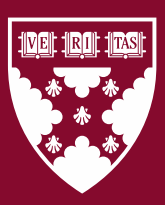
Working Paper 23-050

# Accounting for carbon offsets – Establishing the foundation for carbon-trading markets

Robert S. Kaplan
Karthik Ramanna
Marc Roston



Harvard Business School

**BSG Working Paper Series**

Providing access to the latest
policy-relevant research

# ACCOUNTING FOR CARBON OFFSETS – ESTABLISHING THE FOUNDATION FOR CARBON-TRADING MARKETS

BSG-WP-2023/051

FEBRUARY 2023

**Robert S. Kaplan**, Harvard Business School

**Karthik Ramanna**, University of Oxford Blavatnik School of Government

**Marc Roston**, Steyer-Taylor Center at Stanford Law School

Stanford | Sustainable Finance Initiative
*Precourt Institute for Energy*

FEBRUARY 2023

# Accounting for carbon offsets – Establishing the foundation for carbon-trading markets

*Working Paper*

**Robert S. Kaplan**
Harvard Business School

**Karthik Ramanna**
University of Oxford Blavatnik School of Government

**Marc Roston**
Steyer-Taylor Center at Stanford Law School

# Accounting for carbon offsets – Establishing the foundation for carbon-trading markets

*Robert S. Kaplan*
(Harvard Business School)

*Karthik Ramanna*
(University of Oxford Blavatnik School of Government)

*Marc Roston*
(Steyer-Taylor Center at Stanford Law School)

This draft: 13 February 2023
(Working draft, comments welcome: ramanna@alum.mit.edu)

*Abstract:*

Tackling climate change requires not only reducing GHG emissions but also removing GHG from the atmosphere. Carbon-offset producers purport to provide such removals. But existing carbon-offset markets have been criticized for poor measurement practices and inadequate controls, resulting in transaction of products that do not materially sequester carbon. To address these challenges, we apply basic financial-accounting principles to develop an accurate and auditable framework for offset accounting. The offset-accounting principles in this paper complement and extend the E-liability method of accounting for GHG emissions. Together, rigorous accounting for emissions and offsets can improve and expand markets for impactful decarbonization.

* * *

Emissions of $CO_2$ and other greenhouse gas (GHG) are widely acknowledged to be the leading cause of anthropogenic climate change.[1] Three principal sources account for the great majority of human-created GHG emissions: burning fossil fuels for energy; industrial chemical processes not related to energy production; and agriculture.[2] We may eventually eliminate the burning of fossil fuels to produce energy, but we do not have a realistic path to run our society without agricultural or industrial chemical processes. Any plausible strategy for addressing climate change must, therefore, include removing GHG emissions from the atmosphere.

Carbon offset producers purport to provide such removals through both natural processes, such as photosynthesis, and technological processes that capture and permanently sequester existing atmospheric GHG. Corporations, non-profits, and government entities that want to achieve NetZero goals, but have limited options for removing GHG themselves, will need to purchase carbon offsets from such producers.

Markets that enable the purchase and sale of carbon offsets can supply an essential source of capital for the efficient reduction of atmospheric and oceanic carbon. Such markets help to finance entities that have a comparative advantage in capturing and storing the highest quantity of GHG at low cost. Markets for agricultural commodities have existed and thrived for millennia.[3] Modern capital-market instruments, based on proven accounting principles, have also evolved over centuries to allow buyers and sellers, living in diverse legal regimes, to trade in financial securities. Accounting, auditing, and regulatory processes enable hedgers and speculators to transact in corn futures at the Chicago Board of Trade, equity securities listed on the NYSE, and S&P500 Index futures at the CME. Generations of enforcement actions and case law lower the risks of market failures for these diverse transactions.

Existing carbon-offset markets, however, have been heavily criticized, by revelations that the great majority of products transacted on them do not materially remove GHG from the atmosphere.[4] A market transaction for a valid carbon offset involves non-trivial measurement problems. For instance: How to match the quantity of carbon captured over the productive lifetime of a forest to the quantity of carbon emitted in the current period? Is a kg of carbon captured and stored in trees equivalent to a kg of carbon stored in rocks or agricultural soil? Are the kgs of carbon captured in a forest or underground sequestered for the same duration as the kgs emitted into the atmosphere?

Beyond solving these measurement issues, carbon markets require infrastructure to avoid misrepresentation and fraud. Weaknesses in offset markets create moral-hazard problems: Purchasing entities can become less diligent in reducing their controllable (cradle-to-gate) GHG emissions, while selling entities can become less diligent in ensuring that contracted quantities of GHG emissions remain sequestered during the contract's life. Both potential failures, if not mitigated, will cause carbon-offset trades to increase, not decrease, the GHG quantities entering the atmosphere.

Given the urgent need to reduce anthropogenic climate change, we do not have decades, let alone centuries, to solve the measurement, regulation, and enforcement issues for carbon offset trading markets. Fortunately, we can adapt and apply what we have already learned about accounting, auditing, and regulation of commodity markets to carbon-offset markets. Most importantly, we must ensure that carbon offset trading delivers on its carbon removal promises without creating hidden or unexpected off-balance sheet risks for market participants or the governments overseeing these markets.

In this paper, we apply fundamental financial-accounting principles and practices to develop an accurate and auditable framework for offset accounting. The offset-accounting principles in this paper complement and extend the E-liability method of carbon accounting developed by two of us (Kaplan and Ramanna).[5,a] E-liability carbon accounting enables companies (and other entities) to measure, in real-time, the total cradle-to-gate GHG emissions incurred to produce their products and services. The emissions get capitalized on the entity's E-liability

[a] The third author (Roston) has applied the E-liability method to measure the emissions from electricity use in an unpublished manuscript.

balance sheet and discharged as the entity sells and transfers its outputs to customers, as in a value-added-tax system. Just as the E-liability method rigorously accounts for *emissions*, the principles in this paper allow for accurate and verifiable accounting of *offsets*.

We present these principles as a necessary starting point for more-formal carbon accounting standards. Such standards, if widely adopted, will enable offset market practices to improve and expand in support of impactful decarbonization.

Adoption of rigorous offset-accounting principles will also enable existing carbon-offset assets, such as forests of trees and mangroves, either on public land or without clear ownership rights to be capitalized and assigned to a governmental or other entity. In this way, accountability for maintaining them can be assigned, including, perhaps, with penalties levied when existing carbon capturing assets are degraded or destroyed.

## Clarifying what is an offset

Before proceeding, we must remove one source of ambiguity in existing offset contracts. Climate actors generally describe two completely different concepts − *removals* and *avoidance* − as "offsets."[6] Removal offsets are created by a range of activities from photosynthesis in forests, to direct air capture and mineralization technology. These approaches remove physical quantity of existing carbon from the atmosphere.[b] Removal offsets can be characterized by the *quantity* of gas removed and the *duration* for which it remains captured.

Avoidance offsets arise from modifying or replacing an existing high-emissions process with a lower- or zero-emissions one to prevent some *prospective* quantity of GHG from entering the atmosphere. Examples of avoidance offsets include substituting fossil fuels with renewable fuels in a new supply agreement or replacing a high-emissions material with a low-emissions one, such as making steel or paper from recycled rather than virgin materials.

While a removal offset is measured relative to an objective baseline of zero, the status quo under which no existing carbon would otherwise be captured, an avoidance offset is measured against a hypothetical counterfactual of actions. For this paper, we develop accounting principles only for removal offsets, since the primary goal for offsets should be to remove GHG actually in the atmosphere, not to speculate on potential emissions avoided. Any reduction of prospective emissions will be automatically measured under the E-liability principles when those reductions are in fact realized (see SIDEBAR).

SIDEBAR

Currently, some offset trading markets monetize avoidance offsets and sell them to third parties striving to meet NetZero targets. For example, a U.S. high-tech company can today buy an offset contract where the underlying emissions reduction will come from paying a low-income resident of a developing nation to replace a charcoal-burning stove with one that uses a

[b] Throughout the paper, we refer to carbon or $CO_2$ as a catch-all for GHG.

low-carbon energy source. A correct carbon-accounting procedure would attribute the carbon reduction to the resident who switches to the low-carbon stove. Allowing the high-tech paying entity to also claim credit for the reduction double counts the quantity of GHG not going into the atmosphere. Good intentions are different from good accounting: how the paying entity obtains credit for its good deed requires its own measurement and disclosure treatment, but not a treatment that violates sound accounting principles for actual carbon removals. Achieving NetZero status by netting real carbon emissions against some hypothetical amount based on a counterfactual does nothing to reduce the quantity of carbon actually in the atmosphere.

## Offset accounting principles

We begin by establishing the basic accounting principles relevant to a bilateral agreement between a producer of carbon removal offsets and an offset purchaser. We subsequently introduce the additional features required when intermediaries create an active exchange-market that expands transaction opportunities for offset sellers and buyers.

The first principle motivates the creation of legitimate carbon offsets.

**Offset Accounting Principle 1: Only removal offsets can be used to reduce an organization's E-liabilities.**

OAP 1 states that a company can offset its acquired and produced emissions[c] only through its own removal activities or by purchasing removal offsets produced by others. Put differently, E-liabilities cannot be reduced by avoidance offsets. The principle follows directly from a frequently overlooked carbon-accounting truth that the only emissions entering the atmosphere are direct emissions or what the Greenhouse Gas Protocol labels as Scope 1. The principle indicates that a valid "offset" to the Scope1 emissions produced or purchased by an entity must actually remove (Scope 1) GHG of the same quantity and for the same duration that the gas would otherwise have remained in the atmosphere.

The principle recognizes that if entities cannot receive credit for legitimate carbon removals, they have no incentive to spend money to either capture and sequester their own and purchased Scope 1 emissions, or to compensate other more-efficient entities to perform carbon-removal activities. Absent the ability to use removal offsets to reduce E-liabilities, the market will undersupply carbon removals.

Currently the GHG Protocol, the dominant global standard for carbon accounting, does not substantively distinguish between removal and avoidance offsets, and so does not recommend the netting of any offsets against emissions.[7] Their treatment of actual removals and hypothetical avoidance as equivalent mirrors the flaw in the Protocol's current Scope 3 Standard that fails to distinguish between measurable *incurred* reductions

[c] Readers unfamiliar with E-liabilities might be more comfortable with the description "Scope 1, Scope 2 and upstream Scope 3 emissions" rather than "acquired and produced emissions" defined by E-liabilities.

in an entity's supply-chain emissions from hypothetical (prospective) reductions in downstream emissions.

**Offset Accounting Principle 2: Removal offsets are tradeable; E-liabilities are not tradeable.**

More than 200 years ago, economist David Ricardo introduced the principle of *comparative advantage*, one that motivates the rationale for allowing trading of carbon offsets. Removal offsets are best produced by their lowest-cost providers, not by requiring that entities be able to offset their incurred E-liabilities only by conducting their own offset activities. We should treat carbon removals exactly as every other purchased service: obtain them from high-value, efficient suppliers. Enabling the trading of carbon offsets increases the supply of capital to efficient offset producers, including those with limited access to financial capital markets, such as cooperatives in indigenous communities.

While OAP 2 allows firms to potentially reduce their E-liability balances through purchased removal offsets, it also states that E-liabilities should not be tradeable separately from the underlying inventories to which they are attached. Allowing a company to trade away its E-liabilities would undermine supply-chain decarbonization by allowing entities to sell their E-liability balances to unaccountable shell entities domiciled in unregulated jurisdictions. A company "defeases" its acquired E-liabilities only by having customers willing to transfer them onto their E-liability books when they purchase the company's products. A company can lower the E-liability it transfers to customers only by (i) lowering its direct emissions, (ii) lowering the direct emissions of its suppliers, and (iii) compensating another entity to remove and sequester atmospheric emissions on its behalf.

*Recognition, trading, and netting offset assets:*

We now turn to the accounting principles for determining when an offset producer can recognize captured carbon as an (E-)asset, when such assets can be traded, and when they can be used to net out E-liabilities. We use two stylized example projects to motivate these accounting principles. In the first, a project manager plants a new (virgin) forest on barren land and sells the forest's sequestered carbon to a buyer seeking to offset its E-liabilities. We assume a simple growth model where the virgin forest requires 10 years of growth before it begins to capture and sequester carbon in significant quantities. For the next 20 years the forest absorbs carbon at a predictable rate. Fully grown trees, after 30 years, do not capture net new carbon but continue to sequester previously captured carbon for 20 additional years.

In the second example, a carbon-capture-and-sequestration (CCS) technology firm captures atmospheric carbon and sequesters high pressure gas and water with reactive rock formations that mineralizes (turns to rock) the captured carbon at a constant rate for the next five years. Once mineralized, the underground carbon cannot escape.[d]

[d] Both examples simplify current market practice, which has multiple types of intermediaries, certification agents, and registries. We describe key accounting principles essential to market function, independent of current practices, much of which violates the accounting principles proposed in this paper.

The producer of the removals – the forest project manager or the CCS firm – owns the rights to the future carbon capture. The producer can recognize these offset rights as an E-asset by using accounting standards based on both the *likelihood* that carbon has or will be captured and the *measurability* of the quantity and timing of the carbon capture.[8] In our virgin forest example, the project manager establishes the available tons for a given project (the offset quantity) based on estimated annual tree growth during years 11 through 30. The likelihood and measurability of the captured quantity will be based on the project's financial resources, historical performance, scientific models, and data analytics. These estimates of the carbon to be captured over the 20-year productive life of the forest are uncertain because of both impairment possibilities caused by disease, pests, wildfires, and other hazards that reduce quantity or duration of capture, and accretions due to unexpectedly favorable conditions that increase the carbon captured per year and the duration of the forest's productive life. (See below *Impairments and Accretions.*)

We propose the following recognition principle:

**Offset Accounting Principle 3.1: Rights to carbon removals shall be recognized as an E-asset, and traded as a removal offset, when the timing and magnitude of the offsets are both estimable and probable.[e]**

A newly planted forest will fail to qualify for trading under OAP 3.1 when its lifetime carbon removals are not reasonably estimable or probable. For example, management weaknesses, inadequate funding, uncertainty around location or species selection, and natural or human-caused risks may cause a project to fail to qualify as an offset asset.

Applying OAP 3.1 to the CCS firm, its carbon capture would be recognized as an asset when the device capable of capturing the carbon reliably functions and has known storage capacity. At that point, the quantity of carbon it can sequester is probable and estimable.

If an offset qualifies for asset recognition, based on estimable and probable carbon, it is also considered *tradeable* (i.e., can be sold to an unrelated party). Accordingly, we must introduce the notion of alienability risk, which is the risk that the sale of the offset fundamentally changes the probability that the carbon-removal asset will persist. For example, the forest project manager may have little incentive to maintain long-term performance once the offset is off its books. So, for the probable and estimable criteria to be met, there must be no reasonable expectation that the offset will reverse as a consequence of alienation (sale).[f] In well-functioning offset markets, this provision can be maintained through standard performance contracts (discussed later).

To determine when a company can use a purchased offset asset to reduce its E-liability balance – a process known as "netting" – we require a separate accounting principle. We develop this accounting principle from the accounting standard that requires a company to

[e] Probable in financial-accounting parlance usually means >50%. Whether E-accounting standard-setters define "probable" as anything >50% or at some higher threshold (say >90%) is an empirical matter, but conceptually, probable should be somewhere between 50% and 100%.

[f] The provision is akin to standards in financial accounting that allow only some intangibles, such as patents, to be separably recognized as an asset, whereas others, such as "assembled workforce" to be left as unidentified.

recognize revenue from a sale only when it is both *realizable* and *earned*. A selling company realizes revenue when it receives cash, a cash-equivalent asset, such as a marketable security, or a highly likely commitment to pay cash in the future (i.e., accounts receivable). The company "earns" the revenue when it delivers its product or service. A theatre may receive cash from ticket sales in advance of a performance (satisfying the "realizable" criterion) but can recognize the cash receipt as revenue only after delivering the performance (satisfying the "earned" criterion.)

By analogy, when the forest manager in our stylized example meets the offset asset-recognition criteria, it has also met the "realizable" criterion (i.e., if an offset is estimable and probable, it is realizable). This timing could be in year-0 for a high-quality provider or sometime later for a less-reputable manager or a project with high initial uncertainty for quantity and duration of the carbon capture capabilities. But, regardless of when the realizability criterion is satisfied, the forest manager does not "earn" the carbon offset until year 10 when carbon begins to be captured. When both earned and realizable criteria are met, the offset asset can be used to net (or reduce) an E-liability.[g]

If the forest manager sells the offset asset in advance of the ten years, then the company that buys it will likewise have wait to meet the earned criterion before netting the offset against its E-liability. In effect, the offset asset can sit on the buyer's books until the time (year-10) when the forest begins to capture non-trivial quantities of carbon from the atmosphere. Each year, after year-10, the forest project manager should provide the buyer with an audited report of the quantity of carbon removed by the forest. Thereafter, the buyer can add (credit) the "earned" quantity to a contra-asset account "accumulated offsets netted" and subtract the same amount (debit) from its E-liability balance. We advocate the use of this contra-asset account (analogous to an accumulated depreciation account for a tangible asset) since we want to retain, on the books, the original quantity of the purchased offset should impairments occur in future periods (a topic to be discussed shortly).

The higher standard of "earned" for extinguishing E-liabilities (relative to "realizable" for recognition of E-assets) is based on the economic significance of netting. Revenue recognition by firms triggers an expectation among shareholders for dividends. Similarly, reducing a company's E-liabilities communicates to customers, shareholders, and regulators that the firm's products (its inputs and operations) generated less carbon than its peers. New customer sales and new investments can be made based on such claimed efficiencies. Extinguishing an E-liability, therefore, should meet a higher accounting threshold to be meaningful and difficult-to-bias by management's subjective judgments. This reasoning leads to the following principle for the timing of using offsets to reduce a company's E-liability balance.

**Offset Accounting Principle 3.2**: **A company shall "net" a given quantity of purchased offset against its E-liability account only when that quantity of GHG has been removed from the atmosphere and indefinitely sequestered.**

[g] Delivery in the context of carbon offsets deviates substantially from the traditional concept of delivery in either commodities or financial markets. Captured carbon remains at the site of capture and must remain there to avoid impairment.

The term "indefinitely" in OAP 3.2 additionally recognizes a particularly challenging aspect of netting due to the *duration* of emission liabilities. Estimates from NASA suggest that manmade carbon-emissions "naturally" last at least 300 years in the atmosphere and perhaps as long as 1000 years, a very long duration by the standards of commercial contracts.[9] In principle, the condition for netting is that the duration of an earned removal offset will equal or exceed the duration of the E-liability. In practice, the term indefinite represents this principle. "Indefinite" does not mean "infinite" but rather that the duration of the sequestration has no apparent "definite" end, based on technology, legal restrictions, or regulatory oversight.

Our stylized forest offset project, which holds carbon for at most 40 years from first "earning" it, cannot on its own extinguish a centuries-long E-liability. Netting thus requires a credible assurance that the offset buyer, through the particular project, project manager, or an alternative provider, has the financial capacity to repeat the process so that the carbon can remain sequestered over multiple forest-generation cycles.[10] (For example, the firm could provide very long duration funds in an endowment- or pension-fund type structure.)

Applying OAP 3.2 to the CCS technology project is simpler: netting would be allowed once the carbon has been captured and indefinitely sequestered. The latter would be when mineralization has occurred (five years) or sooner if mineralization is near-certain.

*Impairments and accretions:*

A firm in the offset business sells an asset with impairment risk. In the CCS example, impairment could occur when seismic activity released the high-pressure stored carbon gases prior to mineralization. In the forest project, impairment risk generally rises over time as more accumulated tree carbon is subject to fire, disease, pestilence, or mismanagement – various forms of catastrophic loss – in addition to the risk that the actual amount of carbon captured falls short against tree growth expectations.

Accounting for such shortfalls can follow typical asset impairment criteria. Conversely, and unlike typical assets, a forest might grow larger and faster than expected. Under these conditions, the forest project will be accretive as it captures and sequesters more carbon than expected. Mineralization projects, in contrast, should not realize unexpected accretion.

**Offset Accounting Principle 4: An offset asset shall be impaired or accreted based on the discovery of new information about the quantity and duration of actual carbon sequestration.**

Impairment risk underlies our rationale for maintaining the gross value of purchased removal offsets on the company's E-accounting books, with "netted" offsets recorded in a contra-asset account. With that approach, when an offset has been impaired, the impairment quantity is booked against the offset asset account, analogous to claw-back provisions in insurance contracts, increasing the net balance in the firm's E-liability account, and, correspondingly, increasing the quantity of E-liability to be allocated to the firm's outputs in current and future periods. This accounting treatment leans against a company's incentive to reduce the E-liabilities it transfers to customers by being overly optimistic about

the value of the "nettable" offsets it purchases. Consistent overstatements of offset assets will eventually have to be reversed as actual quantities of carbon removals are revealed. The potential for impairments also provides an incentive for companies to purchase from reliable offset producers, those that consistently deliver on the expected quantity and duration of sequestered carbon.[h]

Since impairments and accretions might occur at any time during the lifetime of the offset asset, all offset contracts need periodic audits to determine whether an impairment or accretion has occurred, as well as to attest to the magnitude of any change. Returning to our examples, forestry offsets will likely require more ongoing audit activity than CCS projects.

*Unaccounted carbon:*

Substantial natural carbon stocks exist globally for which no accounting exists. Examples of such stocks are public and private forest lands and peatlands. Such unrecorded natural assets have significant implications for national and global carbon ledgers. In our context, the offsets embedded in these carbon stocks have never been formally capitalized by any entity, private or public. Hence, no entity is currently accountable should the offsets be reversed, such as by illegal deforestation of mature forests by local farmers, or climatic changes draining peatlands. Full application of the offset principles would have the implicit owner of the offset (i.e., the private landowner or government of the jurisdiction containing the mature forest in which the degradation or destruction occurs) recognize the corresponding E-liability from the carbon released into the atmosphere by the illegal or unexpected activity. This accounting treatment, while seemingly unfair to that entity, provides an incentive for it to capitalize its currently unrecognized offsets, monitor and manage them for continued carbon sequestration, and to legally pursue remedies against those causing their destruction.

As a practical matter, most uncapitalized natural assets (public or private) are already "netted" (against past emissions) and should not, after capitalization, be sold to net against future emissions (as this would constitute double counting).

## Offsets in practice

We next turn to carbon-offset market practice to highlight the ways in which current activity deviates materially from our principles.

Offsets trade for a variety of reasons. Most offsets are purchased by firms to reduce their reported net emissions and demonstrate that they are on some trajectory to NetZero status. Companies also use offsets to introduce additional supply in government-run cap-and-trade systems by claiming the captured carbon in the offset creates the right to emit beyond the government cap. In all cases, the offset is a certificate issued by one of several private registries pointing to sequestered carbon at particular projects.

[h] Many discussions of offset *quality* use a subjective notion of "high quality." We more precisely focus the concept of offset quality on reliability of quantity and duration of that quantity.

A typical offset project, like our stylized forest project, begins as a firm that owns or acquires land on which managers wish to sequester carbon. Managers obtain title to the land,[i] establish a development plan that may include various service providers to plant, support, and maintain the development, estimate the tree growth expectations, identify methods to measure the carbon over time, etc.

At this point, the project managers engage with the various certification agencies or "registries." The certification agencies negotiate with the project managers to reach an agreement about the tonnage the project creates under competing standards. Importantly, the project never sells (transfers title to) any carbon. The certification agency agrees to issue certificates that point to the identified tonnage of the project. The project manager represents to the certificate agency that manager has followed the certification agency rules, and that they will not register with another agency. The substantive penalties to the project manager for any misrepresentation at this stage are unclear.

The project managers, brokers, or other intermediaries then sell the certificates issued by the registry, passing payments to the project managers to fund operations. The registry acts like a transfer agent in securities markets, keeping records of certificate ownership. But the registry does not record ownership of carbon; rather, the certificate represents the holder's entitlement to some nominal claim to carbon against the issuing certification agent, although the agreement typically excludes any substantive penalties for the registry. Finally, the certificate buyer has no direct legal relationship with the actual offset project to ensure its ongoing delivery.

In most cases, carbon certificate buyers "retire" the certificates shortly after purchase. In this process, the buyer returns the certificate to the registry with instructions to remove the certificate from the marketplace, not to be resold. By this instruction, the buyer claims to permanently remove the carbon from the atmosphere.

Obviously, a carbon project with material risk of impairment cannot meet any intuitive notion of duration consistent with OAP 3.2. Under current practice, registries attempt to protect against impairment by two methods. First, registries require that offset project managers represent they have the capacity to replace or refund the value of offsets should things go wrong. This requirement has limited value: buyers have no long-term reason to demand replacement because they retire the certificates immediately after purchase, which, in turn, implies project managers have no incentive to maintain any capital to cover claims. Moreover, depending on revenue recognition methods for the project, such claims could arrive long after revenues (and profits) have been distributed to project managers. (The tripartite relationship between the registry, the project manager, and the buyer means that there is no "earned" criterion to be satisfied by the project manager vis-à-vis the buyer.) Finally, the complex, cross border claims necessary to litigate such issues would be infeasible for the (poorly capitalized, not-for-profit) registries. Simply put: This project

[i] In practice, land title in offset projects can be ambiguous, as the land is public but controlled by indigenous tribes. Moreover, the title is certainly risky on the time scale of carbon sequestration.

manager warranty is about as good as a jewelry store that advertises a lifetime refund policy that it cannot possibly underwrite.

The registry's second protection method depends on their holding back some quantity of carbon project certificates that could have been serialized and distributed to the marketplace, but instead remains available to substitute for impaired projects. This "buffer pool" provides limited capacity to absorb impairments. The buffer pool looks and functions like an insurance company surplus. However, this insurance company has limited transparency, lacks independent evaluation of claims-paying ability, regulatory oversight, and ability to raise additional capital.

As a result, if an emitting firm had an actual E-liability on its E-balance sheet, we are unaware of any offset contracts currently available on the market that could provide an adequate netting asset under the offset accounting principles described earlier.

While we have described a somewhat realistic version of our forestry stylized model, the CCS example we introduced here is almost theoretical. Estimates indicate the mineralization transaction today may cost more than $250/ton of $CO_2e$, versus a few dollars for forestry. Given this price differential, and the absence of meaningful accounting controls, virtually no buyers have incentives to pay the far higher price for direct air capture and mineralization. Why spend the money for a truly permanent offset when you don't have a balance sheet E-liability to which you are held to account?

## Implications for policy and practice

Many climate-driven policies and practices fall short because we do not have adequate principles to account for carbon. The principles we describe form a basis on which we can build additional rules to understand and evaluate climate action. Here, we identify several paths where accurate accounting methods will better inform policy and practice, and lead toward more effective climate action.

*Alienability:*

As discussed above, alienability risk demands that an offset sale transaction itself not increase the risk of project impairment. Under current practice, certificate retirement means the buyer has no ongoing obligation to ensure or even monitor for impairments. The certification agency agreement precludes any liability for impairment on the agency's part. A proper application of asset recognition principles will mean that offset providers should have robust provisions in place to ensure ongoing offset maintenance. (See below: *Insurance and counterparty enhancement*.)

*Emissions liability management:*

Roston, Seiger and Heller (2023) propose *emissions liability management* (ELM) that obligates a firm to remove its atmospheric emissions as quantified by incurred E-Liabilities each year. The firm may accomplish this through a diversified portfolio of various removal offsets that vary with impairment or accretion risk, duration, technology, and price.

For example, a firm using nature-based offsets might hold an endowment-like portfolio of assets to fund repeated 50-year offset transactions indefinitely into the future, subject to actuarially sound capital requirements similar to an insurance company. Or, a single 50-year nature-based offset transaction could pair with a 50-year forward transaction for mineralization from a counterparty credibly able to deliver the future transaction.

*NetZero pledges and claims:*

NetZero pledges and claims abound. No standards exist to define let alone verify such claims. At best, current practice says a firm calculates its emissions by some chosen method and buys offsets that it immediately retires to match its preferred emissions count. ELM, built upon E-Liabilities and the offset accounting principles presented here, provides a systematic basis for investors or customers to evaluate NetZero pledges. Firms would provide "true and fair" accounting for carbon emissions and carbon removal offsets, including carbon flow statements and carbon balance sheets. The firm would qualify as NetZero only if its audited carbon liabilities are matched by nettable (realized and earned) carbon assets. A similar logic would apply to NetZero products.

*Insurance and counterparty enhancement:*

In the previous section, we described counterparty failures in offset markets. We have described why a carbon removal offset contract requires long-duration measurement, reporting, and verification (MRV). On the time scale of atmospheric carbon, most removals, particularly nature-based removals, are perishable. The buyer relies on a third party to maintain the offset because the buyer cannot typically take physical delivery of the carbon from any given project. We consider several approaches to reducing performance risk by carbon counterparties.

First, carbon projects could follow the structure of private equity investments in which a general partner (GP) operates the fund on behalf of limited partners (LPs). The GP earns compensation only after LPs receive specified returns. The GP also maintains partnership operations, including auditing, asset valuation, and reporting, but only for the typical 10-year life of the private equity fund.

Carbon projects might adapt GP/LP structures by having the GP provide subordinate capital beyond standard structures that ensure performance over longer periods. Alternatively, GP/LP structures might provide fixed, shorter duration carbon removals that re-capitalize after a fixed number of years.

A second approach might use insurance or performance bond structures where a larger, better capitalized and more diversified entity (e.g., an insurance company, or other financial institution) guarantees performance for carbon offset projects.

Finally, we might imagine that the registry agents transform into reciprocal or mutual insurers. Reciprocals and mutuals are insurance companies operated by and for the benefit of the insureds. A removal project developer might seek certification from an agency

prepared to guarantee the project's success over the long term. Different registry/insurers might specialize in particular MRV methods.

Many other strategies may emerge. In each case, carbon markets will need to develop securities designs, additional specialized accounting details, and regulatory oversight to maintain counterparty integrity. The OAPs introduced here offer a glimpse of the developments needed for offset markets to actually help in reducing atmospheric carbon.

## Conclusion

Our proposed offset accounting principles will bring rigor and order to the "wild west" of removal offset trading, thereby complementing the E-liability method. While we advocate the E-Liability method for full-scope accounting and auditing of corporate GHG emissions, we acknowledge that others may still prefer a softer, disclosure-based approach such as that in the current version of the GHG Protocol. These disclosure-based approaches are arguably easier to comply with, but we note that the world can never achieve its climate goals if we do not quickly embrace an *accounting* method that records corporate carbon emissions on balance sheets.

---

[1] See, for example, https://royalsociety.org/topics-policy/projects/climate-change-evidence-causes/basics-of-climate-change/.
[2] See, for example, https://ourworldindata.org/emissions-by-sector.
[3] See, for example, Hillel Gamoran, "Talmudic Controls on the Purchase of Futures," *The Jewish Quarterly Review* 1973, https://doi.org/10.2307/1453577.
[4] See, for example, recent pieces in *The Economist*, the *Financial Times*, and *The Guardian* at https://www.economist.com/finance-and-economics/2022/05/19/offset-markets-struggle-in-the-face-of-surging-commodity-prices and https://www.ft.com/content/9b02fcf7-9e04-4b71-ad14-251552d5a78e and https://www.theguardian.com/environment/2023/jan/18/revealed-forest-carbon-offsets-biggest-provider-worthless-verra-aoe, respectively.
[5] See Robert Kaplan and Karthik Ramanna, "Accounting for Climate Change," *Harvard Business Review* 2021, https://hbr.org/2021/11/accounting-for-climate-change.
[6] See Stephen Comello, Julia Reichelstein, and Stefan Reichelstein, "Transparency and Accountability on the Path to Net-Zero," Working paper 2023.
[7] See https://ghgprotocol.org/estimating-and-reporting-avoided-emissions.
[8] See, for example, FASB Concept Statement No. 5, https://fasb.org/page/PageContent?pageId=/standards/concepts-statements.html.
[9] See, for example, https://climate.nasa.gov/news/2915/the-atmosphere-getting-a-handle-on-carbon-dioxide/.
[10] See Marc Roston, Alicia Seiger, and Thomas Heller, "The Road to Climate Stability Runs through Emissions Liability Management," Working paper 2023.