.

> The credibility of a tonne of carbon dioxide removed is now as commercially valuable as the tonne itself

Strategic levers

Executives evaluating positions in this industry can pull several distinct levers depending on whether they are entering fresh or defending an incumbent position. Customer segment focus represents the first lever, since vendors that concentrate on either large enterprise accounts with complex Scope 3 needs or small and mid-size businesses with templated compliance requirements build more coherent products and sales motions than those trying to serve both simultaneously. Vertical integration versus partnership is the second lever and the industry shows both models succeeding:

> some software vendors have integrated forward into credit brokerage and removal offtake, while others deliberately stay software-only and partner with registries and project developers to avoid diluting focus

Geographic expansion ahead of regulatory rollout constitutes a third meaningful lever, since companies that establish credibility and customer relationships in the European Union ahead of its Carbon Border Adjustment Mechanism (CBAM) implementation, or in jurisdictions where mandatory disclosure is imminent but not yet enforced, secure durable first-mover positioning before competitive intensity rises. Ecosystem orchestration is a fourth lever available primarily to well-capitalized incumbents, who can bundle measurement, verification partnerships and removal offtake into a single client relationship, raising switching costs and capturing value across multiple stages of the value chain simultaneously. Finally, disciplined technology selection within removal, favoring approaches with defensible permanence and measurement rigor over the cheapest available credit type, positions a company to capture premium pricing as buyer sophistication continues rising industry-wide.

Structural risks, regulation and trends

Structural risk in carbon management is dominated by regulatory volatility, since demand for nearly every product in this industry traces back to a government mandate or a corporate response to anticipated regulation. Policy reversal risk is real and has already materialized in parts of the United States, where federal support for carbon capture incentives has fluctuated with changing administrations, creating planning uncertainty for developers with decade-long project horizons. The EU ETS provides more durable footing, with prices averaging around eighty-five euros per tonne in 2025 and projected to approach triple digits as the system tightens.4 Technology disruption risk centers on the possibility that a breakthrough in direct decarbonization, such as dramatically cheaper industrial electrification or hydrogen substitution, could shrink the addressable market for offsetting faster than removal technology costs decline, compressing the entire industry's growth runway.

Commodity price risk affects both compliance allowances, which fluctuate with energy prices and economic activity and voluntary credits, whose pricing has proven volatile amid quality controversies that have periodically collapsed demand for entire credit categories. Geopolitical and supply chain risk touches removal technology specifically, since specialized equipment manufacturing for direct air capture and similar processes depends on a small number of suppliers concentrated in a handful of countries. On the demand side, the secular trend is unambiguous: mandatory climate disclosure regulation is expanding globally, from the EU's Corporate Sustainability Reporting Directive to the U.S. Securities and Exchange Commission's climate rules and similar frameworks emerging across Asia, structurally increasing demand for measurement software regardless of voluntary market sentiment.5 Supply-side trends favor consolidation, as smaller registries and software vendors merge or exit under the weight of rising accreditation and audit-grade compliance requirements that only well-capitalized players can sustain.

The strategic playbook for new entrants depends heavily on chosen segment. A niche entry strategy, focusing on an underserved vertical such as agriculture-specific emissions accounting or a single geography ahead of regulatory rollout, offers a more capital-efficient path than attempting a broad horizontal platform against entrenched incumbents. Partnering rather than building is generally the sounder approach for entrants seeking registry or verification credibility, since building trust from zero takes years that most venture-backed timelines cannot accommodate, whereas partnering with an established registry accelerates market access considerably. Regulatory strategy matters enormously here:

> entrants that engage early with standard-setting bodies and regulators to shape methodology requirements gain durable influence over the rules that will govern their eventual competitors

Incumbent strategy divides between defending existing positions and expanding into adjacent stages of the value chain. Defensive incumbents should deepen data and integration moats, making their platforms increasingly difficult to displace through accumulated historical baselines and workflow embedding within customer finance functions. Expansionary incumbents, particularly well-capitalized software vendors, are increasingly moving into credit brokerage and removal offtake facilitation, seeking to capture value across the full customer relationship rather than ceding downstream transaction revenue to specialized competitors. Both strategies share a common thread:

> the winners over the next decade will be organizations that treat carbon data integrity as a core competitive asset rather than a compliance cost to be minimized

Caselet: Climeworks and the commercial reality of direct air capture

Climeworks, a Swiss company founded in 2009 by two mechanical engineering graduates from ETH Zurich, offers a useful window into the economics and challenges facing engineered carbon removal specifically. The company built its reputation on direct air capture technology, which uses large fan-driven collector units to pull ambient air through a filter material that binds carbon dioxide, then heats the filter to release a concentrated stream of carbon dioxide for permanent underground storage. Climeworks opened its first commercial-scale facility, Orca, in Iceland in 2021, followed by a larger facility, Mammoth, designed to remove significantly more carbon dioxide annually, taking advantage of Iceland's abundant geothermal energy and favorable basalt rock geology that permits mineralization storage, where injected carbon dioxide reacts with rock to form stable minerals within a few years.

The company's business model illustrates the offtake-driven economics typical of removal technology. Rather than selling into spot voluntary carbon markets, Climeworks secures multi-year forward purchase agreements with corporate buyers, including companies such as Microsoft, that commit to purchasing a specified volume of removal credits at a fixed price ahead of facility construction or expansion. This structure functions similarly to power purchase agreements in renewable energy, giving the developer revenue visibility needed to justify capital investment while giving buyers early access to scarce, high-integrity removal supply and a hedge against future price increases as demand outstrips capacity. Microsoft's climate team has been among the most active corporate purchasers of engineered removal credits generally, reflecting a broader pattern where technology companies with substantial balance sheet capacity and public net-zero commitments are willing to pay premium prices for durability that nature-based credits cannot match.

Climeworks' cost trajectory also demonstrates the central economic challenge facing the entire engineered removal segment. Direct air capture costs have historically run into the hundreds of dollars per tonne, dramatically above nature-based alternatives that can cost a fraction of that amount, meaning engineered removal has depended heavily on buyers willing to pay for permanence and measurement certainty rather than pursuing lowest-cost abatement. The company has stated ambitions to reduce costs substantially over the coming years through larger facility scale, modular manufacturing and process efficiency improvements, following a cost curve logic similar to what solar and battery manufacturing experienced over the past two decades, though direct air capture remains earlier in that maturation process and its ultimate cost floor is not yet proven at commercial scale.

Climeworks also illustrates the operational realities of scaling physical infrastructure in a young industry. The company has faced questions about whether its actual annual removal volumes have kept pace with its stated capacity targets, a challenge common across early-stage physical infrastructure businesses where commissioning new facilities involves technical debugging periods longer than initial projections suggested. This gap between announced capacity and delivered removal has become a recurring theme across the direct air capture sector broadly, reinforcing why sophisticated corporate buyers increasingly demand verified, delivered-tonne contracts rather than paying purely on projected capacity. The company's continued ability to raise substantial private capital, alongside government support through mechanisms like the U.S. Department of Energy's direct air capture hubs program, suggests investors remain convinced of the long-term thesis even as near-term delivery execution remains the primary operational risk facing the business and the broader

engineered removal segment it represents.

The Climeworks case demonstrates several structural features of removal technology economics discussed throughout this analysis: the offtake-driven revenue model resembling project finance rather than product sales, the premium pricing durable removal commands over nature-based alternatives, the geographic advantages of favorable energy and geology and the execution risk inherent in scaling novel physical infrastructure. It also demonstrates why corporate buyer sophistication, exemplified by companies like Microsoft demanding delivered rather than merely contracted tonnes, has become the primary quality-control mechanism disciplining this segment of the industry, arguably more effective than any single regulatory standard imposed to date.

- 1carbon markets reaching new scale and maturity
- 2how the Corporate Sustainability Reporting Directive raises data quality bars
- 3direct air capture cost trajectory toward net zero
- 4EU ETS price trajectory and reform outlook
- 5global expansion of mandatory carbon disclosure rules

Summary

Carbon management sits at the intersection of regulation, finance and industrial engineering, converting a physical externality into a tradable, auditable corporate obligation. Revenue concentrates in three places: software that renders emissions data investment-grade, registries and verifiers that certify legitimacy and removal developers that control durable, physically verifiable supply. Compliance markets, not voluntary ones, now drive the economics, with the European Union Emissions Trading System setting the reference price and the Carbon Border Adjustment Mechanism extending its reach globally. The strategic levers that matter are vertical integration between measurement and transaction, geographic positioning ahead of new compliance regimes and disciplined selection of removal technologies with defensible permanence claims. Incumbents that treat carbon data as core financial infrastructure, rather than a sustainability add-on, will capture the durable share of this industry's growth.