Scoping the Potential Need for Direct Air Capture

Near-Term Support Is Critical to De-Risk Scalable Solutions

Insight Brief / February 2022

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Introduction

The rapid emergence of carbon dioxide removal (CDR) solutions to pull excess carbon dioxide from the atmosphere raises important questions for investors, policymakers, and the whole of society about what near-term actions to take to advance these technologies. As awareness has grown, a wide range of stakeholders increasingly see CDR as a viable and necessary way to achieve 1.5˚C alignment. But the answers to the climate crisis are never simple. The potential large-scale deployment of CDR solutions brings trade-offs, costs, and uncertain systemic implications.

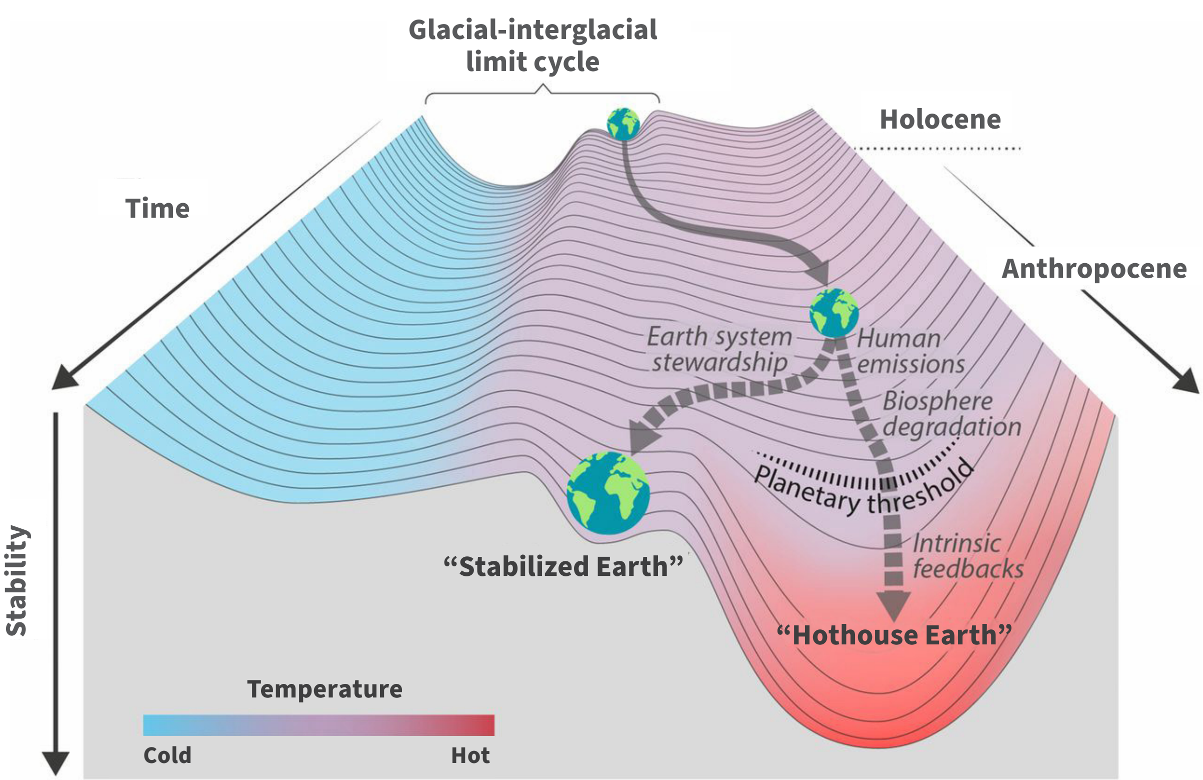
In a series of insight briefs, RMI and Third Derivative (D^3) are exploring the potential role of CDR solutions in a climate-aligned future with a focus on direct air capture (DAC), and specifically direct air carbon capture and storage (DACCS). In this brief, we assess (1) the potential role that CDR plays in scenarios that limit long-term temperature increase to 1.5°C, and (2) what we should be doing now, given the time needed to develop and deploy these technologies at scale. Based on our analysis, we believe that CDR solutions, especially nascent solutions like DAC, should be de-risked now as an insurance policy against worsening climate change.

How CDR Contributes to 1.5°C Pathways

At RMI, we remain steadfastly committed to limiting global warming to 1.5°C or less. According to the latest climate science, if we cross the 1.5°C threshold, the risk of runaway climate change **grows significantly**. This "Hothouse Earth" scenario, shown in Exhibit 1, is driven by melting permafrost, altered currents, runaway glacial melting, and other self-reinforcing feedbacks that could push the Earth system toward continued warming, even if emissions are reduced. From a climate crisis risk perspective, it is therefore especially important to stay within the safe zone below 1.5°C, and to develop solutions that might help get us back to 1.5°C should we exceed it. Given that the world has already warmed 1.1°C since 1850, and cumulative global emissions are still rising, this is a challenging goal.

Exhibit 1

Illustration of the "Hothouse Earth" scenario



Source: **Steffen et al. (2018)**

Even with transformative progress in policy, social systems, and technologies to mitigate greenhouse gas emissions, limiting warming to 1.5°C will be difficult. As climate action and the climate crisis evolve, we need to understand the full landscape of options so that we can make the most prudent and least costly decisions. CDR must not be seen as a magic bullet to solve our climate crisis, but such solutions could provide a critically important insurance policy for removing excess emissions later.

Even the Most Transformative 1.5°C Scenarios Require CDR

A major component of 1.5°C alignment is **the carbon budget**, the cumulative carbon dioxide we can release from 2020 onward while staying within a long-term temperature goal. The Intergovernmental Panel on Climate Change (IPCC) and others put this budget at around 500 Gt CO_2 for a 50% chance of limiting warming to 1.5°C by the end of the century.[i] For the past decade, the world has emitted on average **38.8±2.9 Gt CO_2 per year**, a rate that is quickly consuming the 1.5°C carbon budget. To stay within the budget, we need to cut CO_2 emissions roughly in half by 2030 and reach net zero by 2050. Even if we hit these milestones, we may still need to remove emissions by deploying CDR solutions to make up for other greenhouse gas emissions and uncertainties.

Exhibit 2

Carbon budgets for 2020–2050 (Gt CO_2)

Limit of Global Warming	50% chance	66% chance	90% chance
<1.5˚C	500 Gt CO_2*	340 Gt CO_2	NA
2.0˚C	1,420 Gt CO_2	1,090 Gt CO_2	500 Gt CO_2

*For 50% chance of 1.5°C, we must also reduce emissions of methane 50% and N_2O 30% by 2050.

Source: **Energy Transitions Commission, *Keeping 1.5˚C Alive* (2021)**

i The range of uncertainty reflects the complexity of Earth's natural systems. One unit of emissions does not always lead to one unit of warming. Feedback loops, for example, are one way in which warming might accelerate.

Key Terms

The terms CDR and NETs are increasingly used in academic and technical literature as well as public media coverage. We distinguish between key terms as follows:

- **Carbon dioxide removal (CDR)** is a broad term comprising human-initiated activities to directly remove and store carbon dioxide from the atmosphere. It excludes ongoing natural processes already acting as sinks of CO_2. We distinguish between two categories of CDR: engineered CDR such as DACCS and BECCS (defined below) and nature-based solutions such as improved soil and forest management. The term CDR is sometimes used interchangeably with negative emissions technologies (NETs).

- **Carbon capture and storage (CCS)** typically refers to the capture of CO_2 directly from an industrial point-source waste stream such as a fossil fuel power plant. Point-source CCS merely avoids emissions; it does not reduce the carbon dioxide in the atmosphere. Therefore, it is a mitigation strategy, not a carbon removal strategy.

- **Bioenergy with carbon capture and storage (BECCS)** refers to the use of biomass for energy production with point-source CCS. Depending on the associated life-cycle emissions (e.g., carbon sequestered in the biomass less emissions from production and transport), BECCS can result in either carbon dioxide removal or carbon-neutral energy production.

- **Direct air carbon capture and storage (DACCS)** is an engineered CDR, using industrial-scale chemical processes to extract CO_2 from ambient air before permanently storing it in underground geological formations. Also known as direct air capture and storage (DACS).

- **Carbon capture and utilization (CCU)** is the process of using captured carbon dioxide (from any source) in products or services such as synthetic fuels or fibers. It only counts as CDR when the carbon is stored for long periods of time (referred to as carbon capture, utilization, and storage [CCUS]); otherwise it is referred to as carbon recycling.

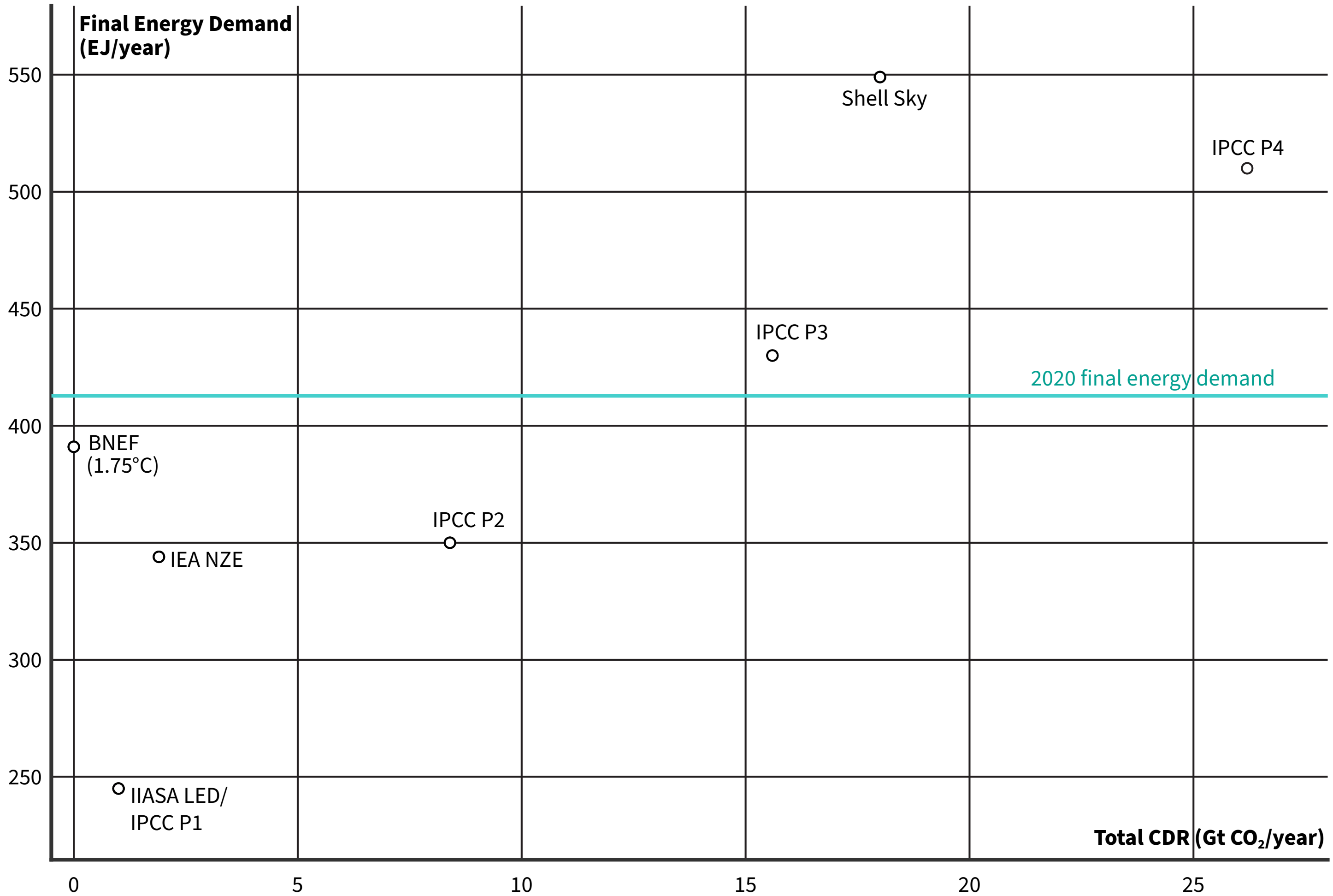
To understand what a potential future path for CDR solutions could look like, the climate community relies on integrated assessment models (IAMs) to generate scenarios. In a special report on 1.5°C released in 2018, the IPCC generated many 1.5°C scenarios, from which it selected four model mitigation scenarios, ranging from the most aggressive (P1) to the least aggressive (P4). Exhibit 3 compares these and other recent 1.5°C scenarios against an important trade-off—final annual energy demand and total annual CDR required in 2050.

The narrative behind a P4-type scenario is to support economic development with increased energy use, continued reliance on fossil energy, and heavy use of CDR in the second half of the century. In fact, the only way P4-type scenarios can achieve 1.5°C alignment is with significant carbon dioxide removal. While this does create a 1.5°C-aligned scenario, it presents a clear moral hazard. A P4 scenario approach relies on technologies that are currently unproven at scale, shifting costs and risks to future generations instead of adopting emissions reduction technologies that are already proven and lower-cost. One example of a P4-type scenario is Shell's 2021 Sky scenario, which relies on 18 Gt CO_2/y of CDR as well as another 13 Gt CO_2/y of CCUS.

Other scenarios show how more rapid transformation may be possible. The International Energy Agency (IEA) Net Zero in 2050 scenario (published in 2021 and hereafter referred to as IEA NZE 2050), a P2-type

Exhibit 3

Annual final energy demand and estimated CDR capacity in the second half of the century in select scenarios



Note: Scenarios shown include the BloombergNEF New Energy Outlook (2021), Shell Sky (2021), IEA Net Zero (2021), IIASA LED (2018), and IPCC model pathways 1-4 (P1-P4) from the IPCC 1.5°C report (2018). Note that the 2021 BNEF NEO is 1.75°C aligned.

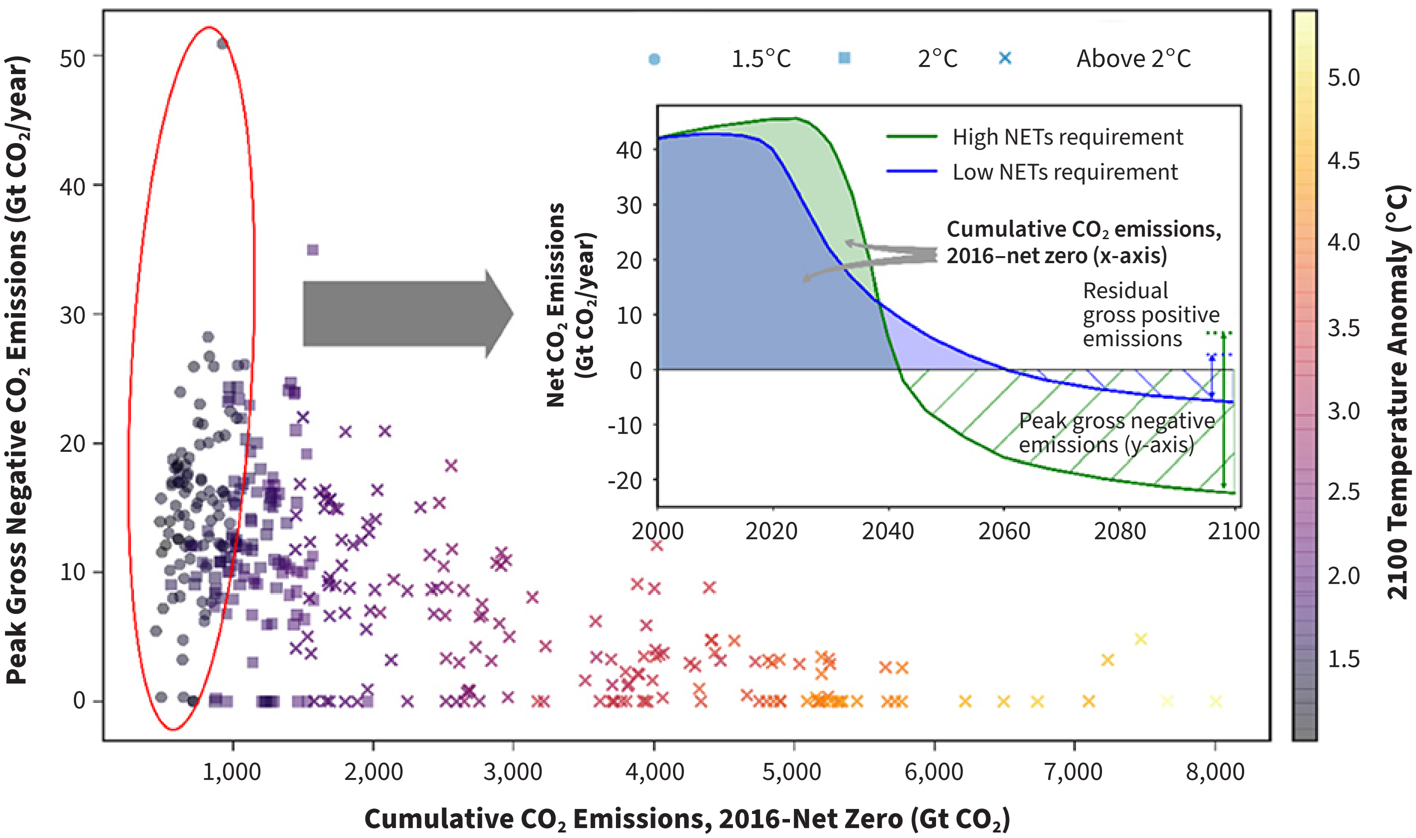
Source: RMI analysis of above noted scenarios

scenario, offers an approach that reduces the need for CDR through faster shifts to a more energy-efficient and low-carbon energy system. The International Institute for Applied Systems Analysis (IIASA) Low Energy Demand (LED) scenario from 2018 was the only P1 scenario. It shows how we might achieve 1.5°C alignment through rapid transformation of the energy system plus dramatic efficiency gains without any use of *engineered* CDR (though it does include extensive reforestation).

While not all scenarios incorporate CDR, the vast majority of 1.5°C-aligned scenarios require it. In fact, the IPCC 1.5°C report (2018) states that "all pathways that limit global warming to 1.5°C with limited or no overshoot project the use of carbon dioxide removal (CDR)." The report goes on to project that we will need cumulative CDR on the order of 100–1,000 Gt CO_2 over the 21st century. **Other reviews** suggest needing more than 20 Gt CO_2 of removal per year by 2050. As shown in Exhibit 4, 1.5°C-aligned scenarios span a range of 0–50 Gt CO_2/y of CDR, and **a 2018 review** of 1.5°C-aligned scenarios suggests a median of 15 Gt CO_2/y by 2100. Even with significant transformation of the global economy to low-carbon energy sources, most scenarios suggest **a significant and increasing need** for CDR by 2050 totaling somewhere between 5 and 20 Gt CO_2/y across all solution types.

Exhibit 4

The majority of 1.5°C-aligned IAM scenarios require 5–20 Gt CO_2/y of gross carbon dioxide removals



Source: **Fuhrman et al. (2019)**

The Future Is Ours to Shape

Despite some scenarios' heavy reliance on CDR for 1.5°C alignment, we must not be fatalistic about their outputs. We rely on scenarios because they provide a structured way of thinking about an uncertain future, but they are not predictions. They are modeled examples of what the future *could* look like. Most study authors take pains to emphasize this point, but it is often lost in the discussion of viable pathways.

The *best* insurance policy is the one that leverages proven, low-cost, and rapidly scalable alternatives to fossil fuel use in the form of efficiency, demand flexibility, and inexpensive renewable energy.

In fact, scenario models have a variety of well-known flaws, including presenting a limited range of possible pathways. Most are supply-side oriented, with a strong focus on energy production and an undervaluation of important solutions to reduce demand. Their methodologies often sidestep complex dynamics, for example, by underestimating S-curves and nonlinearity in technology adoption, social changes, and business model disruption. Some, like the IEA NZE 2050 scenario, state that such shifts are required, but only make vague assumptions about their timing and speed. No modelers can predict the future, so they rely primarily on extrapolations of the past. As a result, most scenarios are doomed to miss on the emergence of wholly new social and technical paradigms.

The IPCC's P3- and P4-type scenarios lay bare the supply-side bias in the correlation between higher final energy demand, long-term reliance on fossil fuels, and long-term CDR demand. But only recently have scenarios begun to investigate in earnest the other end of that spectrum—where efficiency, demand flexibility, behavior change, and increasingly low-cost renewable energy fundamentally change the underlying system being modeled. In fact, IIASA's LED scenario is the *only* P1 scenario in IPCC's study, versus dozens factored into each of the P2, P3, and P4 archetypes. Recent scenarios like **Oxford's probabilistic scenario model** and **Rystad Energy's 1.6˚C scenario** have added to the growing evidence that low energy demand and rapid decarbonization are achievable while saving society trillions of dollars, even before accounting for climate-related risks, damages, and societal costs.

This does not mean that we should forego preparing for a future where we might need large-scale deployment of CDR solutions. But it does underscore that the *best* insurance policy is the one that leverages proven, low-cost, and rapidly scalable alternatives to fossil fuel use in the form of efficiency, demand flexibility, and inexpensive renewable energy. As technological, social, business, and regulatory paradigms evolve to prioritize such decarbonization solutions, these changes may reveal new possibilities and pathways that bear on the ultimate scale of CDR required in ways that we cannot foresee.

Where DACCS Fits in the CDR Landscape

Supply-side bias does not only apply to energy and climate models.[ii] Academic papers often report maximum theoretical potentials, and technologists are often invested in high deployment of CDR. To better understand what levels of CDR deployment are plausibly achievable, we modeled the potential scaling of eight different CDR solutions within physical, geophysical, biological, social, and political constraints.[iii] Our results are summarized in Exhibit 5. Deployable CDR potential is small in the near term but grows to a cumulative potential of more than 20 Gt CO_2/y in 2050 in our projections. Even a 5 Gt/y CO_2 removal capacity by 2050 will likely require a portfolio approach because it is unlikely that a single technology could supply that much capacity alone, according to our estimates.

Overview of RMI analysis: Considerations for modeling the technical potential of eight CDR solutions

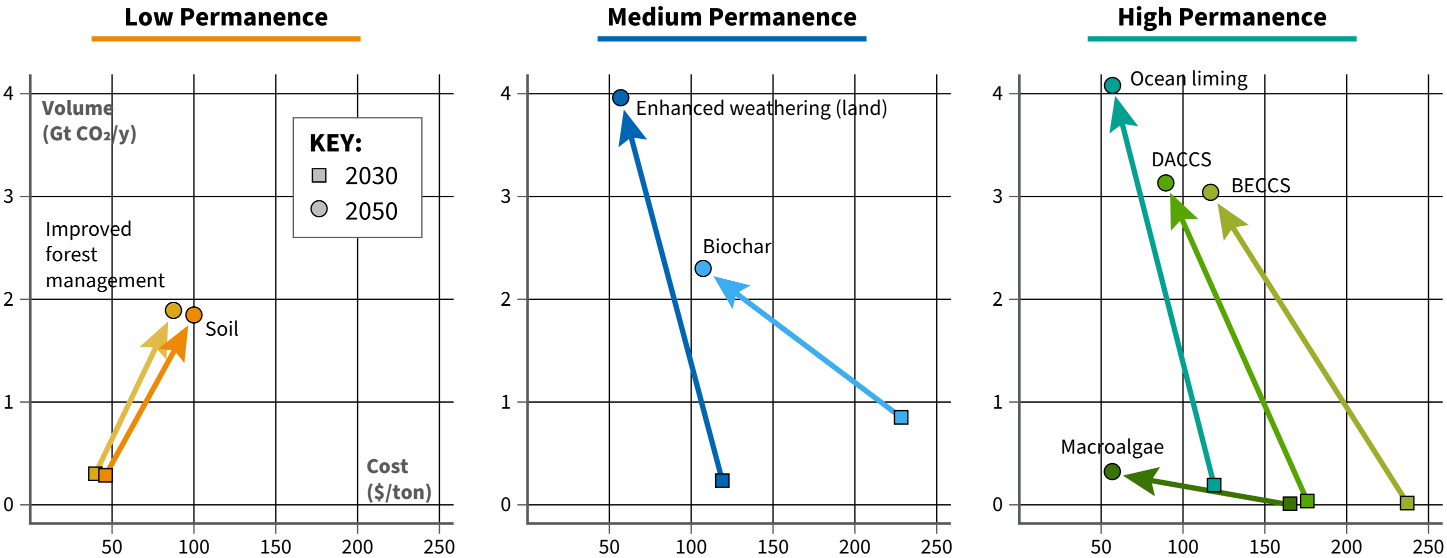
- **CDR solutions modeled:** Improved forest management, improved soil management, biochar, enhanced weathering, ocean liming, bioenergy with CCS (BECCS), macroalgae, DACCS.
- **Data sources:** Academic literature review (primarily from 2018 onward), expert interviews, nongovernmental organization reports, disclosed data from CDR operators, Microsoft and Shopify CDR project bids.
- **Scaling assumptions:** Engineered CDR like DACCS and BECCS were modeled primarily with learning curves and growth curves. Natural CDR like improved management of forests and soils included social and behavioral parameters in line with realistic trends of adoption.
- **Growth inhibitors:** For models with sufficient data, such as soil- and forest-based CDR, we capped our models based on physical and biophysical constraints such as land availability. Some models, like our enhanced weathering model, were capped based on the scale of their systems implications. We calculated that if today's entire coal mining industry (~7 Gt coal mined in 2020) were converted to mine, crush, distribute, and apply basalt for CDR purposes, this would capture 2.4 Gt CO_2/y under the best circumstances (assuming that ~3 Gt crushed basalt on soil can sequester ~1 Gt CO_2/y).
- **Exogenous elements:** Our analysis focused only on net CO_2 removal potentials and benefits, given realistic technoeconomic constraints. Each CDR solution in our analysis has an inherent real potential for additional social-environmental benefits and impacts that must be taken into consideration in a full assessment of the solution's net benefit.
- **Model outputs:** All the final outputs presented in this paper are the median estimate scenario, unless otherwise stated.

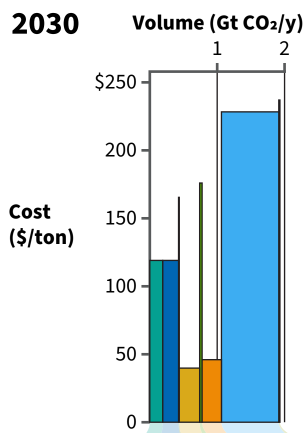
ii Supply-side bias is the result of an approach that focuses primarily on increasing supply to meet demand while focusing proportionally less on reducing demand. In energy systems modeling, this bias has historically led models to overestimate the amount of energy and resources that will be consumed in the future because it underestimates the savings produced by efficiency gains.

iii We analyzed each CDR technical potential in isolation; our analysis did not model dynamic interactions among the eight CDR solutions.

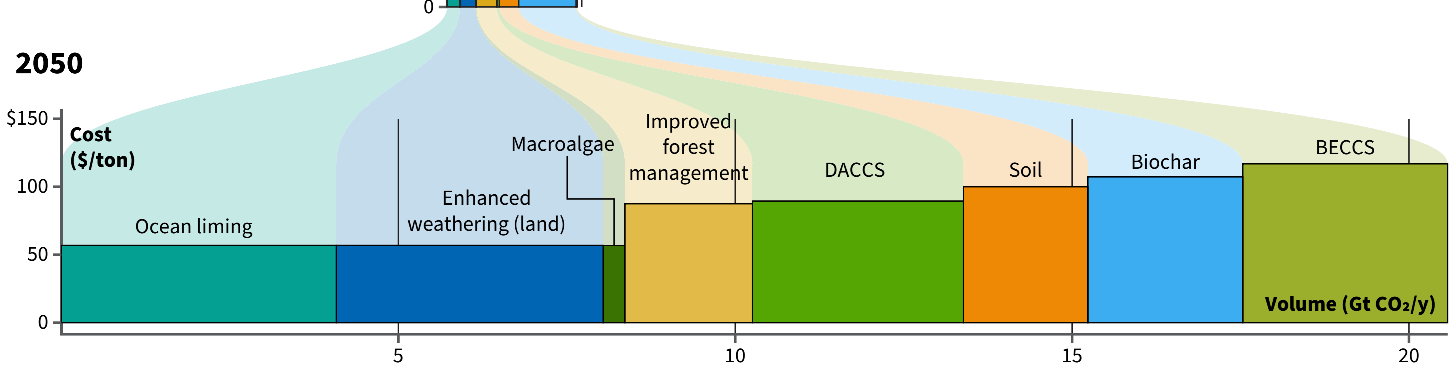
Exhibit 5

CDR technical potential (Gt CO_2/y) and cost ($/ton CO_2) for identified technologies in 2030 and 2050





Total volume of all CDR (Gt CO_2/y)	2030	2050	CHANGE
	1.93	**20.6**	**+965%**
Average cost per ton of all CDR	**$141**	**$84**	**-40%**



Note: All results are based on RMI's median estimated scenario.

Source: RMI analysis

In the near term, nature-based CDR solutions, such as improved management of soil and forests optimized for increased organic carbon stocks, provide most of the CDR potential. These approaches are well established and relatively low cost, mainly relying on adoption of best management practices (e.g., cover crop and no till, or longer forestry rotation cycles) already proven to be increasing in popularity among agriculture and forestry stakeholders. As such, they could be scaled rapidly in the near term when accompanied by the right set of economic incentives and political interventions. Our models project these solutions to be cheaper and to have greater potential than most other CDR solutions in the years leading to 2030.

As companies and governments begin to look further into the future, however, the limitations of nature-based CDR become more pressing. Microsoft, for example, has **publicly stated** that its CDR portfolio is actively assessed by four criteria: (1) scalability, (2) affordability, (3) commercial availability, and (4) verifiability. Nature-based CDR techniques are cheap and available in the near term but are difficult to verify, suffer from permanence issues,[iv] are becoming more expensive over time, and have limits to how much they can scale. Additionally, serious concerns are raised about the potential environmental and social impacts (e.g., biodiversity degradation, infringing on Indigenous land rights) that nature-based CDR could inflict if scaled rapidly and without careful planning and consultation of all stakeholders. As a result, Microsoft has said that it will pursue nature-based CDR in the near term with the goal of shifting to more scalable, permanent, engineered-based solutions as they become more viable. Similarly motivated actors are likely to follow suit.

While both BECCS and DACCS enjoy the advantage of permanent long-term storage, DACCS is less limited by biophysical and geospatial systems. For this reason, it has generated great interest among climate philanthropists, policymakers, and investors.

Mineralization, enhanced weathering, biochar, and macroalgae are all examples of CDR techniques that better meet more stringent offset requirements. Macroalgae and biochar sequester carbon dioxide through photosynthesis, but unlike other nature-based CDR solutions, they secure that carbon **in a more permanent way**. Macroalgae involves growing large volumes of algae biomass and then storing that biomass deep in the ocean. Biochar is produced by combusting biomass in a low-oxygen environment (i.e., pyrolysis) to produce inert stable carbon that can be stored in soil or durable products.

Mineralization, either on land through enhanced weathering or in the oceans through ocean liming, works by reacting CO_2 with minerals to form stable carbonates. This process occurs naturally on Earth at a modest rate of only about 300 Mt CO_2/y but has enormous scaling potential, at least theoretically. Near-surface formations

iv Permanence is a metric that characterizes the CO_2 storage durability over a long timescale. CDR techniques such as afforestation and soil management have low permanence values because the mechanism by which their carbon is sequestered can be easily reversed by disturbances like forest fires or soil erosion. More permanent techniques such as mineralization react CO_2 into a rock form, where it is far harder to disturb and release.

such as those being used by CarbFix at the Climeworks Orca facility in Iceland have an estimated capacity of 100,000 Gt CO_2, while seafloor aquifers have an additional **estimated potential to store 60 million gigatons of CO_2**. This all sounds promising from a theoretical perspective, but these CDR techniques would require the mining, crushing, and distribution of massive volumes of rock with as yet unknown consequences that are likely to limit deployment in practice.

The CDR techniques with the fewest geospatial constraints, highest permanence, and greatest long-term potential are the technology-based solutions such as BECCS and DACCS. While both enjoy the advantage of permanent long-term storage, DACCS is less limited by biophysical and geospatial systems.[v] For this reason, it has generated great interest among climate philanthropists, policymakers, and investors.

Future operating costs for DACCS are **difficult to estimate** because the emerging technologies in this space are so new. No single DAC technology has yet established itself as the market leader. The technologies **receiving the most attention today** are those based on high-temperature liquid-base systems and low-temperature solid-amine processes, but neither has achieved significant operational scale. In the future, new alternative technologies such as membrane separations could be developed. In our median estimate, DACCS could supply as much as 3.1 Gt CO_2/y of removals by 2050. See Exhibit 6 for the entailed annual growth required to achieve such capacity.

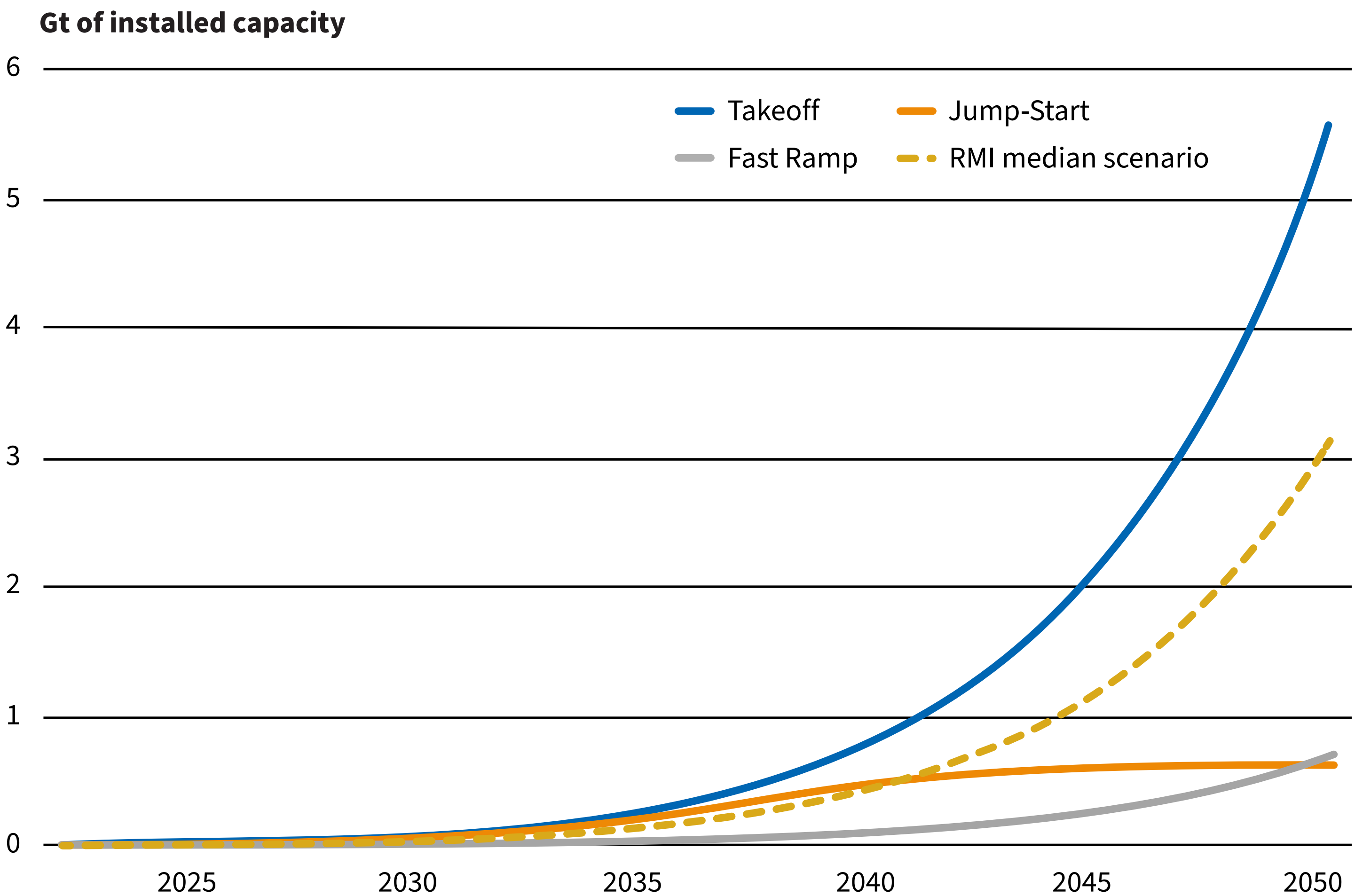
Early Investments De-Risk DACCS

Today, the world has less than 10,000 t CO_2/y of operational DACCS capacity, equal to annual avoided emissions from **two wind turbines** (2.4 MW each). Given looming uncertainties about the future value and cost of carbon removal, large-scale deployment by 2050 will require working through the early learning stages of a technology as soon as possible, a process that we refer to as de-risking. If DACCS is to play a role in addressing contingencies such as 1.5˚C overshoot, tipping points, and long-term temperature reduction, near-term deployment is essential to accelerate learning and improvement.

Consider the three scenarios in Exhibit 6. Our "Fast Ramp" scenario, which results in 700 Mt CO_2 removal of installed DACCS capacity in 2050, is the result of yearly doubling in new capacity from now to 2030 and then 20% yearly growth thereafter. For comparison, the historic deployment rates of onshore wind and solar photovoltaics going back to 1980 never once reached a 100% growth rate, even in their early years. Our "Jump-Start" scenario is calibrated to align with the IEA NZE 2050 scenario, which sees even more rapid growth to 2030 (annual removals of 71 Mt CO_2) followed by a decrease in growth to 2050. Our "Takeoff" scenario aligns with the IEA NZE 2050 scenario up until 2030 but then continues to grow at 20% per year thereafter.

v Some studies, including from the **Energy Transitions Commission**, suggest that BECCS and biochar together might be limited to about 1 Gt CO_2/y in 2050.

Exhibit 6 **Range of modeled deployment scenarios for DACCS**



	Annual change growth rates					
DACCS deployment scenarios	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**
Takeoff: Jump-Start + continued high growth from 2030	300%	100%	20%	20%	20%	20%
Jump-Start: IEA NZE 2050–aligned	300%	100%	13%	12%	-28%	-18%
Fast Ramp: Steadily doubling until higher annual growth	100%	100%	20%	20%	20%	20%

Note: The Jump-Start scenario achieves the same cumulative DAC deployment in 2030, 2040, and 2050 as the IEA's NZE 2050 scenario. Our Takeoff scenario follows IEA's NZE 2050 scenario to 2030 but then continues growing at 20% per year to 2050. The Fast Ramp scenario sees a yearly doubling of deployment in the 2020s followed by 20% yearly growth thereafter.

Source: RMI analysis

The viability of each of these three scenarios is largely dependent on how fast the cost of DACCS can come down. DACCS technologies are expected to develop along a learning curve, meaning that for every doubling of cumulative deployed DACCS capacity, the cost of a marginal unit of capacity is expected to decrease by a constant percentage. These sustained cost decreases should, in turn, foster more deployments and reinforce the learning cycle, **feeding the exponential growth curve**.

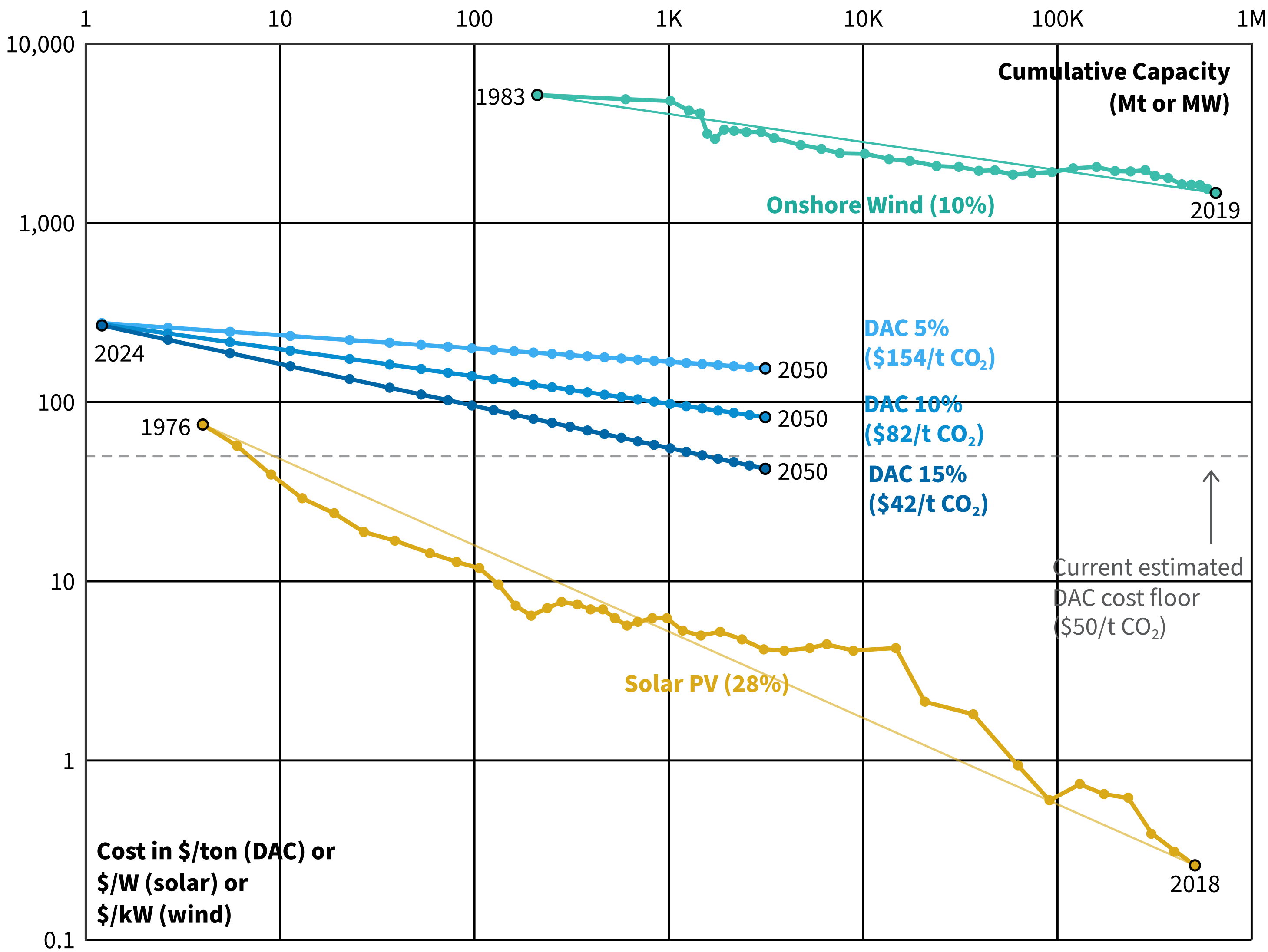
DACCS technologies are expected to develop along a learning curve, meaning that for every doubling of cumulative deployed DACCS capacity, the cost of a marginal unit of capacity is expected to decrease by a constant percentage. These sustained cost decreases should, in turn, foster more deployments and reinforce the learning cycle, feeding the exponential growth curve.

The learning curve for DACCS is, at this point, speculative, but we can assess a likely rate based on comparisons with other technologies. For example, it has been shown that one of the key drivers of a technology learning rate is the unit size of the technology. Smaller unit sizes **typically lead to higher learning rates** because production allows for more cycles of iteration. As an example, solar photovoltaics (PV), a technology of small unit sizes, has seen a very steep learning curve whereas wind turbines, with large unit sizes, have seen a much shallower learning curve. DACCS facilities are currently more similar in size and scope to large facilities, suggesting that they will have fewer iteration cycles per increase in capacity and, therefore, a lower learning rate.

The **Emerging Climate Technology (ECT) Framework**, a Breakthrough Energy initiative dedicated to establishing clear, high-quality climate metrics, estimates that a 10% to 15% learning rate for DACCS is possible when coupled with policy drivers, but that, as a large-scale process system, a lower learning rate is more likely. For our final DACCS model we used a learning rate of 10%, consistent with ECT and **others**. While this proposed learning rate is less than the historic learning rate of solar PV (28%), it is equal to the historic learning rate for onshore wind (10%). As shown in Exhibit 7, the difference between 5% and 15% learning rates leads to a $112/ton difference in the price of carbon removal in 2050, assuming volumes increase according to our median scenario.

Exhibit 7

Historic learning rates of solar PV and onshore wind compared with proposed learning rates of 5%, 10%, and 15% for DACCS



Note: DACCS learning curves use a unit size of a 1 Mt CO_2/y DACCS facility and deployment rates that match our median scenario.

Source: RMI analysis

Learning effects are a key factor in driving down technology costs, but ultimately a sustained increase in cumulative deployment is critical to achieving large-scale impact. Fluctuations in the rates of deployment were one of the reasons that both solar PV and onshore wind cost declines stagnated in the late 1980s and 1990s. Nascent technologies like DACCS will similarly take many iteration cycles to mature. By investing now, we can de-risk the development path of these technologies. A small investment today is a prudent insurance policy for the future.

Recommendations: Begin De-Risking DACCS Now

The long lead times necessary for developing and scaling DACCS mean that in order to have the option for large-scale contributions by the middle of the century, we need to invest now. Here are some activities that the public and private sector can undertake to make this happen:

- **Foster high-quality carbon markets.** Stable pricing of carbon dioxide is one of the best ways to boost the deployment of DACCS. This can be achieved through government pricing, as in the case of California's Low Carbon Fuel Standard trading scheme (**trading at \$180/t CO_2** at the time of writing), or through nongovernmental-led initiatives such as the **Voluntary Carbon Markets Integrity Initiative (VCMI)**. In addition to price signals, high-quality carbon markets must include social and environmental safeguards with robust quality standards of credit integrity. Ensuring monitoring, verification, and accounting for long-term carbon storage is also **crucial to ensuring permanence and additionality**.

- **Support private-market demand.** Companies such as Stripe and Microsoft are increasingly committing to purchasing DACCS-based credits, and as more companies and individuals make commitments, they will drive new DACCS capacity.

- **Fund research, development, and small-scale pilots of multiple DACCS technologies.** As DACCS technology is relatively new, both basic and applied research into DACCS technologies and funding small-scale pilot plants will help achieve potential step changes in DACCS cost while de-risking early-stage private sector investment. A good starting point is the US Department of Energy's 2021 support for both **research** and **pilot-scale deployment** of various DAC technologies. Such public investments help bolster private-sector efforts like Third Derivative's **First Gigaton Captured** initiative, which aims to to build a new ecosystem to rapidly deploy, scale, and commercialize viable carbon removal solutions.

- **Pursue policy drivers.** Government incentives such as tax credits, grants, and other mechanisms can play a role in boosting deployment. In the United States, DACCS developers can now benefit from the 45Q tax credit, in addition to the \$5 billion for carbon transport and storage infrastructure earmarked in Title III of the 2021 Infrastructure and Jobs Act. Other government-sponsored innovation and development initiatives include the Australian CCUS Development Fund, the £1 billion UK CCUS Infrastructure Fund, and the recently announced Carbon Negative Shot initiative by the US Department of Energy, which looks to fund DAC solutions at a cost of less than \$100 per ton of CO_2.

In the near term, de-risking of DACCS is a sensible insurance policy for an unpredictable future. In the long term, if DACCS does need to scale, we will need to shift our policy focus toward an assessment of the whole-system, life-cycle costs and benefits of these and other CDR solutions. While DACCS has fewer direct natural ecosystem impacts than other CDR solutions, it will likely require large amounts of energy and may add to the dramatic increase in renewable and clean energy required for the energy transition. The balance of these competing interests will be discussed in a forthcoming brief in this series.

About RMI

RMI is an independent nonprofit founded in 1982 that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and nongovernmental organizations (NGOs) to identify and scale energy system interventions that will cut greenhouse gas emissions at least 50% by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing.

About Third Derivative

Founded by RMI and New Energy Nexus in 2020, Third Derivative (D3) is an open, collaborative climate tech ecosystem that accelerates startups and moves markets. By guiding and supporting climate tech entrepreneurs who are bringing new ideas and innovation to market, D3 is accelerating the clean future worldwide. Through a vast global network of deep experts, corporate partners, and investors, D3 helps startups go to market faster with their breakthrough ideas, create real impact, and transform markets.

Rudy Kahsar, Guy Wohl, Charlie Bloch, and James Newcomb, *Scoping the Potential Need for Direct Air Capture*, RMI, 2022, **https://www.third-derivative.org/first-gigaton-captured#insight-brief-2**.

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