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Recentering goals: A guide to CDR policymaking for a net-negative world

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Introduction

As global greenhouse gas (GHG) emissions continue to rise, the need to decarbonize only gets more urgent. Carbon dioxide removal (CDR) is not a viable alternative to deep decarbonization.[1] However, it can play a niche, though vital, role in climate policy: it offers the opportunity to reach a net-negative future.[2] Realizing this potential requires an ambitious policy effort that combines deep decarbonization with thoughtful deployments of CDR.[3]

From the standpoint of the atmosphere, removing CO_2 does not differ from not emitting it in the first place. What distinguishes CDR from decarbonization — and justifies the substantial public investment it requires — are the roles it could play in the future. CDR can enable global net zero by counterbalancing residual emissions, allowing global temperatures to stabilize.[4] Beyond that point, it could drive net negativity and lower global temperatures.

This report begins with the premise that near-term policy choices must align with a coherent long-term vision of a net-negative world. Without this alignment, CDR will fail to achieve its potential as a climate intervention. Here, we examine the implications of designing CDR policy with a net-negative future in mind. We distill these implications into three tasks:

1. Identifying CDR activities that merit policy support.
2. Designing policy mechanisms that develop the capacity of these activities to play their most valuable long-term roles.
3. Setting standards that allow particular policies to function effectively.

The goal of this report is to help policymakers more clearly conceptualize the role of CDR in society, and make near-term decisions that set the stage for a net-negative future. Each section introduces a few core ideas, outlines a way to apply them in the policymaking process, and provides an example of what that might look like in practice.

While we present these tasks sequentially, we recognize that policymaking is not a neat process. It is often nonlinear, and different tasks can fall to different institutions. Furthermore, good policymaking is always iterative. Regardless of the situation, we hope that this report can help connect discrete policy decisions to the overarching reasons that CDR policy is worth developing.

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1 Andrew Bergman & Anatoly Rinberg, "The case for carbon dioxide removal: From science to justice," *CDR Primer* (Jennifer Wilcox et al. eds., 2021).

2 IPCC, "Summary for policymarkers," *Climate Change 2021*, 29-30 (Masson-Delmotte et al. eds., 2021).

3 Emily Grubert & Shuchi Talati, "The distortionary effects of unconstrained for-profit carbon dioxide removal and the need for early governance intervention," 15 Carbon Management 1 (2024).

4 Myles Allen et al., "Geological net zero and the need for disaggregated accounting for carbon sinks," 638 Nature 343 (2025).

Section 0: Concepts

The following concepts provide the foundation for the discussion that follows. This section is both a primer and a reference, ensuring that all readers begin the report with a shared understanding.

Policymaking is the process of setting social goals and designing the mechanisms for achieving these goals. In this report, we reference two global climate goals:

- **Net-zero emissions**: The state in which the total removal of greenhouse gases from the atmosphere balances the total emissions entering the atmosphere.[5]

- **Net-negative emissions**: The state in which the total removal of greenhouse gases from the atmosphere exceeds the total emissions entering the atmosphere.[6]

For the purposes of this report, we assume that policy efforts should aim for a net-negative world.[7] This goal reflects a simple ethical intuition: we want to do everything we can to help repair the harm already done. Net negativity offers a pathway not only to stop adding to the problem, but to meaningfully reduce long-term climate risks, protect vulnerable communities who are the least responsible for causing climate change, and ease the burden of climate change on future generations.[8] In a net-negative world, greenhouse gas removals could play two roles:

- **Neutralization**: Balancing ongoing emissions to achieve net zero and stabilizing global temperatures.[9]

- **Drawdown**: Removing "legacy" emissions from the atmosphere and reducing global temperatures.[10]

In this report, we focus on carbon dioxide emissions and removals specifically, given the roughly linear relationship between cumulative CO_2 emissions and global

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5 "Concepts," *CDR Primer* (Jennifer Wilcox et al. eds., 2021).

6 *Id.*

7 Oliver Geden & Andy Reisinger, "Overshoot: Returning to 1.5°C requires net-negative emissions targets," 47 Stiftung Wissenschaft und Politik (Nov. 2025) ("This will require reframing 'net-zero' as a transitional stage towards net-negative GHG emissions rather than an endpoint, and developing policy instruments that are able to deliver this").

8 *See*, e.g., Olúfẹ́mi O. Táíwò, "An African case for carbon removal," Africa Is a Country (Sep. 29, 2020); Andreas Malm & Wim Carton, "Seize the means of carbon dioxide removal: The political economy of direct air capture," §8 (Mar. 2021).

9 Myles Allen et al., *supra*; IPCC, *supra* at 29.

10 IPCC, *supra* at 30. The distinction between "legacy" vs. "ongoing" emissions is an accounting distinction, rather than one about the physical makeup of the atmosphere. However, it is useful for understanding the different roles that CDR can play in climate policymaking. As we understand the concept, "legacy emissions" refers to anthropogenic greenhouse gas emissions that occur before the point of achieving net zero.

temperature change.[11] Recently, there have been disagreements about which real-world activities "count" as carbon dioxide removal (CDR).[12] For simplicity, we use the following inclusive definitions:

- **Carbon dioxide removal (CDR)**: The anthropogenic process of removing CO_2 from the atmosphere and storing it in geological, terrestrial, or ocean reservoirs, or in products.[13]

- **CDR activity**: Any activity that could theoretically contribute to carbon dioxide removal, even if it doesn't achieve CDR itself.

As we'll explore more in Section 1, not all CDR activities will contribute to either neutralization or drawdown. For example, some CDR activities rely on sectors whose emissions exceed the activities' removal capacity. Whether such CDR activities could ultimately contribute to drawdown depends on the extent to which these sectors can decarbonize. To capture this difference in potential future roles, we distinguish between:

- **Flexible CDR**: A CDR activity that is likely to contribute to drawdown.

- **Inflexible CDR**: A CDR activity that is likely to come hand-in-hand with sectoral emissions that will exceed the activity's removals. Because of this linkage, it is unlikely to contribute to drawdown, but may contribute to neutralization.

This report focuses on the public interventions necessary to develop different types of CDR so that they can deliver drawdown and neutralization in the future, ultimately enabling a net-negative world. Public policy can mean many things to different people; we use the following distinction throughout the report:

- **Policy mechanism**: A general type of policy approach (e.g., imposing an import tariff).

- **Policy**: A specific implementation of a policy mechanism (e.g., the U.S. Tariff Act of 1890).

Finally, the following analysis relies on identifying "residual emissions," which we define simply as:

- **Residual emissions**: emissions that remain in a net-zero or net-negative world.

Neutralization and residual emissions

How do we identify the sources of residual emissions? This is a fundamental question for CDR policymaking, and a topic of disagreement across the climate policy field. Since the concept of residual emissions plays a key role in this report, it merits a brief discussion. Definitions of residuals often involve the

11 Damon Matthews et al., "The proportionality of global warming to cumulative carbon emissions," 459 Nature, 829–832 (2009).

12 Freya Chay et al., "'What is CDR?' is the wrong question" CarbonPlan (Feb. 25, 2025).

13 "Concepts," *CDR Primer, supra.*

idea that certain emitting activities are both essential to the basic functioning of society and infeasible to decarbonize due to technical or economic constraints. Activities that meet these criteria will require CDR to offset their emissions in the medium to long term.[14] However, it is rarely clear how to determine what is "essential" and "infeasible," and who gets to decide.[15]

There is broad agreement that some emissions, such as the N_2O produced by at least some agricultural practices, will qualify as residuals.[16] However, aside from a handful of such examples, there isn't a standard conceptual understanding of either the categories of emissions that should qualify or the process for identifying them. As a starting point, identifying residual emissions will require scientific and engineering assessments of the feasibility of decarbonizing certain activities, as well as economic assessments of the associated costs.

While some barriers to decarbonizing may be straightforwardly technological, others are primarily about social visions and values. Is an activity socially "essential"? Is the cost of decarbonizing it "worth it" to society? What do we want a net-negative world to look like, and what are we willing to invest to realize it? There is no way to avoid this evaluative element of climate policymaking. Addressing it will likely require a high degree of participatory, deliberative decision-making — particularly important in light of the implications that decarbonization policies could have for employment in certain sectors of the economy.

In this report, we do not take up the task of identifying residuals, though we offer some considerations to inform the analysis in the specific examples that follow each section. With that said, we do ask planners to grapple with the unavoidable linkages between CDR policymaking and residual emissions, and to make their assumptions about residuals explicit.[17]

14 Holly Buck et al., "Why residual emissions matter right now," 13 Nature Climate Change 351 (2023).

15 As Buck et al. write, "Our analysis of the [long-term low-emissions development strategies (LT-LEDS)] submitted to the UNFCCC so far shows that (1) residual emissions do not have a standard conceptual definition; (2) countries' projected residual emissions are a substantial percentage of current emissions, averaging around 18% for Annex I countries in the most ambitious scenarios; (3) while most residual emissions in ambitious scenarios are indicated to come from agriculture, industry and mobility, few countries specify sectoral breakdowns; (4) for countries analyzed, LULUCF sinks by 2050 cannot balance out all residuals emissions." Holly Buck et al., *supra* at 354. Countries may voluntarily submit LT-LEDS under Article 4, paragraph 19 of the Paris Agreement.

16 *See* Harry Smith et al., "Residual emissions in long-term national climate strategies show limited climate ambition," 7 One Earth (May 2024).

17 "[S]pecifying residual emissions will mitigate against the risk that governments put things that are expensive or politically inconvenient to abate into the "residual box," thus increasing the amount of residual emissions — and thereby creating pressures for an even larger carbon removal infrastructure." Buck et al., *supra* at 355. *See also* Andreas Malm & Wim Carton, *Overshoot* (2024), Part I (explaining the ways in which integrated assessment models implicitly set social priorities).

Section 1: Identifying eligible CDR activities

The first step in developing effective CDR policy mechanisms is to ensure that they only support CDR activities that are likely to enable neutralization or drawdown in the future. This is a deceptively challenging task, because it requires thinking through how a CDR activity — and the broader system it relies on — could evolve over time.

This section introduces two related tools for assessing the roles a particular CDR activity could play in a net-negative world. First, we introduce a framework for categorizing the greenhouse gas fluxes associated with an activity. Second, referencing these flux categories, we present a decision tree to evaluate CDR activities on the basis of the future roles they could play: neutralization, drawdown, both, or neither. Assuming that the role of CDR policymaking is to support activities that can plausibly deliver neutralization or drawdown, our decision tree functions as a policy eligibility screen.

Tool 01 — Categories of GHG fluxes

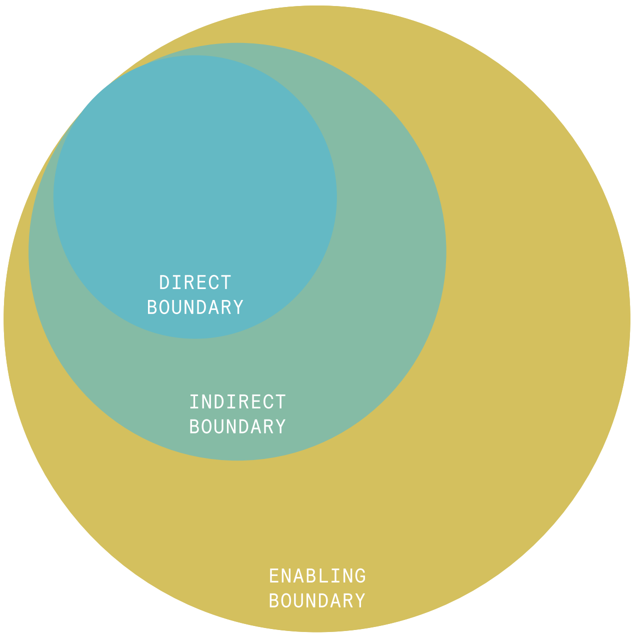
The whole point of CDR is to remove carbon from the atmosphere and store it elsewhere. Therefore, assessing whether an activity is effective begins with understanding GHG fluxes — the movement of specific quantities of GHGs between the atmosphere and other reservoirs.[18] We can separate the GHG fluxes associated with a CDR activity into three categories:

- **Direct boundary**: Fluxes that are direct consequences of the activity.
- **Indirect boundary**: Fluxes that are indirect consequences of the activity.
- **Enabling boundary**: Fluxes from processes that the activity does not cause directly or indirectly, but nevertheless relies on to operate.

These three categories are necessary for understanding the roles that a CDR

18 We focus on carbon fluxes in this report, but reaching net-zero emissions will require using CDR to counterbalance the warming effects of other types of emissions as well, notably methane (CH_4) and nitrous oxide (N_2O).

Figure 1. Taken together, the direct, indirect, and enabling boundaries include all of the fluxes that are relevant to understanding the role(s) that a CDR activity can play in enabling a net-negative world.



activity could plausibly play in a net-negative world. Below, we elaborate on each and explain what type of information it provides.

The direct boundary

The direct boundary includes the fluxes that a CDR activity directly causes. This boundary is useful because it allows us to compare different activities based on their technological characteristics and operational practices, and to track how these evolve.

For example, in a typical direct air carbon capture and sequestration (DACCS) project, the direct boundary would include the gross flux of CO_2 out of the atmosphere and into permanent storage, as well as the emissions from the operation of the capture, transportation, and storage facilities.

The indirect boundary

The indirect boundary includes the fluxes that a CDR activity indirectly causes, namely, those that arise from economic activities that are beyond the CDR operator's control. The indirect boundary is a useful category because it allows us to identify the ways in which the quantity of emissions that a CDR activity causes depends on other emitting activities in the economy. These emissions (as distinct from the goods they arise from, such as electricity or steel) are not essential to the technology or operational practices of the CDR activity. Rather, they are due to the fact that other firms have not yet decarbonized their production.

Continuing with the DACCS example, the indirect boundary includes the emissions that arise from producing any capital and operational inputs, such as building materials and capture media — "embodied emissions." While the quantities and types of these inputs that an operator consumes are a direct consequence of the activity itself, the emissions from producing them depend on the manufacturing processes of other firms — for instance, the source of heat in steel production. The indirect boundary also encompasses secondary grid effects, such as drawing additional fossil generation online or reducing the amount of renewable electricity available for other uses.[19] Identifying emissions within the indirect boundary is essential, both for understanding the full impacts of a CDR activity, and for thinking about how to develop CDR activities in ways that are conducive to economy-wide decarbonization.[20]

The enabling boundary

The enabling boundary includes GHG fluxes from production processes that the CDR activity *does not directly or indirectly cause*, but which the activity relies on to achieve its gross carbon removal.

There are at least two important ways that an activity could rely on a larger system. First, some CDR activities do not contain all of the elements necessary to move CO_2 from the atmosphere to permanent storage. For example, a CDR activity that retrofits an existing bioenergy facility with carbon capture and storage (CCS) does not cause biomass production, but does depend for its existence on the bioenergy production process. In this case, the enabling boundary includes the biomass production in which atmospheric removal actually happens, including the emissions from land use changes. This analysis applies to any CDR activity that relies on biomass that it does not cause the growth of.

Second, even if the activity does contain all of the elements necessary to move CO_2 from the atmosphere into permanent storage, it may still depend on other production processes. For instance, the concrete in buildings naturally mineralizes and, as such, is directly responsible for removing carbon from the atmosphere. But this form of carbon removal depends on the continued operation of the cement, concrete, and construction industries, which are major emitters today. We would exclude these emissions if we only considered the direct and indirect boundaries. However, understanding these enabling fluxes is essential for understanding what role concrete mineralization could play in a global climate strategy. A similar analysis would apply to any CDR activity that integrates with existing industrial infrastructure.

Understanding the flux categories in relation to familiar carbon accounting systems

The flux categories we present above are a descriptive tool — they pick out the fluxes that are potentially relevant to evaluating a CDR intervention. As such, they are tools for accounting, but are not part of a specific accounting method. Depending on their purposes, different accounting systems would pay attention

19 The same quantity vs. emissions distinction applies for grid electricity consumption. The activity may directly cause a certain quantity of electricity consumption, but associated emissions depend on the generation mix that the grid in question happens to have.

20 *Note:* Deciding what the indirect boundary includes requires making judgments about which emissions are administratively feasible to account for, given the long chains of indirect consequences that attach to any economic activity. While the secondary impacts of energy consumption are a significant indirect consequence of the activity's operation, we exclude more remote consequences that are relatively insignificant and would be prohibitively difficult to quantify. For example, suppose that the operation of a large DACCS facility pulls new electricity into the grid from a coal-fired power plant. Suppose further that this marginal effect is enough for the plant to require additional maintenance. In this case, the indirect boundary would include, by our lights, the DACCS facility's secondary energy impacts, but could reasonably exclude emissions arising from the additional maintenance.

Table 1: Relating existing carbon accounting systems to the flux categories.

	GHG Protocol	Consequential LCA	Allocational LCA	E-ledgers
TARGET	Entity (e.g., corporation, city)	Intervention (e.g., activity, policy change)	Product or entity	Transaction
GOAL	Identify the "carbon footprint" of the entity, i.e., the GHG fluxes that it is "responsible" for.	Understand the marginal change in GHG fluxes of a decision or intervention.	Allocate a share of the total quantity of GHG fluxes to the entity or product.	Package carbon removal into an asset that can travel along the supply chain.
DIRECT BOUNDARY	Included (Scope 1)	Included	Generally included	Included
INDIRECT BOUNDARY	Included (Scopes 2 and 3)	Included	Depends on allocation rules.	Represented as embodied emissions transferred along the supply chain.
ENABLING BOUNDARY	N/A	N/A	Generally excluded	N/A

to different subsets of these fluxes. In the table above, we describe some familiar carbon accounting systems using the language of the flux categories.[21]

Note that none of these accounting systems explicitly consider GHG fluxes within the enabling boundary. However, this concept is essential for effective CDR policymaking. The key distinction between the enabling boundary and the other flux categories involves causation. The enabling boundary includes all of the fluxes that an activity does not cause, but whose production it nevertheless relies on. As we explain more below, this is crucial for understanding what roles CDR activities can play in a net-negative world.

21 For a primer on common carbon accounting systems, *see* Michael Gillenwater, "The differences between allocational and consequential greenhouse gas accounting — Summarized," GHG Management Institute (Jan. 2025).

Tool 02 — Decision tree for assessing an activity's future roles

We can use the flux categories to evaluate the future roles a CDR activity could play: neutralization, drawdown, both, or neither. The decision tree below illustrates the steps.

We start by examining the activity itself. Within the direct boundary, does it store more carbon than it emits? How about the indirect activity boundary, which includes emissions from inputs? A "no" at the direct boundary could signal that the activity is not viable or that it requires basic research and development (R&D). A "no" at the indirect boundary might indicate a need to reconsider activity inputs, or may simply highlight the need for decarbonization policy efforts to focus on production within the supply chain.

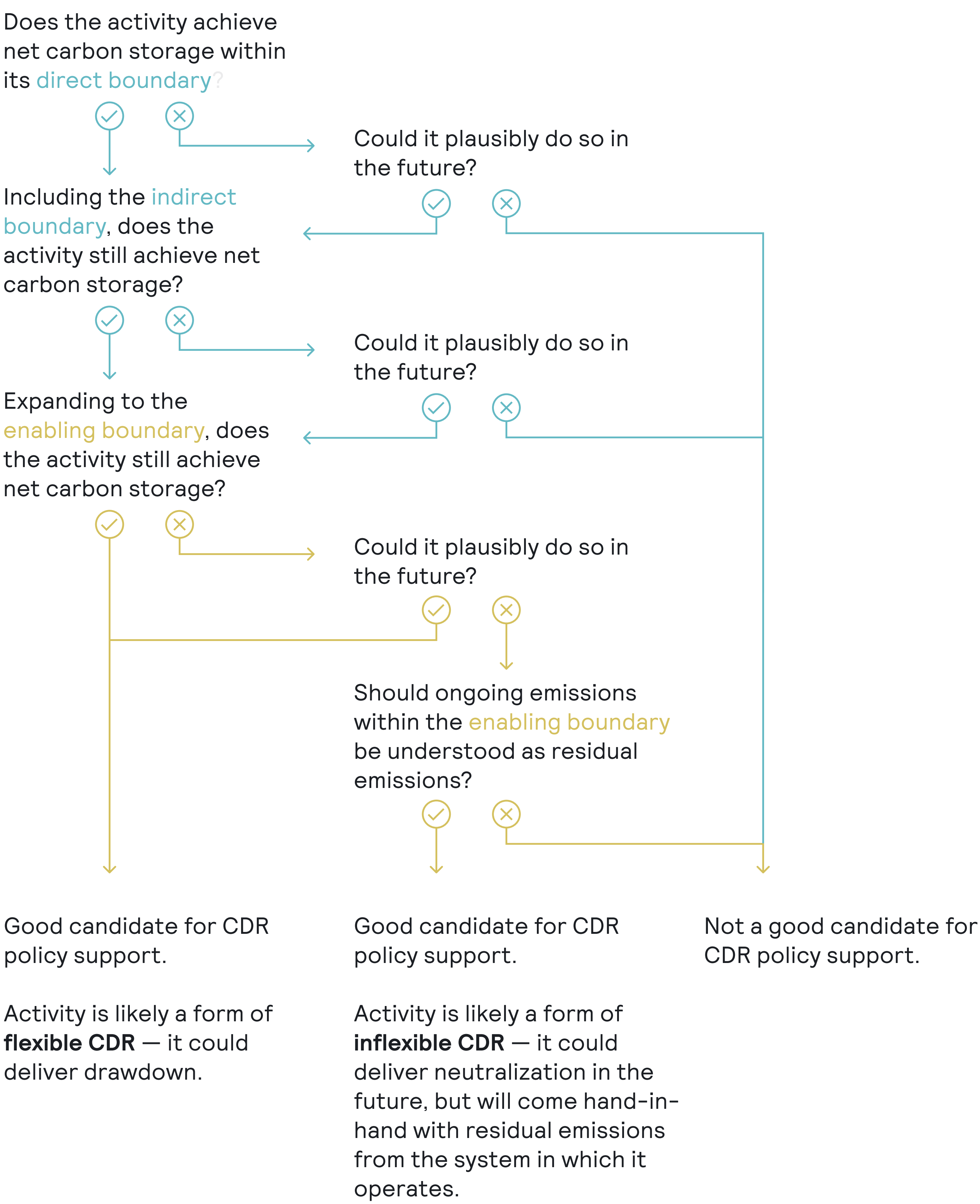
Net negativity across the activity's direct and indirect boundaries is central to how many people currently understand an activity's capacity to deliver carbon removal, and indicates a strong candidate for policy support. But to fully understand an activity's potential role in a net-negative world, it's necessary to look at the enabling boundary.

If an activity relies on a broader system (not all CDR activities do), the starting point for analyzing the enabling boundary is asking whether this system has a path to decarbonization. To contribute to drawdown, the activity — accounting for its direct, indirect, and enabling fluxes — must remove more carbon from the atmosphere than it emits. This requires deep decarbonization of the system, such that the activity's removals outstrip the system emissions that enable it. If this could plausibly be true, we can classify the CDR activity as **flexible CDR**: it could contribute to drawdown in a net-negative future.

If not, we must ask whether the system will exist at scale in a net-negative world — that is, whether its ongoing emissions should qualify as "residual." If not, a CDR activity that relies on it is unlikely to contribute to neutralization or drawdown. If, however, we are willing to consider the system emissions residuals, we can classify the activity as **inflexible CDR**. As we will see in Section 2, this activity can still be very useful, but for long-term policy planning purposes, we cannot treat it as capable of freely compensating for emissions from any sector, nor can it deliver drawdown.

This framework allows us to assess whether a specific CDR activity can contribute to a future net-negative world. It can be challenging to apply, because it involves judgments about what will be possible to decarbonize and what societies may envision for a net-negative world. However, we believe that these judgments are unavoidable. Making them explicit is essential for designing CDR policies today that align with tomorrow's climate goals.

Figure 2. A decision tree for determining eligibility for policy support.



Example — Assessing eligibility for policy support

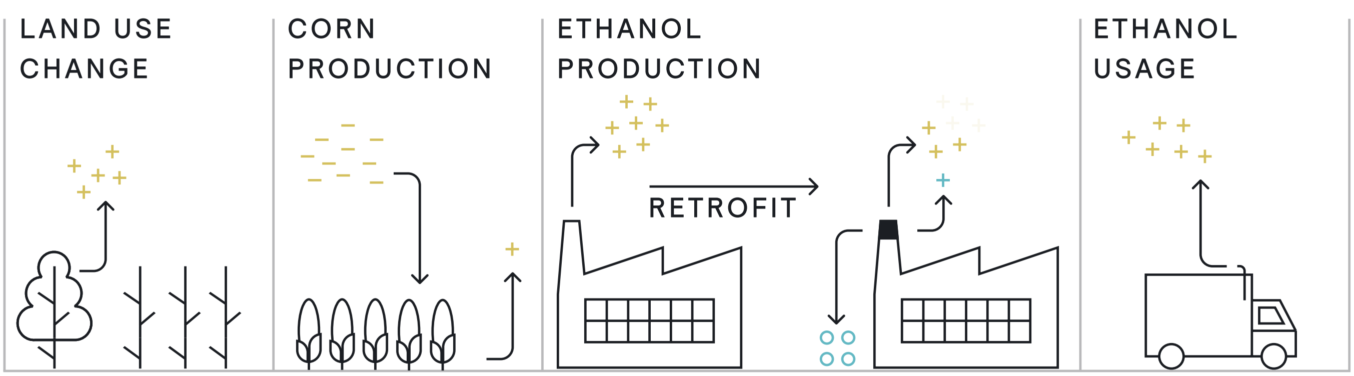
As an illustrative example for applying these tools, consider a hypothetical facility in the Midwestern U.S. that has produced ethanol from corn for over a decade. The facility recently retrofitted its operations with carbon capture and storage (CCS) equipment, and now captures a significant portion of the CO_2 generated during fermentation. The operator owns a pipeline and local injection well for transporting and permanently storing the CO_2. Using the decision tree in Figure 2, we can ask: is a project like this eligible for CDR policy support?

Question — Does the activity achieve net carbon storage within its direct boundary?

Answer — Yes.

Figure 3. Different methods of accounting for the fluxes associated with an ethanol CCS activity.

	EMISSIONS COUNTED	REMOVALS COUNTED	NET EMISSIONS
No activity	19 × +	10 × −	+09 relative to atmosphere
Direct + indirect boundary	01 × + -04 × +	00 × −	-03 relative to no activity
Direct + indirect + enabling boundary	01 × + 15 × +	10 × −	+06 relative to atmosphere



Achieving net carbon storage across the direct boundary is necessary (though not sufficient) for a CDR activity to contribute to neutralization and drawdown. In some cases, the nearer-term process of researching and developing CDR technologies may "cost" emissions, but R&D investment only makes sense if the activity has a path to net negativity in the future. In this case, the direct boundary would include the fossil emissions from constructing and operating the CCS system, as well as the flux of biogenic CO_2 into permanent storage. With high confidence, we can assume that the activity achieves net negativity within this boundary.[22]

Question — Expanding to include the indirect boundary, does the activity still achieve net carbon storage?

Answer — Yes.

The indirect boundary would include the embodied emissions of the CCS system, e.g., the emissions from cement and steel consumption, as well as emissions from grid electricity consumption. With high confidence, we can assume that the activity achieves net negativity within this boundary.[23]

Question — Expanding to include the enabling boundary, does the activity and the system that it relies on plausibly have a path to net-negative emissions in the future?

Answer — Unlikely.

In order for the activity to contribute to drawdown, the system that it relies on must have a path to decarbonization. In theory, a corn ethanol CCS system could evolve to remove more carbon from the atmosphere than it emits. However, this would require not only decarbonizing the ethanol production process, but also eliminating the direct and indirect land use change emissions that corn demand drives. Although some researchers have explored process modifications and fuel cycle interventions that could help corn ethanol move closer to net negativity, those ideas remain in the R&D phase, and there is little indication that ethanol CCS projects contemplate adopting them.[24] We therefore consider it unlikely that ethanol CCS could deliver system net negativity in the future. As such, it is unlikely that the activity could qualify as flexible CDR.

Question — Will the activity's enabling emissions qualify as residuals in a net-negative world?

Answer — Unlikely.

For ethanol CCS to operate at scale in a net-negative world, corn ethanol would need to emerge as one of the most compelling options for producing carbon-negative or near-zero liquid

22 *See*, e.g., the documentation for the Gevo North Dakota Ethanol CCS project. This project has produced credits through the Puro Geologically stored carbon methodology (v1.1), according to which it claims net negativity for the capture and storage processes (direct boundary), and raw materials and energy consumption (indirect boundary).

23 *Id*.

24 John Dees et al., "Cost and life cycle emissions of ethanol produced with an oxyfuel boiler and carbon capture and storage," 57 Environmental Science & Technology 13 (2023).

fuels, fully accounting for its costs, benefits, and available alternatives. If policymakers were to decide which liquid fuel systems should persist in a net-negative future on the basis of a comparative cost–benefit assessment, we think it is unlikely that corn ethanol would rank among them.[25] The key reasons for this are the high land use opportunity cost of dedicating cropland to fuel production, and the significant negative externalities of conventional corn cultivation.[26]

Given these factors, we consider it unlikely that emissions from the underlying ethanol system should qualify as "residuals" in a net-negative world.

Outcome of decision process: Corn ethanol with CCS is unlikely to be a good candidate for CDR policy support.

25 *See, e.g.*, World Resources Institute, "Under new guidance, 'sustainable' aviation fuel in the US could be anything but," (2024).

26 Timothy Searchinger et al., "Use of U.S. croplands for biofuels increases greenhouse gasses through emissions from land-use change," 319 Science 1238 (2008); Joseph Fargione et al., "Land clearing and the biofuel carbon debt," 319 Science 1235 (2008). Despite increasing the carbon intensity of gasoline consumption significantly, the federal government supports ethanol production with both direct and indirect subsidies. For a commentary on the risks of biomass-based carbon removal approaches, *see* James Temple, "Big Tech's big bet on a controversial carbon removal tactic," MIT Technology Review (Oct. 15, 2025).

Section 2: Designing CDR policy mechanisms

The decision tree (Section 1, Tool 02, *supra*) helps planners decide which CDR activities are eligible for policy support. The second task of the policymaking process is to identify near-term policy mechanisms that can develop the capacity of eligible activities to deliver both neutralization and drawdown. While the diversity of eligible CDR activities presents a challenge for policymakers, we argue that it also creates opportunities for creative policy design.

First, we outline a process for creating a "conceptual map" of a net-negative future, which policymakers can use to iteratively test whether policy efforts are supporting a useful portfolio of CDR activities. Next, we introduce the concept of "intermediate goals" — milestones that a specific CDR activity must achieve to progress from its current state of development toward its mature role. Finally, we offer prompts for designing policy mechanisms that can achieve these goals, emphasizing the need to think beyond the "technology-neutral" market approaches that dominate the policy planning conversation today.

In practice, there are many ways to design CDR policy mechanisms, and politics and institutions will shape what is optimal in a given jurisdiction. Regardless of the context, we hope the ideas we present in this section can help planners support CDR in strategic and creative ways.

Tool 01 — Conceptual maps of a net-negative future

Discussions of CDR's role in future climate policy often focus on total volume. It's common, for example, to hear statements like "we will need one — or five, or 10 — gigatons of CDR per year" to meet climate goals. But orienting policy efforts toward a single, undifferentiated number obscures important differences between CDR activities and their potential future roles. It also obscures the assumptions that lie behind estimates of emissions reduction shortfalls.

Instead, we recommend grounding CDR policy in a picture of the future that distinguishes between the needs of neutralization and drawdown. We need to take a more granular look at the forms of CDR that will be necessary in a net-negative world, and develop near-term policy mechanisms accordingly. This is, in essence, an exercise in long-term capacity planning: what portfolio of CDR activities do we need to develop today in order to deliver the net-negative scenarios we imagine for the future?

To begin, we recommend developing a conceptual map of a net-negative future.

This map should distinguish between the needs of neutralization and drawdown, and map those needs onto the future roles that different CDR activities could plausibly play. Doing so enables planners to identify a portfolio of CDR approaches in the near term that can satisfy the needs of future net-negative scenarios.

Developing this conceptual map requires an understanding of residual emissions (*see* Section 0, *supra*). Most jurisdictions have not outlined decarbonization strategies in enough detail to identify residual emissions. This highlights the way in which CDR policymaking is secondary to decarbonization policymaking — CDR is only relevant to a world that has largely decarbonized, and accurate CDR scenario planning is only possible once the outlines of ambitious decarbonization policy agendas emerge. As such, CDR policymaking is likely an iterative process. Planners today can do their best to imagine what a net-negative world will look like, but will need to update their models as time goes by.

Mapping neutralization capacity

By definition, neutralization requires balancing residual emissions with removals to reach net zero and stabilize global temperatures. Assessing neutralization capacity, therefore, involves identifying CDR approaches that, if they successfully mature, could credibly offset the warming impact of residual emissions.

For this long-term planning exercise, we understand the removals of inflexible CDR activities (Section 1, Tool 02, *supra*) as scaling with the emissions from their enabling system. For example, enhanced rock weathering in agricultural fields is unlikely to remove more carbon than the quantity of emissions that arises from conventional agricultural practices that influence weathering outcomes, such as tillage, irrigation, and fertilizer use. As such, we consider it a form of inflexible CDR. For planning purposes, we conceptualize removals from agricultural enhanced rock weathering as “bringing along” their system emissions, rather than as a tool for neutralizing emissions from any sector. This is because if we fail to distinguish between flexible and inflexible CDR, we run the risk of underestimating the total quantity of flexible CDR that we need to achieve a net-negative world.

To be clear, the purpose of this exercise is to assess long-term CDR capacity needs. A policy mechanism that ultimately governs the deployment of an inflexible CDR activity does not necessarily need to count its removals against its system emissions. As we discuss in Section 3, this is an accounting choice. In the capacity planning stage, however, it is essential to understand the relative proportions of flexible and inflexible CDR within the portfolio that policymakers plan to support.

Table 2. Imagine an economy consisting of three sectors: A, B, and C. Each sector causes emissions, removals, or both.

SECTOR	EMISSIONS	REMOVALS
A	++	–
B	+	None
C	None	–

Table 2 (continued). Policymakers choose a long-term net-negativity target of 2 units of net removals, which will require achieving 5 units of total removals. But simply delivering these 5 units isn't sufficient for hitting the target; the types of CDR activities matter as well.

NET-NEGATIVE GOAL	5 REMOVALS	2 NET REMOVALS
Scale A without other sectors 05 × ++-	✓ 05 × -	✗ 5 net emissions 10 × + 05 × -
Scale A with other sectors 04 × ++- 01 × + 01 × -	✓ 05 × -	✗ 4 net emissions 09 × + 05 × -
Scale C with other sectors 01 × ++- 01 × + 04 × -	✓ 05 × -	✓ 2 net removals 03 × + 05 × -

When assessing whether future emissions and removals will align, it is important to go beyond simply counting "tons." There are other characteristics that influence whether a given activity can effectively neutralize residual emissions. We highlight two in particular: durability and geographic location (Table 3).

One key characteristic that is already the subject of significant discussion in the CDR field is durability. From the standpoint of the carbon cycle, achieving real neutralization (that is, neutralization that permanently stabilizes global temperature) requires matching the duration of the cooling benefit provided by CDR with the duration of the warming that emissions cause. For fossil CO_2 emissions, neutralization requires CDR that achieves permanent carbon storage. In contrast, CDR with more temporary storage[27] could potentially neutralize

27 Sam Frankhauser et al., "The meaning of net zero and how to get it right," 12 Nature Climate Change (2022); Myles Allen et al., "Net zero: Science, origins, and implications," 47 Annual Review of Environment and Natural Resources (Oct. 2022); Myles Allen et al., "Geological net zero and the need for disaggregated accounting for carbon sinks," *supra*; Cyril Brunner et al., "Durability of carbon dioxide removal is critical for Paris climate goals," 5 Nature Communications Earth & Environment (2024).

Table 3. Aligning characteristics of emissions and removals for a net-negative future.

ACTIVITY	Type of CDR (inflexible or flexible)	Durability of storage	Jurisdiction of removals
EMISSIONS	Emissions source	Atmospheric lifetime of GHG emissions	Jurisdiction of emissions
NOTES	• See Section 1, Tool 02 for classification. • Inflexible CDR brings along its system emissions.	Neutralization requires like-for-like matching from the standpoint of the carbon cycle.	Neutralization is global from the standpoint of the atmosphere. For planning purposes, though, it's important to begin by aligning removals and emissions within a given jurisdiction. To the extent that it's necessary to look elsewhere for removal capacity, it's likewise necessary to consider further decarbonization options.

emissions with a shorter warming lifetime.[28]

Although neutralization is only relevant at a global scale — the atmosphere does not care where removal or emissions occur — jurisdictions need a practical way to plan for their own contributions, and these contributions must be compatible with a global strategy for net zero. A useful starting point is to group emissions and removals within their jurisdictional boundaries. This clarifies responsibilities and makes assumptions about residual emissions explicit. It also helps ensure that the removal portfolio the jurisdiction envisions is compatible with an equitable vision of global climate policy, rather than relying by default on the land, labor, or ecosystems of other

28 Neutralization policy must be sensitive to tradeoffs between near-term and long-term warming. *See* Zeke Hausfather, "Superpollutants are trendy but we should be careful how we use them," The Climate Brink (Nov. 3, 2025) (a thorough overview of the complexities of cross gas comparisons). The basic principle is to ensure that emissions and removals match in terms of the duration of their atmospheric impacts. For a longer discussion of how to make use of temporary storage, *see* Danny Cullenward, *A framework for assessing the climate value of temporary carbon storage*, Carbon Market Watch (Sep. 2023).

regions.[29] Finally, it exposes an important coupling: if a jurisdiction intends to rely on CDR beyond its borders, it must coordinate its decarbonization and CDR policies with the relevant rightsholders.

Mapping drawdown capacity

Net negativity depends on removals exceeding emissions, which only flexible CDR can achieve (Section 1, Tool 02, *supra*). Unlike neutralization, which targets a specific quantity of residual emissions to stabilize global temperature, drawdown capacity doesn't need to precisely map onto emissions. To the extent that the supply of flexible CDR is limited — due to natural resource constraints, public funding, or other factors — using it for neutralization may reduce the amount available for drawdown, creating an important tradeoff in portfolio design.[30]

Tool 02 — Setting intermediate goals

Long-term scenario planning can illuminate the portfolio of CDR activities that require near-term policy support. But developing that portfolio requires addressing the distinct hurdles that

29 On the problems with various forms of "atomized" net zero, *see* Shelley Welton, "Neutralizing the atmosphere," 132 Yale L.J. 171, 217-228 (2022). *See also* Alan Whitehead, *Independent review of greenhouse gas removals* (Oct. 2025), Chapter 3.

30 Emily Grubert & Shuchi Talati, *supra*.

Table 4. Menu of possible intermediate goals.

SCIENTIFIC CONFIDENCE
Understand the science well enough to characterize atmospheric outcomes and uncertainty.
Understand the science well enough to characterize durability and uncertainty.
Develop and validate effective tools for measurement and quantification.
Characterize potential ecosystem impacts and biophysical constraints across deployment scales.
OPERATIONAL FEASIBILITY
Develop supply chains.
Develop supporting physical infrastructure (e.g., storage).
Develop regulatory frameworks, e.g., for permitting, siting, environmental impact, etc.
SOCIAL LEGITIMACY
Characterize co-benefits and risks.
Earn community support and legitimacy.
Establish a durable political constituency.

specific activities face on the path from their current state of development to playing their most valuable future role. Access to funding is only one type of hurdle. To mature, an activity must satisfy a constellation of conditions involving evidence, infrastructure, institutional capacity, and political acceptance.

These conditions offer clues about the "intermediate goals" of a CDR policy effort, i.e., the milestones that any policy mechanism must reach in order to support a specific activity to effectively contribute to neutralization or drawdown. Making these goals explicit helps clarify which policy mechanisms are most appropriate, and when different activities require different treatments. For brainstorming purposes, Table 4 introduces six conditions that any CDR activity must meet in order to operate effectively in a net-negative world. Each condition serves as a prompt for diagnosing what needs to change before a specific activity can contribute to neutralization or drawdown.

Revisiting the conceptual map of a net-negative world (Section 2, Tool 01, *supra*) is one potential way to surface less intuitive intermediate goals. Suppose, for example, that we consider an activity to be a form of inflexible CDR (Section 1, Tool 02, *supra*). After sufficient R&D and cost reductions, we might ask if there is a path for the CDR activity to become a standard part of the system's operations, effectively delivering "free" removal as a co-benefit. If so, what evidence, infrastructure, or regulations would need to be in place for that integration to occur? Answers to those questions might highlight important intermediate goals for policy efforts to target.

Table 4 (continued).

ECONOMIC VIABILITY
Demonstrate a path to cost reductions.
Establish a funding mechanism for first-of-a-kind deployment.
Establish a funding mechanism for nth-of-a-kind deployment.
Establish funding mechanisms for ongoing deployment in a net-negative world.
SYSTEM ALIGNMENT
Establish symbiotic relationships between CDR and decarbonization (considering both incentives and resource constraints).
When appropriate, integrate a CDR activity into the normal operation of the system on which it relies.

It's also useful to see that intermediate goals differ in their temporal structure. Policymakers must tackle some goals sequentially, e.g., resolving major scientific uncertainties or building demonstration facilities before large-scale deployment would make sense. They can pursue other goals in parallel, such as strengthening administrative systems for monitoring and verification, developing workforce capacity, or refining siting and permitting processes. Distinguishing sequential from parallel goals helps avoid common pitfalls, such as pushing activities into premature deployment before foundational evidence exists, or deferring institutional capacity building until it becomes a bottleneck.

Explicitly naming the intermediate goals of each CDR activity is the foundation for designing effective policy mechanisms. It ensures that policy support is appropriate for the specific evidence, capabilities, and structural conditions that a CDR activity involves.

Tool 03 — Outlining near-term policy mechanisms

With intermediate goals in hand, planners can outline policy mechanisms for achieving those goals. The core question is: what could policymakers do in the near term — with imperfect information, uneven readiness across CDR activities, and limited public resources — to lay the foundation for the portfolio we identified in Tool 01? Here, we present two key considerations for approaching the task of near-term policy design.

Distinguishing between near-term and long-term policy mechanisms

It is useful to distinguish between two policymaking contexts for CDR. One is long term: in a deeply decarbonized future, what policy mechanisms might a country use to deploy CDR at scale and maintain net negativity? The other is near term: as a country starts down the path to deep decarbonization, which policy mechanisms could build a CDR portfolio that will eventually deliver net negativity? The same CDR activity may require very different types of policy support across these two timescales. For example, policymakers of the future might design a regulatory framework that directly funds rock spreading on agricultural fields in ways that reliably lead to both agricultural benefits and durable CDR. In the near term, however, appropriate policy mechanisms for enhanced rock weathering would focus on intermediate goals related to scientific confidence (Table 2).

Near- and long-term policy decisions also influence one another, which complicates the task of designing near-term policy mechanisms. Future choices about how to deploy a mature CDR activity can shape the intermediate goals that near-term policies must target. For instance, if future policymakers decide to count enhanced rock weathering removals against agricultural system emissions, they may adopt an approach that does not require high-accuracy quantification — an assumption that would influence the quantification methods that near-term policies seek to develop.[31] For these reasons, when outlining near-term policy mechanisms, it is useful for policymakers to anticipate the ways in which it may make the most

31 The question of which removals to count against which emissions will be significant for the choice of long-term CDR policy mechanisms. Since we focus primarily on near-term policymaking in this report, we don't take up this question. With that said, we assume that durability and geography are key factors, as in the conceptual mapping task (Section 2, Tool 02, *supra*). Maximizing quantification certainty subject to cost and administrative feasibility constraints is likely an important factor as well. Taken together, these considerations may underlie the intuition that it makes sense to match emissions and removals according to a "like for like" principle.

sense to deploy mature CDR activities in the future.

Shifting away from the market paradigm of CDR policy

Which near-term policy mechanisms will be most helpful for developing a portfolio of CDR activities that can deliver a net-negative future? Today, much of the momentum for developing CDR policy is toward “technology-neutral” market mechanisms — standing up or intervening in offset markets, “procurement” programs for purchasing undifferentiated tons, or tax credits that would treat diverse CDR activities as fungible. The primary aim of these mechanisms is to lower the cost of CDR activities across the board, increasing competitiveness in offset markets. They offer an appealing simplicity: avoiding the political and technological risks of “picking winners,” and allowing policymakers to defer difficult judgments about the role that CDR will play in a broader climate policy agenda.

But this simplicity comes at a cost. Technology-neutral market mechanisms aim to solve very specific problems (e.g., bringing the cost of removals below $100/ton), which are not necessarily the problems of developing a CDR portfolio that is useful in the long run. They do not reflect a process of conceptual mapping that identifies the CDR needs of a net-negative world. Instead, they often presume that the end goal of CDR policy efforts is for activities to compete in offset markets. In this context, willingness to pay determines which emissions are “residuals,” as well as which CDR activities receive financing.

Crucially, market mechanisms do not provide the granularity for achieving the wide range of intermediate goals that CDR policy efforts must attain. The problem comes from assuming that financing, in any form, will effectively advance CDR technologies. In practice, funding mechanisms differ dramatically in what they deliver. If an activity’s most urgent need is foundational scientific learning, a subsidy for Nth-of-a-kind deployment with minimal monitoring will not generate the necessary evidence for validating long-term carbon outcomes. The policy moves money, but not science.

We recommend that planners begin by thinking through the demands of a net-negative world, and identifying a portfolio of activities that can potentially satisfy those demands. At that point, it becomes possible to design bespoke mechanisms for meeting the developmental needs of different activities. These will often take the form of research, development, and demonstration programs, which policymakers already have deep experience with. Crucially, the entire process is iterative. For example, scenario planning will develop as new CDR activities come into view, decarbonization trajectories change, or research programs surface new evidence.

Example — Outlining a near-term policy mechanism

Step 01 — Conceptual mapping of future emissions and removals

Conceptual mapping of emissions and removals across a jurisdiction requires information about durability, the atmospheric lifetimes of GHG emissions, geography, and long-term emissions trajectories for both CDR activities and enabling systems.

For the purposes of this example, we assume that wastewater alkalinity enhancement (WAE), the process of adding alkalinity to wastewater at treatment facilities to regulate pH and alter microbial activity, is eligible for policy support (Section 1, Tool 02, *supra*). Under certain conditions, WAE can lead to long-term carbon storage in the ocean.[32] However, there is currently very little evidence for assessing the CDR potential of WAE. In practice, pH requirements of the water treatment process itself are likely to place an upper bound on alkalinity dosing and therefore on achievable removals.[33]

Removals from WAE can occur only when wastewater flows through the treatment system, meaning that WAE scales with the emissions profile of its enabling system. Today, municipal wastewater treatment is a significant source of energy and process emissions, including methane, nitrous oxide, and CO_2 from decaying organic material, as well as fossil CO_2 from the degradation of petroleum products (e.g., detergents).[34] However, there are few detailed emissions studies, and greenhouse gas inventories likely underreport emissions.[35] In a deep decarbonization scenario, total emissions will decline due to grid decarbonization, while biogenic emissions seem likely to persist. For the purposes of this example, we assume that a fraction of wastewater treatment emissions qualify as residuals in a net-negative world, given the essential public health function of wastewater management, and limited near-term abatement options for some of its process emissions.[36]

Given current uncertainty, both about the achievable CDR potential of WAE and the future emissions intensity of wastewater treatment, there is insufficient evidence to confidently estimate how removals from WAE stack up against emissions from the enabling system. For the purposes of this example, we assume that the ratio of removals to

32 Li-Wen Zhang et al., "The potential of wastewater treatment on carbon storage through ocean alkalinity enhancement," 11 Science Advances (May 2025).

33 *Id.*

34 Xinyue He et al., "Quantifying greenhouse gas emissions from wastewater treatment plants: A critical review," 27 Environmental Science and Ecotechnology (Sep. 2025).

35 Daniel Moore et al., "Comprehensive assessment of the contribution of wastewater treatment to urban greenhouse gas and ammonia emissions," 3 Nature Water (Oct. 2025).

36 Harry Smith et al., *supra* ("Waste represents a small but persistent contribution to residual emissions [in LT-LEDS], averaging around 9% for Annex I countries and 6% for non-Annex I countries").

enabling system emissions is less than one — the system remains net-emitting. On this basis, we treat WAE as a form of inflexible CDR, whose removals scale together with, rather than independently of, residual emissions from wastewater treatment.

Step 02 — Setting intermediate goals

WAE has the potential to become a standard practice in wastewater treatment, assuming its compatibility with the most effective overall decarbonization strategy for the sector. Indeed, many treatment plants already practice alkalinity dosing, with the goal of managing pH rather than accomplishing CDR. Could near-term policies help facilitate the broader adoption of a more climate-effective version of existing practices? There are many intermediate goals that could facilitate progress toward this long-term vision. For illustrative purposes, we can focus on two.

First, there are several sources of uncertainty that limit our ability to assess the role WAE could play in a net-negative future (Step 01, *supra*). One intermediate goal is to gather evidence to answer the following questions:

- How much durable carbon storage could WAE achieve?
- What are the actual quantities of GHG emissions that wastewater treatment causes? (Inventories have historically estimated these emissions primarily by using default emissions factors.)
- How do methane emissions and nitrous oxide emissions vary with respect to pH?

Second, for WAE to become a part of standard practice, its implications for wastewater management's efficiency, efficacy, and existing regulatory frameworks must be clear. As such, another intermediate goal is to answer questions like the following:

- What is the optimal dosing regimen to maintain or improve facility performance?
- How does downstream nutrient pollution vary with respect to pH?

These intermediate goals bring out the iterative nature of the policy design process. As evidence accumulates about removal capacity, emissions from the enabling system, and the interaction between pH and other system goals, planners can revisit and refine their initial conceptual maps (Step 01, *supra*). This iterative character also underscores the importance of avoiding technological or regulatory "lock-ins."

Step 03 — Propose and refine near-term policy mechanisms

There are a variety of near-term policy mechanisms that could advance the intermediate goals we highlight above. We consider three.

First, public funding for demonstration projects inside operational wastewater facilities is a clear near-term need. Research-focused demonstrations can generate evidence about feasibility, emissions impacts, and carbon storage outcomes under real conditions, while also supporting the development of monitoring approaches. To be effective, projects must focus explicitly on learning goals like the ones we identify in Step 02.

Second, in tandem with demonstration funding, targeted research and development (R&D) programs could address gaps in scientific understanding. Research efforts could extend their focus to questions that are difficult to answer within the scope of project-level measurement and monitoring, such as detailed mechanistic studies. Public research programs like the UK Research and Innovation Strategic Priorities Fund could support this work.

Finally, within the context of a jurisdiction's emissions-reporting framework, technical assistance programs for refining wastewater emissions estimates and direct monitoring techniques could facilitate learning and lay the foundation for incorporating WAE into municipal greenhouse gas inventories. For example, the National Institute of Standards and Technology (NIST), the national metrology institute for the United States, develops measurement tools for various applications, including GHG monitoring systems.[37] The U.S. Environmental Protection Agency (EPA) also develops sector-specific tools to improve GHG estimates.[38] Together, these types of programs could improve our understanding of emission and removal fluxes within wastewater facilities.

WAE is beginning to appear in offset markets. However, market participation does not directly address any of the intermediate goals we identify in Step 02. In the best-case scenario, market activity may contribute indirectly to learning, but only insofar as learning goals overlap with the goals of firms competing to generate credits. In the worst case, marketization will develop WAE in ways suitable to credit optimization, rather than supporting the activity to play its most valuable long-term role in CDR policy. A related risk is that early market participation could create constituencies whose interest is in preserving WAE as a niche offsetting activity. In contrast, near-term policy mechanisms like those we outline above can create constituencies dedicated to integrating WAE into standard wastewater practice, if and when the evidence supports doing so.

37 NIST, Greenhouse Gas Measurements Program (last visited Dec. 29, 2025).

38 U.S. EPA, CPRG Tools and Technical Assistance: Greenhouse Gas Inventory (last visited Dec. 29, 2025).

Section 3: Setting standards

The final task of the CDR policy design process is setting standards — the nuts and bolts rules of a policy that allow it to function properly.[39] Here we focus on standards for assessing the atmospheric impact of CDR activities.[40] Crucially, establishing these standards is not solely a scientific exercise. While science informs how we quantify GHG fluxes, standards must ultimately surface the information that is necessary for knowing whether a policy is achieving its intermediate goals. Hence, the questions that a standard must answer depend on the goals of the policy mechanism itself.

To navigate the distinction between science and policy in setting standards, we introduce two conceptual tools. First, we distinguish between quantification standards, which arise from scientific knowledge, and accounting standards, which reflect policy judgments. This distinction can help us clarify many of the accounting disagreements that have taken up airtime in the CDR field in recent years. It also highlights a simple idea that is easy to overlook: planners must articulate their goals before they can set standards. Second, we distinguish between general and specific accounting standards. This distinction illustrates the dialogue between science and policy that is necessary for effective standard setting.

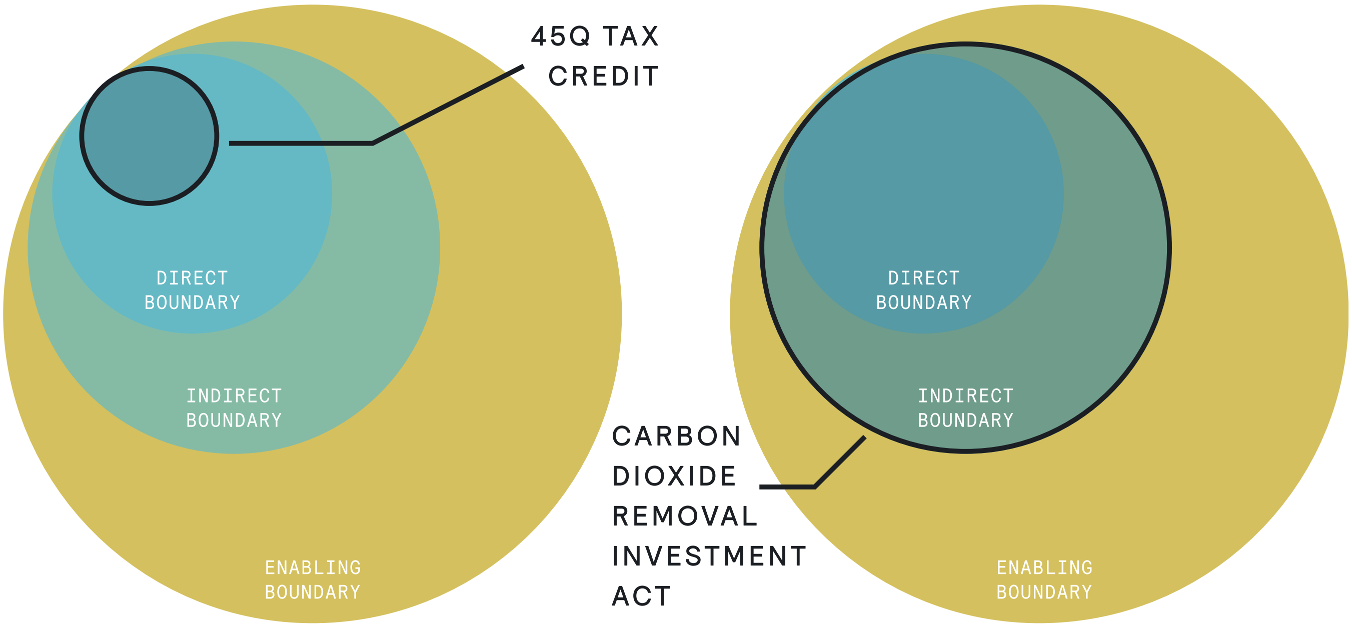
Tool 01 — Distinguish between quantification and accounting standards

We can think of standards for assessing a CDR activity's atmospheric impact as falling into two categories: **quantification standards** and **accounting standards**. Quantification standards specify how to measure or model specific GHG fluxes, and how to quantify uncertainty. In this sense, they are "scientific" — they leverage a body of empirical knowledge and provide instructions for characterizing changes in the carbon cycle. Accounting standards, by contrast, determine which fluxes to quantify in the first place. Accounting standards embody policy judgments — they tell us which

39 We use the word "standard" to refer to the rules or formal conventions that specify the characteristics that a good or a process needs to have in a given context. Standards govern everything from the strength of building materials like concrete or steel, to the format of data sent over the internet. For an engaging primer, *see* David Lang, "Standards make the world," (Dec. 2023).

40 While we do not discuss them in this report, CDR policies will certainly rely on standards that govern an activity's "non-carbon" characteristics, for example, its impacts on ecosystems or human health.

Figure 4. The Section 45Q tax credit for DACCS only accounts for gross removals, so the accounting boundary is narrower than the direct boundary. 26 C.F.R. §1.45Q-1. In contrast, the Carbon Dioxide Removal Investment Act would have required an accounting boundary that includes all the fluxes in the direct and indirect boundaries. S. 5369, 118th Cong. (2023), §e(2).



information is relevant to accomplishing a particular policy goal.[41] Thus, developing CDR standards involves a mix of scientific and policy judgments.

The set of fluxes that a standard singles out for quantification is its **accounting boundary**. The accounting boundary encodes a policy judgement about which empirical information is necessary for a policy to function effectively.

Crucially, this means that different policy mechanisms require different accounting boundaries — reflecting their distinct goals, and therefore their distinct informational needs. Seen through this lens, many debates over CDR standards become more tractable. There are no “correct” accounting standards for CDR; only standards that do (or do not) serve a policy’s goals.

In some cases, the accounting boundary may be narrower than the direct boundary — for example, in a national greenhouse gas inventory whose goal is simply to quantify gross removal fluxes. In other cases, it could encompass the direct, indirect, and enabling boundaries.

The fact that accounting standards embody policy judgments explains why attempting to develop CDR standards in the absence of explicit goals is an

41 We can see this characteristic of accounting standards as a “means” to a policy’s end(s) in other contexts. Consider, for example, the two simplest inventory accounting standards in business: last in, first out (“LIFO”), and first in, first out (“FIFO”). For an inventory of goods, the business can use either accounting method to calculate the cost of its goods sold and the value of its remaining inventory. Which of these standards it chooses to use depends on the outcome the business wants to achieve. For example, depending on the conditions, if the business wants to report higher profits, FIFO may be preferable. If it wants to lower its taxable income, LIFO may be preferable (though is not legal in many jurisdictions).

intractable challenge. Without knowing its purpose, it is impossible to judge whether a standard surfaces the information necessary for the policy to function effectively.

Tool 02 — Distinguish between general and specific accounting standards

Another useful distinction for CDR standard setting is between general and specific accounting standards. **General accounting standards** specify the characteristics that any CDR activity would need to have in order for a policy mechanism that supports the activity to function properly. They could include factors such as the appropriate accounting boundary, the necessary precision of quantification, the mode of quantification (total or marginal), durability, or whether an additionality criterion is useful for the policy to impose.[42] **Specific accounting standards**, in contrast, translate general standards into actionable guidance for a particular activity, including by adjudicating between available alternative quantification methods.

Figure 5. Setting specific accounting standards requires a dialogue between scientists and policymakers. Scientists must understand a policy's general accounting standards, and policymakers must understand which quantification methods will allow the policy to meet its general accounting standards.

For example, a jurisdictional inventory policy mechanism might have a general accounting standard that requires a narrow accounting boundary, capturing only an activity's gross removal fluxes. It could require total quantification, rather than assessing the marginal impact of the activity. It might also adopt a broad standard of additionality, distinguishing only between anthropogenic and natural activities, rather than comparing the activity against an anthropogenic baseline. Specific accounting standards would then translate these requirements into operable requirements for a particular CDR activity, specifying which measurement or modeling methods to use and how to convert removal and uncertainty estimates into a row in the program administrator's inventory.

The distinction between general and specific accounting standards is especially useful during the process of

42 *See*, e.g., Michael Gillenwater, "What is additionality? Part I," Greenhouse Gas Management Institute (Jan. 2012). In a long-term policymaking context, policies might aim to achieve a specific atmospheric outcome, regardless of the cost. In this case, a lack of additionality would be economically inefficient, but not necessarily represent a suboptimal atmospheric outcome.

developing CDR standards. Different types of expertise are necessary for crafting general versus specific standards. General standards require a clear understanding of what a policy is trying to achieve and what information it needs to function effectively. Specific standards require combining this clear picture of policy goals with domain-specific knowledge of an activity's operations and underlying science. This implies that developing fit-for-purpose CDR standards requires a collaborative exchange between policy and technical experts. Conflating the two types of standards — in particular, treating standard setting as purely a scientific exercise — risks producing standards that are either scientifically precise but unsuitable for a policy's goals, or policy-relevant but technically flawed. Clarifying general accounting standards is also a critical first step when policymakers seek to evaluate existing CDR standards for use in a new policy context.

Example — Setting accounting standards

To illustrate how we might set accounting standards in a specific policy context, consider agricultural enhanced rock weathering (ERW), a CDR activity that accelerates chemical reactions between rocks, water, and air to remove CO_2 from the atmosphere. This form of ERW involves crushing rocks and spreading them on agricultural fields.[43] As we discuss above, standards for assessing the atmospheric impact of this activity will differ depending on the policy mechanism that supports it.

In this example, we imagine a long-term policymaking scenario (Section 2, Tool 03, *supra*), in which policymakers set up a "pay for practice" regulatory framework with three operative goals. The first is to raise soil pH. This goal is important because the regulatory framework would need to maintain or improve upon farmers' existing pH management efforts. The second is to accomplish durable CDR within a desired confidence interval. The third is to take advantage of opportunities to improve our understanding of ERW's carbon removal outcomes at scale.

For the purpose of our example, we assume that this choice of policy mechanism follows from the tasks we present in the first two sections. ERW is a distinctive CDR activity: it has significant climate potential, but also substantial scientific uncertainties across multiple disciplines and physical systems.[44] These uncertainties mean that it likely does

43 The goal of enhanced rock weathering is to speed up natural water-rock reactions that can help store more carbon in water and less in the atmosphere. We speed up the process by increasing the amount of rock surface area available to weather — by varying the grain size and/or quantity of rock — and exposing it to an aqueous, carbonic acid-rich environment. Once the rock powder is spread on the soil, acids dissolve it in the presence of H_2O. Under favorable conditions, this can lead to the transformation of dissolved CO_2 into bicarbonate, which allows the solution to accept "new" CO_2 from the atmosphere to replace the CO_2 lost in the bicarbonate formation. Some of the dissolved bicarbonate is ultimately flushed out of the soil into rivers and, eventually, the ocean. The carbon can remain in the ocean as dissolved bicarbonate for millennia.

44 *See* Tyler Kukla et al., "Does enhanced weathering work? We're still learning.," CarbonPlan (Mar. 18, 2024).

not make sense to pair ERW with policy mechanisms that require high degrees of quantification accuracy and precision. This would require sophisticated, resource-intensive quantification and accounting regimes, raising concerns about administrative feasibility. In the long term, a pay for practice approach, which would fund the practice of rock spreading rather than the removal of precise quantities of CO_2, could reliably deliver climate benefits, integrate with standard agricultural practices, and impose a feasible administrative burden. We assume that in this long-term policymaking scenario, scientific research has already established with confidence the general conditions in which agricultural ERW leads to net CDR within the direct and indirect boundaries. For example, policymakers could fund laboratory, modeling, or field studies in the near term, depending on the questions they want to answer. To assess the activity's scale potential, it may also be useful to compile location data for different types of rocks within the jurisdiction. Lastly, it will be necessary to have information sufficient for estimating weathering rates for the rock types and soil conditions that policymakers include in the program.

General accounting standards

A successful regulatory framework requires standards that apply to both the agricultural and CDR elements of the policy mechanism. At the level of the individual farmer or field, the policy simply needs enough information to fund the rock spreading practice. Thus, the agricultural standards focus on the practice itself — for example, what material to apply at what specifications, how much, where, and when.

The CDR standards, in contrast, allow the policy to achieve the CDR goal by generating useful information about its CDR outcomes at larger spatial and temporal scales.[45] These standards will include:

- An accounting boundary. This should include both the direct and indirect activity boundaries (Section 1, Tool 01, *supra*), aggregated across space and time. It is crucial to understand the total climate effect — that is, CDR with permanent storage — of the practices the policy causes. This means that program administrators need to account not simply for field-level outcomes, but also those at the catchment scale, potentially over multi-year timescales. Accounting for system-level fluxes is necessary for assessing the jurisdiction's progress toward its aggregate climate goals, but not for the operation of the pay-for-practice policy itself.

- A specification for quantification accuracy and precision. A pay-for-practice program aims to fund a rock spreading practice, rather than specific quantities of CDR. This is in contrast to a compliance-neutralization policy mechanism, for example, which aims to deploy precise quantities of CDR in order to fully neutralize the atmospheric impact of precise quantities of emissions. In this case, policymakers have the flexibility to balance achievable accuracy and

45 *See*, e.g., Levy et al., "Enhanced rock weathering for carbon removal – Monitoring and mitigating potential environmental impacts on agricultural land," 58 Environmental Science and Technology (Sep. 2024).

precision against administrative burden and cost.

- A specification for the mode of quantification. A marginal mode of quantification is most appropriate in this context. The goal is to compare the impact of the practice against the non-policy baseline.

Quantification standards

Quantification standards specify how to measure or model specific GHG fluxes, and how to quantify uncertainty. Policymakers are not responsible for developing quantification standards themselves. Instead, they must survey the available scientific tools for quantifying changes in the relevant carbon fluxes, in order to evaluate which tools best satisfy the policy mechanism's general accounting standards.

At the practice level, quantification needs are relatively straightforward: counting tons of crushed rock, tracking application rates, and maintaining records of material properties. These are tractable tasks, similar to existing agricultural record-keeping systems.

At the level of CDR outcomes, the landscape of options is far more complex. A menu of quantification approaches exists — each with strengths, limitations, and uncertainties. It likely includes:

- Different geochemical and biogeochemical models, representing different physical processes or statistical approximations, involving different assumptions and capacities for resolving outcomes across space and time;
- Diverse validation and calibration protocols for modeling;
- A variety of measurement tools (e.g., soil sampling, pore-water chemistry, stream monitoring, flux towers); and
- A variety of sampling strategies.

Specific accounting standards

A policy applies the same general accounting standards to any CDR activity that it supports, but these standards will have different implications for different CDR activities. When we adapt general accounting standards to the characteristics of a particular activity, we get specific accounting standards. This involves choosing from the menu of measurement and modeling techniques that are applicable to the specific activity. This, in turn, requires a conversation between policy experts and scientists. Key questions from scientists to policymakers likely include: What goals does your policy effort pursue? What information do you need for the policy to function, and to evaluate its efficacy? Key questions from policymakers to scientists likely include: What results can you currently produce? What are the tradeoffs — with respect to cost, administrative burden, accuracy, precision, generalizability, etc. — between different quantification standards?

Proposing specific accounting standards is beyond the scope of this report. However, the general accounting standards we identify above suggest several considerations for specific accounting standards.

- There are multiple ways to quantify fluxes within the accounting boundary we identify above. Farmers already make many soil agronomic measurements, including soil pH. The program can fund additional measurements that are necessary for CDR quantification, including base saturation, cation exchange capacity, and mineralogy and organic matter content. The program can also fund downstream monitoring. This would involve the construction of river monitoring stations, which would yield more accurate estimates of carbon removal fluxes at the catchment scale.[46] With that said, downstream monitoring may be more expensive than in-field monitoring, at least initially.

- In terms of accuracy, in-field monitoring is not currently sufficient for generating reliable estimates of fluxes at the catchment scale, though this could change after more R&D. However, deploying both upstream (in-field) and downstream (stream gauge) monitoring would help validate each individual method. This means that eventually, policymakers could have confidence in their CDR estimates on the basis of some combination of in-field measurements, river measurements, and modeling. This combination would aim to optimize accuracy subject to administrative burden and cost.

- The quantification techniques we discuss here do not require deploying agricultural ERW to function, so policymakers could use them to establish a non-policy baseline.

- Specific accounting standards can facilitate learning. For example, making all data and quantification methods open will speed up the process of identifying the optimal combination of monitoring and modeling techniques. Hence, finding a way to ensure openness while protecting privacy would be a useful goal for the policy.

46 Such stations already receive policy support; for example, the USGS runs the primary network of US stream gauges.

Discussion

Designing CDR policy in the present requires grappling with visions for the future. Policymakers must decide which activities to support, which outcomes to prioritize, and which emissions to target — decades before CDR has the chance to play its unique roles in a net-negative future. This report approaches CDR policymaking as a problem of alignment across time. We propose three tasks for addressing this problem. First, policymakers must identify which CDR activities are eligible for policy support. That is, which activities could plausibly contribute to neutralization and drawdown in the future (Section 1)? Second, they must identify intermediate goals that bridge the gap between an eligible activity's current state of development and its most valuable long-term role, and design near-term policy mechanisms to achieve these goals (Section 2). Third, they must set standards that allow these policy mechanisms to function effectively (Section 3).

These tasks reflect an overarching priority for CDR policymaking: making goals explicit. Doing so helps policymakers evaluate whether a given initiative will advance society toward a net-negative world, and clarifies disagreements. Currently, accounting debates about boundaries, baselines, or other standards stem from implicit differences about what an initiative is supposed to accomplish. When goals remain implicit, discussions can become circular and unproductive. By contrast, once stakeholders agree on the objectives that an initiative seeks to achieve, they can move to tractable questions about evidence, effectiveness, and tradeoffs. Or, as the case may be, different stakeholders may realize they are simply attempting to pursue incompatible goals.

Finally, a report on CDR policy strategy would be remiss if it did not acknowledge that the current politics of climate change fundamentally limit what CDR policymaking can achieve. Ambitious CDR policy will not arise in the absence of equally ambitious deep decarbonization policy. This is because CDR, as a tool for addressing climate change, is only relevant to a world that deeply decarbonizes. In the near term, policy planners will face tight limits on resources, authority, and political will. Under these conditions, we hope that this report is useful in two ways: first, by helping planners make strategic use of the levers that are available to them; and second, by providing an aspirational guide to crafting CDR policy in a future world of higher climate ambition.

Credits

Chris and Freya conceived of the report. Chris wrote the first draft with support from Freya. Anu contributed significantly to the second draft. All authors contributed to the final draft. Kata Martin designed the figures and print format of the report.

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Terms

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