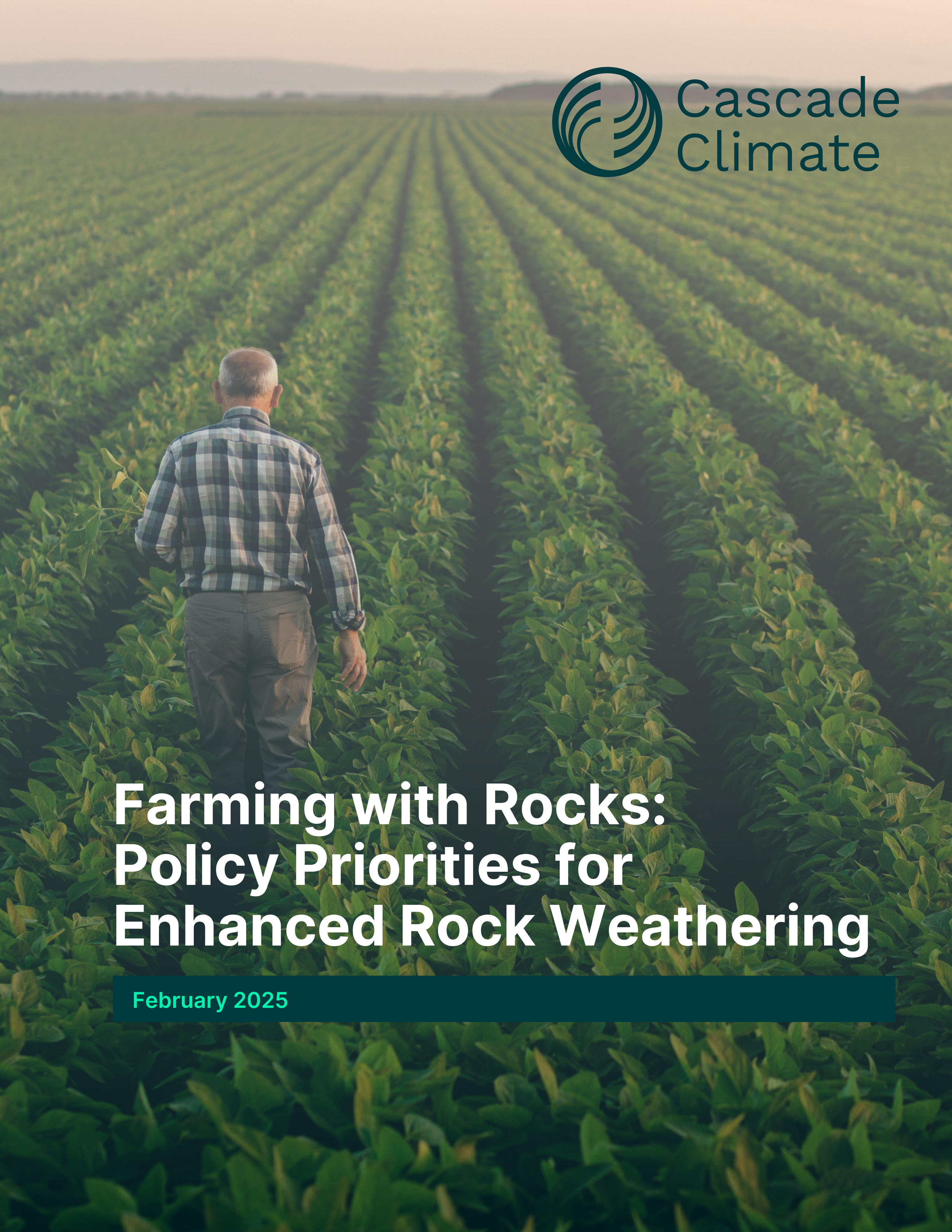

Cascade Climate

Farming with Rocks: Policy Priorities for Enhanced Rock Weathering

February 2025

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About Cascade Climate

Cascade is a philanthropically-backed nonprofit organization working across industry, government and science to accelerate progress in natural system climate interventions. We help remove the biggest bottlenecks inhibiting progress by coordinating ambitious cross-sector initiatives, building tools and infrastructure that unlock cycles of learning-by-doing, and resourcing high-leverage R&D and policy work.

Authors

(in order of contribution):

Rachel Smith, Vilas Rao, Hara Wang, Brad Rochlin

Get in touch

To learn more about the content and recommendations of this report, please reach out at policy@cascadeclimate.org.

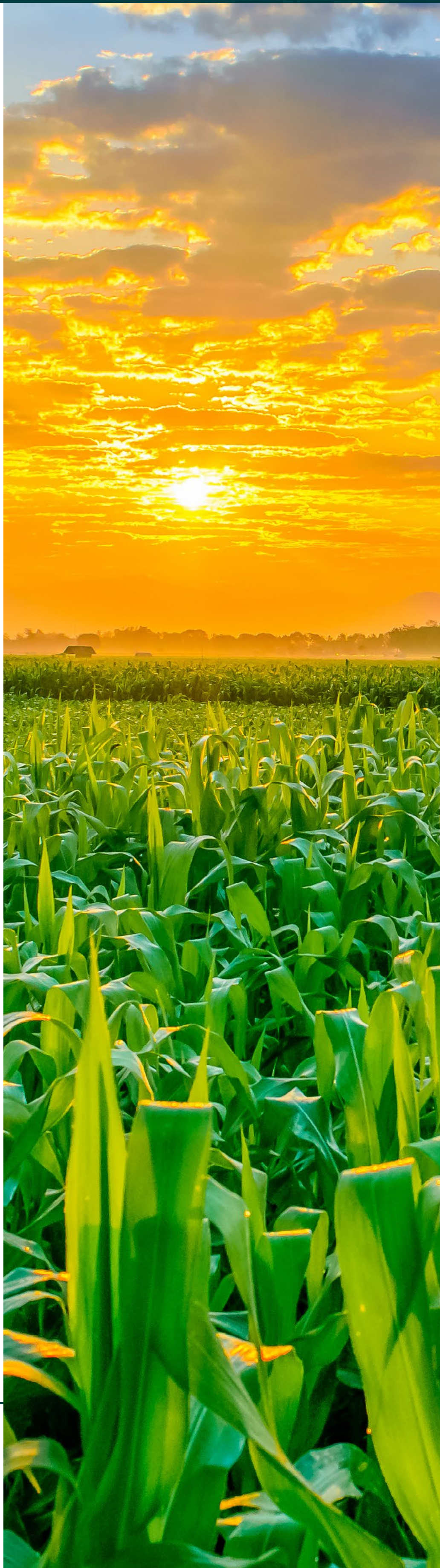
Executive Summary

Overview

Enhanced rock weathering (ERW) is a promising durable carbon removal and land management solution that involves spreading finely crushed alkaline rocks onto fields. By speeding up the natural weathering process of rocks, ERW can absorb CO_2 from the atmosphere and durably store it for millennia. Carbon dioxide removal (CDR) solutions like ERW are essential for achieving mid-century climate targets.[i] ERW has the dual potential to reach the gigaton scale of carbon removal annually while addressing widespread soil acidification concerns.[1,ii]

The agricultural sector contributes 26% of global greenhouse gas emissions, and balancing decarbonization with the need to feed a projected 9.7 billion people by 2050 is a significant challenge.[iii] Farmers, ranchers, and forest landowners must be included in global climate discussions to ensure the practicality of proposed solutions. Practices to mitigate agricultural emissions or increase CDR via agricultural systems must sustain–and ideally improve–the health and productivity of these systems.

To date, ERW has been deployed across more than 20,000 hectares (50,000 acres) on four continents, with leading catalytic carbon removal buyers like Frontier, Google, Microsoft, and NextGen having signed multi-million dollar agreements to purchase tens of thousands of tons of CO_2 removal through the end of the decade.[2] Public sector support for ERW is also growing: the U.S. Department of Energy has awarded $16 million to four ERW pilot projects, and Horizon Europe–the EU's research and innovation funding program–has provided approximately €450,000 to ongoing ERW research projects.[3]



[1] One gigaton is equivalent to one billion metric tons. References to "tons" in this report refer to metric tons. A metric ton or "tonne" is equivalent to 1,000 kilograms, or approximately 2,204 pounds.
[2] 20,000 hectares (50,000 acres) is an estimate based on a survey conducted with 16 project developers and analysis of publicly announced deployments.
[3] The €450,000 approximation includes the OASIS and the CORES projects.

Recommendations

Although there has been early momentum in ERW across the public and private sectors, the current market and policy environment is insufficient to responsibly scale ERW in the time needed to meet global climate targets. To unlock ERW's full climate and agronomic potential, governments should:

1. Invest in dedicated ERW research and development on carbon quantification, agronomic impacts, and environmental risks and co-benefits.

Publicly-funded R&D should target remaining uncertainties for ERW that the private sector is not well-positioned to address. In particular, long-term field trials and associated data collection and management will be critical to understand ERW's carbon, agronomic, and environmental impact across a range of soil types, operational systems, and regional climates.[4]

2. Provide financial assistance to address barriers to scale and support farmer adoption.

Government financial assistance is needed to overcome barriers to scaling ERW—such as high measurement, reporting, and verification (MRV) costs—while supporting farmer adoption through new business models. This can take the form of funding for pilot projects, procurement policies, and direct compensation to farmers for ERW adoption.

3. Increase confidence of prospective carbon removal buyers and investors to enter the market through high-rigor standards and clear regulatory frameworks.

Uncertainty around the durability and credibility of carbon removal credits, a lack of regulatory clarity, and overall market immaturity have kept prospective CDR buyers and investors from entering the market. Governments can address these challenges through non-financial levers, including the development of high-rigor MRV standards, regulations with transparent timelines, and clear carbon accounting frameworks.

The purpose of this report is to introduce policy stakeholders to ERW and highlight opportunities to further support this promising carbon removal and land management practice through both new and existing policy levers.

[4] Throughout this report, the term "near-term" is used to refer to the next 1-to-5 years, "medium-term" is used to refer to the next 5-to-10 years, and "long-term" is used to refer to the next 10+ years.

Overview of Enhanced Rock Weathering

Rock weathering is a core part of Earth's natural carbon cycle, which has been removing CO_2 from the atmosphere for millennia. *Enhanced* rock weathering (ERW) simply harnesses and accelerates this natural process. ERW involves spreading finely crushed silicate or carbonate rock—such as basalt, olivine, and limestone–onto fields, which speeds up the natural process of breaking down or "weathering" rocks by increasing their reactive surface area. Under many conditions, this weathering absorbs CO_2 from the atmosphere, durably storing the carbon as bicarbonate in the ocean on the timescale of tens of thousands of years (Figure 1).

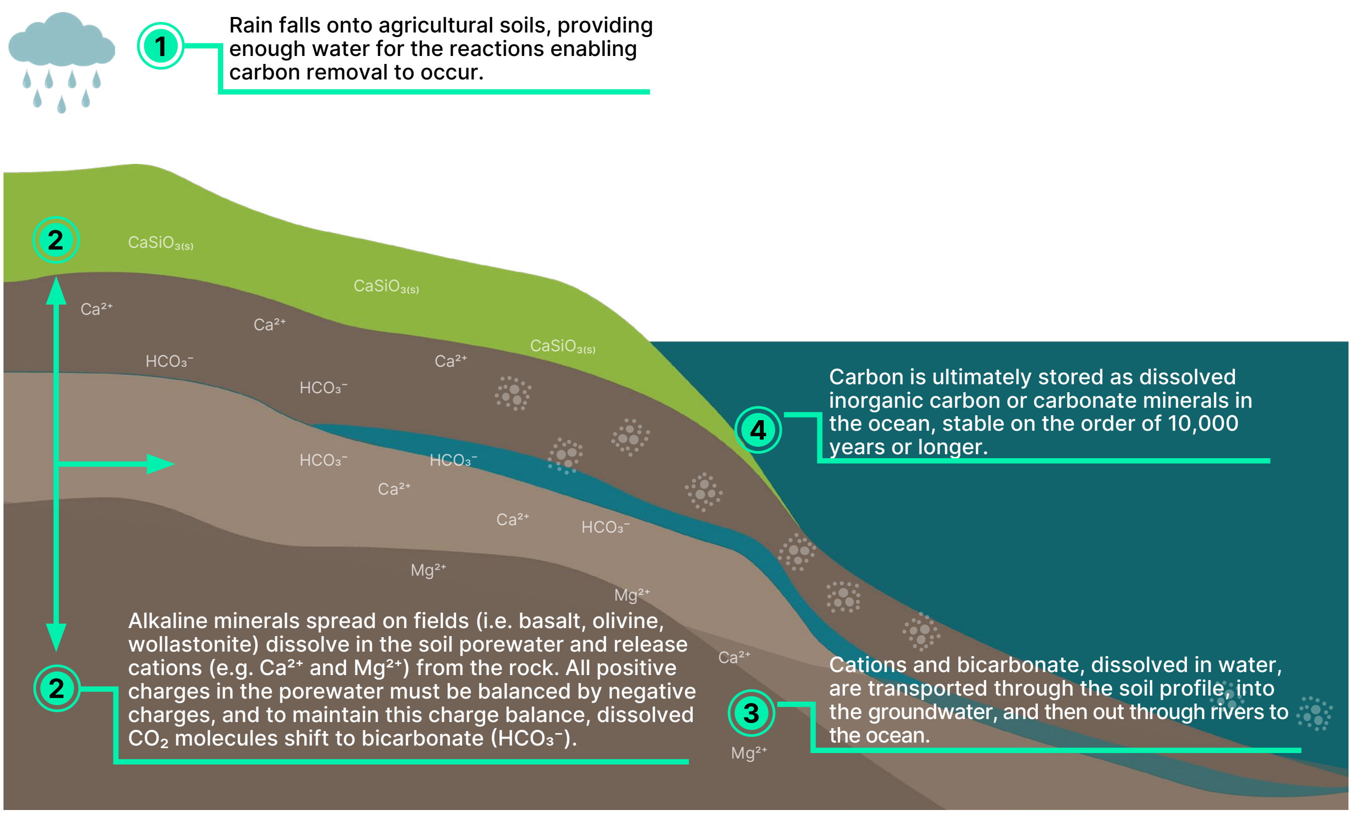


Figure 1. Overview of ERW carbon removal process.

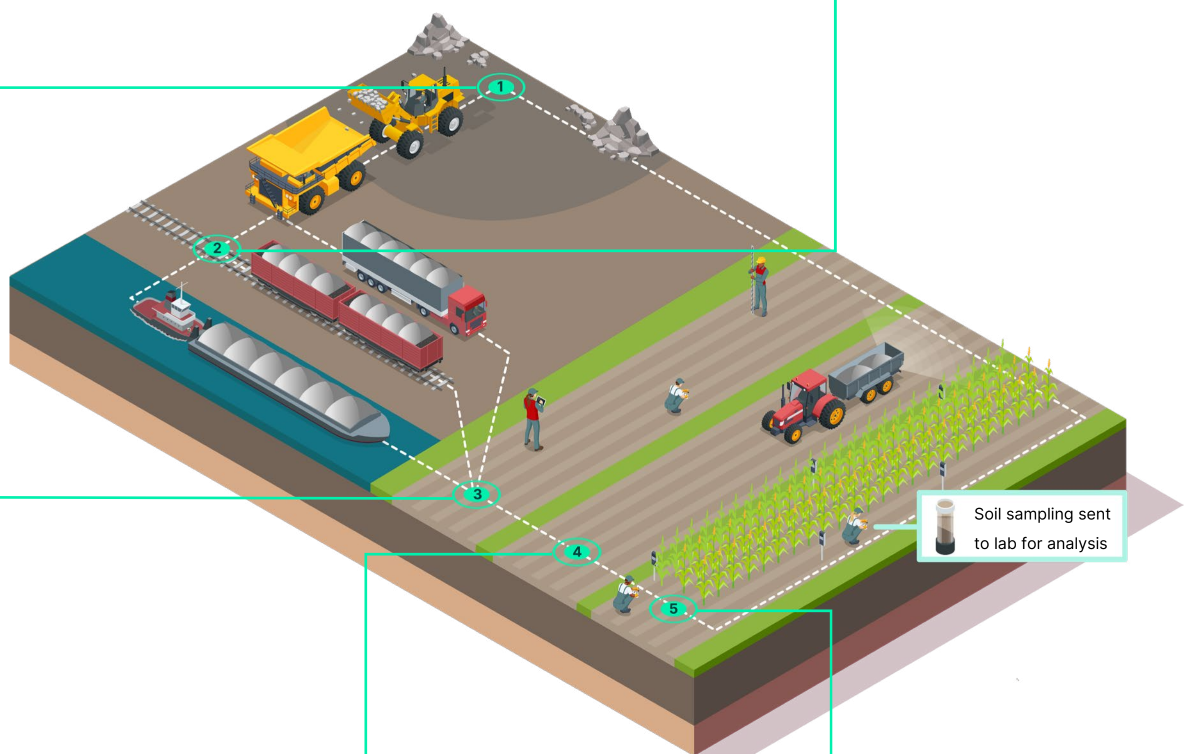
ERW's Climate Potential

As a CDR solution, ERW has the potential to remove carbon at the gigaton scale globally if widely adopted and optimized, making it a highly promising pathway for large-scale impact. Currently, the Earth naturally removes approximately one gigaton of CO_2 per year via natural silicate weathering.[iv] ERW at its maximum potential scale could remove another one to four gigatons of CO_2 per year (including 0.3-0.8 gigatons from the U.S. alone).[v] The carbon removal potential for ERW in the U.S. is comparable to that of Bioenergy with Carbon Capture and Storage (BeCCS).[vi]

To be considered a carbon removal solution, ERW must be net carbon negative, inclusive of its life cycle emissions—i.e., the emissions associated with the mining, processing, and transport of feedstock material (Figure 2). Opportunities to reduce emissions and maximize net CDR impact include using waste feedstocks such as basalt powder, sourcing feedstock from local quarries to limit transport distances, and utilizing low- or zero-carbon fuels and electricity for upstream processes.[5]

1 Quarrying, sourcing, and processing
Sourcing ERW-appropriate feedstock (such as basalt, olivine, or wollastonite), typically via stockpiled quarry or mining byproducts (waste).

2 Transport
Moving feedstock from original location to the farm via truck, barge, and/or rail.



3 Site planning
Measuring critical attributes of the deployment site (e.g., soil type, pH, weather surveys) and feedstock (e.g., elemental composition and background soil concentration of metals).

4 Spreading
Spreading feedstock onto agricultural fields.

5 Ongoing measurement, monitoring, and reapplication
Sampling and measuring soil, water, and/or gasses to evaluate progression of carbon removal, and year-over-year repetition of the process as needed.

Figure 2. Overview of the ERW value chain.

There is also early evidence that ERW can provide additional climate benefits beyond carbon removal. ERW has the potential to reduce on-farm emissions of nitrous oxide, a long-lived potent greenhouse gas that comes primarily from the agriculture sector.[vii] Initial research has also shown that ERW could improve pest and drought resilience in crops.[viii]

[5] Decarbonizing upstream processes may take time depending on the availability of, and access to, low- and zero-carbon fuel and electricity sources.

Current ERW Business Model

The current business model for ERW as a CDR solution is based primarily on the voluntary carbon market (VCM)—a decentralized market where private companies voluntarily buy carbon credits to offset their greenhouse gas emissions. The purchase of carbon credits funds projects that reduce greenhouse gas emissions or remove carbon dioxide from the atmosphere. In the ERW context, project developers seeking to access carbon credit revenue typically partner with a farmer to provide a free agricultural lime substitute ("aglime", which is commonly used for on-field pH management), while the farmer provides access to their farmland for ERW deployment along with relevant practice and farm data (Figure 3).

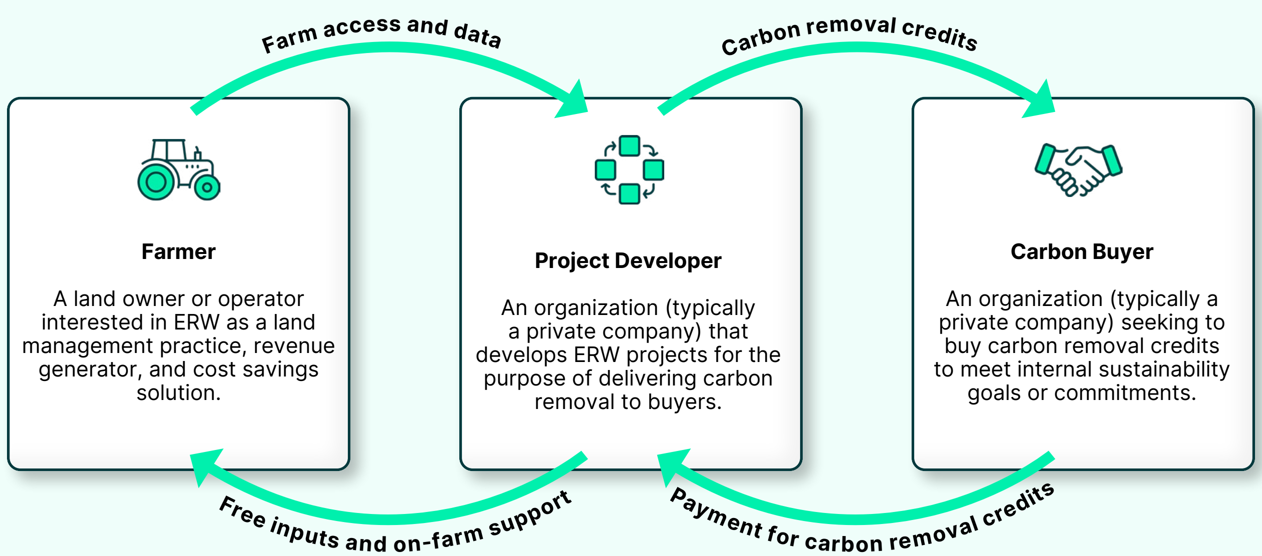


Figure 3. An overview of the current ERW business model

ERW's Agronomic Potential and Farmer Value Proposition

Applying rocks to fields is not a new concept—farmers have a long history of adding soil amendments such as aglime (calcium carbonate) to counteract soil acidification. Although the term "ERW" is commonly used to refer to the use of silicate rocks to manage soil pH, conventional use of aglime can be thought of as a form of ERW using carbonate–rather than silicate–rocks.[6] In many settings, using silicate rocks in place of carbonates has the potential to improve carbon removal efficiency while providing additional agronomic benefits over carbonate rocks.[ix] This is why many ERW projects that are funded through carbon credit revenue are exploring the use of silicates.

There are three primary aspects of ERW's value proposition to farmers:

1

Agronomic benefits: ERW has the potential to deliver agronomic benefits to farmers, such as pH control, improved nutrient availability, and–through these benefits–increased crop yield. Like traditional aglime, ERW feedstocks address soil acidification by raising soil pH.[x] Silicate-based ERW feedstocks can also increase the availability of key micro- and macronutrients in soils, improving overall crop nutrition.[xi] As a result, silicate-based ERW feedstocks could enable reductions in fertilizer use and the associated emissions.

2

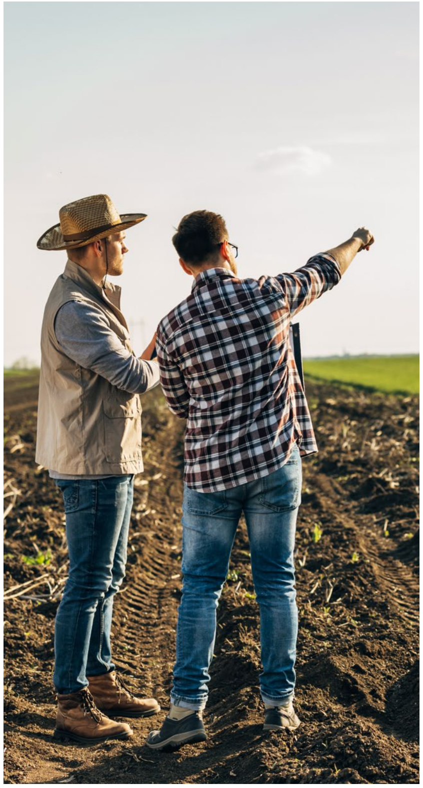
Reduced input costs: ERW has the potential to reduce farmer costs of pH management by replacing the farmer's traditional aglime application. In the current business model, ERW project developers partner with a farmer to deliver and apply the ERW feedstock free of charge. The farmer benefits by receiving an aglime substitute for free, while project developers receive a payment for the carbon that is removed via the voluntary carbon market. Project developers may also pass on a portion of the carbon revenue to farmers. Government financial assistance through pay-for-practice programs that compensate farmers directly for soil pH management could support the adoption of ERW outside of the VCM by offsetting the costs for farmers to acquire and spread ERW feedstock.

3

Ease of adoption: Compared to some carbon farming practices that may require significant on-farm practice changes, ERW is relatively easy and cost-effective for farmers to adopt. Farmers can use existing equipment to spread feedstock and do not need to significantly adjust their operational practices to accommodate ERW application.[7] Many carbon farming practices require continued practice change to maintain climate impact; notably, ERW does not require farmers to implement the practice indefinitely in order to achieve durable carbon removal and get compensated.

[6] There are other less commonly applied amendments used for pH modification, such as wood ash or quicklime, that are not considered carbonate-based ERW.

[7] In the current business model, project developers typically cover costs and work associated with measurement, reporting, and verification (MRV) of the carbon removed. If a farmer is interested in adopting ERW to access carbon credit revenue directly without partnering with a project developer, they would need to implement MRV methods on their own, similar to other carbon farming practices.



ERW's Broader Economic Benefits

ERW has the potential to contribute to economy-wide job creation, with one analysis estimating that 22,000 to 29,500 ongoing jobs could be created in the U.S. if ERW were deployed at scale.[xii] This includes new jobs in the mining and transportation sectors, which are critical for sourcing and transporting ERW feedstocks from quarry to field. Additionally, some ERW feedstocks could provide a domestic source of phosphorus—a key crop nutrient.[xiii] Global phosphorus reserves are finite and concentrated in a few countries, leading to fertilizer price volatility. Domestic ERW feedstocks with phosphorus could help reduce price volatility and reliance on foreign phosphorus supply, though additional research is needed to quantify these benefits.

A comprehensive understanding of the agronomic and economic benefits of ERW adoption in different regions still needs to be developed. There are certain regions of the world where agricultural liming has long been an established practice, yet globally application of aglime is constrained by cost and supply chain challenges. The benefits of ERW can be even greater in regions that do not currently have access to aglime, supporting global food security efforts.[xiv]

SILICATE VS. CARBONATE ENHANCED ROCK WEATHERING

Silicate ERW feedstocks are not a one-to-one replacement for more traditional carbonate ERW feedstocks (e.g., aglime). Silicate ERW feedstocks dissolve at a slower rate than carbonates, taking longer to achieve the same pH benefit. This means that a greater quantity of silicate rocks are needed to achieve the same pH-balancing effect as carbonate rocks. However, silicate ERW feedstocks will often be more efficient in carbon removal, and can be provided at a lower (or no) cost to farmers by leveraging voluntary carbon markets. Farmers typically use calcium-carbonate equivalency (CCE) calculators to determine the liming rate needed based on the material used. Integrating silicate ERW feedstocks into aglime equivalency calculators through rigorous equivalence testing is an ongoing area of research requiring additional support.

ERW Impact Considerations and Risks

Like other land management practices, local contexts such as climate zone, soil type, and crop type are key in estimating ERW's climate and agronomic impact. ERW is likely to achieve faster and more efficient carbon removal impact in regions with high temperatures, significant rainfall, and easy access to feedstocks. In some conditions–particularly in acidic soils–applying carbonate rocks to soils can lead to an increase in life cycle greenhouse gas emissions. More research is needed to map ERW feedstock availability and climate and agronomic potential by region to support targeted applications that maximize impact.

Scaling ERW must also involve identifying, mitigating, and monitoring potential negative impacts, such as heavy metal accumulation in soils and respiratory risks from dust inhalation during spreading.[xv] These risks vary across feedstocks, soils, and operational contexts, so it is important for project developers to create site-specific environmental health and safety (EH&S) risk assessments and associated monitoring and mitigation plans. Government programs should require EH&S plans to be submitted and evaluated as part of the application and review process for public funding of ERW projects. It is also critical to implement robust feedstock screening and site characterization plans prior to ERW feedstock application, rather than solely relying heavily on post-application monitoring to mitigate environmental risks. There is a growing body of research that identifies potential risks (and the associated monitoring and mitigation best practices) which can guide fit-for-purpose ERW regulation. Regulations will need to address potential liability for negative impacts that may be caused by ERW.

State of ERW as a CDR Solution

The body of research on ERW as a carbon dioxide removal solution has been steadily growing, with over 45 new publications in 2024 alone.[8] Since 2022, the field of ERW has progressively shifted from a handful of small-scale field trials to hundred-to-thousand hectare deployments, thanks in large part to demand for carbon removal from catalytic buyers. Roughly 20 commercial ERW project development companies have emerged, overseeing projects across a range of crop types, including corn, soy, cotton, rice, sugarcane, and alfalfa. By the end of 2024, ERW has been deployed on over 20,000 hectares (50,000 acres) globally, and over 500,000 carbon credits from ERW projects have been purchased through offtake agreements, which stipulate that these credits will be quantified, verified, and delivered to buyers over the course of the decade.[9] These initial carbon removal purchases are on the order of $300 to $400 per ton of carbon removal.

One of the primary challenges to scaling ERW is uncertainty around carbon quantification–in particular, the measurement, reporting, and verification (MRV) of the amount of carbon removed. This first wave of ERW projects funded through voluntary carbon market demand offers an opportunity to test MRV methods in real-world settings through a "deployment-led learning cycle" (Figure 4). If these early deployments generate high-quality datasets by aligning measurement methodologies with the best available science on quantification, they can provide critical information beyond what can be learned through research alone due to the scale of commercial deployments and the diversity of operational approaches.[10] To advance the foundational science underpinning ERW, those commercial datasets must then be made accessible to academic researchers, spurring learning for the whole field.

Figure 4. The ERW deployment-led learning cycle.

8 Based on an academic ERW bibliography developed by Tim Jesper Shurfhoff.
9 20,000 hectares (50,000 acres) is an estimate based on a survey conducted with 16 project developers and analysis of publicly announced deployments. The total of over 500,000 carbon credits is calculated from the CDR.fyi database.
10 The estimated 20,000 hectares of commercial deployment represents 200x more area than all academic field trials combined.

To support the deployment-led learning cycle, Cascade Climate has released three resources for the ERW field:

Foundations for Carbon Dioxide Removal Quantification in ERW Deployments

A shared framework for rigorously quantifying CDR in ERW deployments and a distillation of the best available science, practices, and guidance for ERW practitioners. "Foundations" is the culmination of a multi-stakeholder process involving approximately 50 academic scientists; 20 ERW project developers, credit issuers, and buyers; and not-for-profit organizations. "Foundations" is being used as a reference for leading voluntary standards bodies in ERW methodology development, and can similarly be used to inform government-led methodology development and MRV standardization efforts.

Data Quarry

A permissioned-access data sharing system that connects researchers with ERW commercial data. As of its launch in October 2024, ten project developers and two buyers have signed on to contribute their datasets to the ERW Data Quarry. Government researchers can also access the data to inform policy design and implementation.

ERW MRV Cost Estimator (EMCE)

A free-to-use cost estimator and accompanying cost database to support project developers in understanding MRV and feedstock transportation and application costs. This information can be useful for government-led techno-economic assessments and similar policy efforts.

ERW Policy Priorities

Scaling ERW cannot be left up to the voluntary carbon market alone; a recent BCG analysis found that across all CDR pathways, voluntary CDR demand will be insufficient to reach the scale required to offset residual greenhouse gas emissions.[xvi] Furthermore, the VCM is not the most reliable and sustainable form of long-term demand for carbon removal, as it depends on private sector commitments that ebb and flow depending on a range of profit and market drivers. It is also not well-suited to account for ERW's potential agronomic benefits, nor to provide sufficiently consistent guardrails around the environmental impacts of ERW projects.

These challenges highlight the critical role governments can play in both addressing near-term needs to mature the ERW field, as well as providing conditions for long-term scale-up and farmer adoption. To unlock ERW's full climate and agronomic potential, governments should:

1. Invest in dedicated ERW research and development on carbon quantification, agronomic impacts, and environmental risks and co-benefits.

2. Provide financial assistance to address barriers to scale and support farmer adoption.

3. Increase confidence of prospective carbon removal buyers and investors to enter the market through high-rigor standards and clear regulatory frameworks.

Initial government support for ERW has primarily been in the form of research and development and pilot project funding (Table 1). For example, the U.S. Department of Agriculture (USDA) awarded $4.9 million to ERW field trials across 40+ states through its Partnerships for Climate Smart Commodities program, and the U.S. Department of Energy (DOE) provided $16 million to four ERW pilot projects. The EU Horizon program is actively funding €450,000 of direct ERW research and development, and an additional €5.3 million for CDR pathways broadly.

Table 1. Select government programs actively ERW in the U.S. and EU (as of January 2025)

Program Name	Program Lead	Stage of Funding[1]	Award year	Description	Award Amount
Horizon C-SINK	EU Commission	R&D	2023	Process to develop pre-standards to build MRV systems across CDR pathways.	€5.3M
Horizon OASIS	EU Commission	R&D	2023	Field experiments to assess the potential of ERW in dryland soils.	€260,000
Horizon CORES	EU Commission	R&D	2023	Study on the climate adaptation potential of ERW.	€190,000
Global Change and Photo-synthesis Research	USDA Agricultural Research Service	R&D	2023	Research to develop, test, and quantify the benefits of ERW and other GHG mitigation practices.	N/A
Voucher Program	U.S. DOE Office of Technology Transfer	R&D	2024	Provides technical assistance and access to DOE national labs equipment and testing. Two ERW companies were selected.	N/A
CDR MRV Lab Call	U.S. DOE Office of Technology Transfer	R&D	2023	Develops an adaptive MRV framework for mineralization-based CDR pathways.	$15M
EAR Division of Earth Sciences	U.S. National Science Foundation	R&D	2022	Three-year ERW field trial using basalt and a silicate industrial waste product in Minnesota.	$320,000
Partnerships for Climate-Smart Commodities	USDA Natural Resources Conservation Service	Pilot	2023	Project to deploy ERW for CDR and pH balancing on over 100 farms across the U.S.	$4.9M
Carbon Negative Shot Pilots	U.S. DOE Office of Fossil Energy and Carbon Management	Pilot	2024	Pilot-scale tests of enhanced mineralization technologies with appropriate MRV. Four ERW projects were awarded ~$4M each in Round 1.	$16M
CDR Purchase Pilot Prize	U.S. DOE Office of Fossil Energy and Carbon Management	Pilot	2025	Companies compete for the opportunity to deliver carbon dioxide removal credits directly to DOE. Three ERW companies are semi-finalists out of a total of 24.	Up to $3M
Conservation Programs	USDA Natural Resources Conservation Service	Deployment	2025	Interim Conservation Practice Standard 805 allows farmers to amend their soil with agricultural lime and alkaline weathered rock to adjust soil pH. USDA will evaluate the interim versions for final adoption in 2025.	To be determined

1 Stages of funding include research and development ("R&D"), small-scale pilot or field trials support ("pilot"), and large-scale commercial deployment support ("deployment").

Notably, in the US, ERW has historically not been covered by many of the programs targeting either conservation on working lands or carbon removal. In the EU, the Carbon Removals and Carbon Farming regulation process is informed by existing directives for various CDR pathways (such as the Carbon Capture and Storage Directive), but there is no foundational legislative equivalent for ERW. In the EU, the Carbon Removals and Carbon Farming regulation process is informed by existing directives for various CDR pathways (such as the Carbon Capture and Storage Directive), but there is no foundational legislative equivalent for ERW.

In addition to closing eligibility gaps in existing programs, policymakers should explore the creation of new "fit-for-purpose" programs to target the barriers specific to ERW maturation that cannot be achieved through existing programs. Table 2 showcases examples of policy opportunities across the three dimensions listed above. [11]

Table 2. Examples of policy support mechanisms for ERW.

	Policy support type	Description	What this achieves	Examples *(not exclusive to ERW)*
Research and development	R&D funding	Public investment in research and innovation.	Addresses research gaps that commercial actors are not best positioned to answer. This can include life cycle and techno-economic assessments.	Horizon Europe*, USDA Agriculture and Food Research Initiative*
	Inter-governmental coordination	Formal or informal coordination across various government departments on R&D.	Ensures funding is allocated where there is the greatest potential for scientific advancement, reducing redundancies and increasing efficiency of public money spent on research.	U.S. Marine Carbon Dioxide Removal Fast-Track Action Committee (mCDR FTAC)***
Financial assistance for scale-up and adoption	Government procurement	The government acts as a direct buyer of carbon removal credits.	Provides financing support for early deployments, which can accelerate technology development and provide a longer-term demand signal depending on the length of the program.	U.S. DOE CDR Purchase Pilot Prize*, Canada's Low-Carbon Fuel Program Expansion to include CDR procurement*
	Pay-for-practice programs	A government program providing compensation to farmers directly for the implementation of ERW as an on-field practice.	Encourages early adoption of innovative practices, but requires strong conviction in the tie between the practice and the desired outcome.	USDA Natural Resources Conservation Service (NRCS) Environmental Quality Incentives Program**
	Tax credits for carbon removal	A production tax credit for carbon removal.	Provides a tax credit for the quantity of carbon removed on a per ton of CO_2 basis, which offsets some of the production cost for domestic project developers.	Carbon Dioxide Removal Investment Act***
	Tax credits for biofuels that incorporate ERW	Incorporation of ERW into carbon intensity calculations for biofuels tax credits.	Provides a tax credit for biofuel production. Eligibility is based on the carbon intensity (CI) of the fuel. ERW could be incorporated as an accepted practice to lower the CI of biofuels for eligibility, creating demand support. Any practice incorporation would require strong conviction in the tie between the practice and the desired climate outcome.	Incorporation of ERW into § 45Z tax credit guidelines as a climate-smart agriculture practice**

11 Please note: while Table 2 provides an overview of potential policy support mechanisms, their applicability for ERW and specific jurisdictions require further discussion.

	Policy support type	Description	What this achieves	Examples *(not exclusive to ERW)*
Increased confidence in carbon markets	Compliance markets	Creation of carbon compliance markets or incorporation of CDR into emissions trading schemes as a method for generating emissions allowances.	Provides market clarity and long-term certainty to buyers and industry players on how and when CDR will be incorporated into existing emissions trading regulations.	EU's Carbon Removal and Carbon Farming regulation*, Japan's GX-ETS acceptance of CDR credits*
	Government approval of VCM protocols	The government certifies or labels existing standards or protocols in the voluntary carbon market as high-rigor.	Reduces uncertainty around which protocols are high-rigor, increasing demand for projects using approved or certified protocols.	U.S. Greenhouse Gas Technical Assistance Provider and Third-Party Verifier Program*
	MRV standardization efforts	The government leads efforts to standardize MRV approaches.	Widely accepted standards can improve confidence in MRV approaches and measurement comparability.	National Institute of Standards and Technology MRV Consortium*

* ERW is currently eligible under this program.
** This program could be expanded to include ERW.
*** A new program would need to be created.

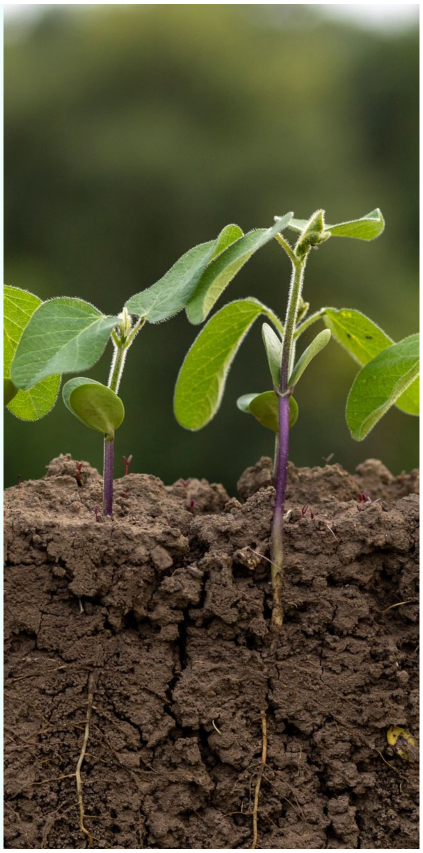
Invest in Dedicated ERW Research and Development

Innovation is essential to address remaining CDR quantification gaps, drive down MRV costs, and ensure the safe scale-up of ERW. Although commercial deployments can answer certain open questions, government support is better suited to address broader system-level needs across CDR quantification, agronomics, and environmental and community impacts. In particular, public funding for long-term field trials and data collection will be critical to understand ERW's impact across a range of soil types, operational systems, and regional climates. To the extent possible, policymakers should encourage data sharing and transparency from these publicly-funded ERW projects to advance learning for the field.

LEVERAGING USDA'S LONG-TERM AGROECOSYSTEM RESEARCH NETWORK FOR ENHANCED ROCK WEATHERING

USDA's Agricultural Research Service (ARS) currently oversees the Long-Term Agroecosystem Research (LTAR) network, which consists of 18 research sites nationwide. Scientists within this network are focused on addressing key questions essential for the future sustainability of agriculture and which require more than the usual 2-5 year project cycle to fully understand. In fiscal year 2023, LTAR was appropriated $15M.

For FY 2026, Congress should consider increasing LTAR funding and requesting that USDA expand LTAR to evaluate long-term carbon, agronomic, and environmental impacts of ERW. This is similar to FY 2023 report language from Congress, which explicitly called out ERW's eligibility for Agriculture and Food Research Initiative funding.



ERW does not fall neatly under one government department or agency's purview. In the U.S., ERW is being explored by the National Science Foundation (NSF), DOE, and USDA. To ensure learnings are shared across the government, greater inter-agency coordination is needed. The Marine Carbon Dioxide Removal Fast Track Action Committee is an example of how the U.S. is approaching the coordination of marine CDR research across multiple agencies which can act as a model for ERW. Governments should explore both informal and formal coordination opportunities across departments, as well as prioritizing ERW in broader CDR inter-agency efforts.

Through the "Foundations" process, Cascade identified a list of ERW quantification R&D needs. Note that some of these research topics will be more relevant for government programs than others. Beyond CDR quantification, additional research is needed to evaluate ERW's agronomic and environmental co-benefits and risks, as well as feedstock availability and mapping. Cascade–along with a coalition of NGOs, academics, and ERW project developers–has identified key government R&D priorities for ERW, with a focus on the U.S.

Table 3. Examples of priority ERW research and innovation gaps in need of government funding support.[1]

	Research area	Potential U.S. Programs
MRV and carbon quantification	Efficiency of carbon removal and emissions reduction under different agriculture system conditions and mineral types.	USDA Long-Term Agroecosystem Research Network
	Data collection and management at both the project and field levels, including watershed-level monitoring and data management across government data systems.	USDA Agriculture Research Service GHG Monitoring Network
	MRV tools (e.g., novel sensor development) and model development.	DOE Carbon Negative Shot
	Life cycle assessments and the development of decision-support tools for land managers to effectively deploy ERW.	DOE National Labs, EPA GHG Inventory
Agronomic impacts	Silicate ERW feedstock efficacy as a soil pH amendment in comparison to aglime, including an assessment of yield impacts.	USDA Sustainable Agriculture Research and Education
	Techno-economic assessments to better understand farmer return on investment from ERW adoption, particularly compared to baseline liming practices.	DOE National Labs
	Tool development for estimating silicate ERW application rates under different soil conditions and mineral types (such as ERW silicate-carbonate equivalence calculators).	USDA NRCS Conservation Innovation Grants (CIG)
Environmental and community impacts	Increasing evidence base for future identification of appropriate thresholds for trace metal accumulation rates and maximum allowable concentrations.	USDA NRCS CIG
	Social science research to engage farmers on their management priorities.	USDA Climate Hubs
	Large-scale environmental monitoring.	US Geological Survey

[1] Adapted from the Enhanced Weathering Policy Working Group Research Priorities.

Provide Financial Assistance for Scale-up and Adoption

Additional public financial assistance is needed to address barriers to scale, create long-term demand, and support farmer adoption outside of the voluntary carbon market. This funding can help scale sustainable feedstock sources and their associated supply chains, creating new avenues for farmers to access feedstocks. Although demand support through pilot project funding and procurement policies can help bolster the ERW field in the near- to medium-term, new policy frameworks will be needed to reach meaningful scale in the long-term. The success of the ERW field will require significant farmer buy-in, and governments should explore new avenues to support farmer adoption of ERW outside the VCM.

Support early pilot projects to address barriers to scale

In the near-term, government programs are needed to provide financial support for early-stage ERW pilot projects focused on addressing key barriers to scale such as high MRV costs, environmental safety at scale, and sustainable feedstock sourcing. In the U.S., the Carbon Negative Shot program is supporting four small mineralization pilots through approximately $16M total in awards, while the USDA's Partnerships for Climate Smart Commodities program has provided $4.9M for small-scale ERW pilots through partnerships between farmers and academic research institutions. In the EU, the Horizon C-SINK program is supporting two mineralization pilots.

Create long-term policy demand signals through procurement

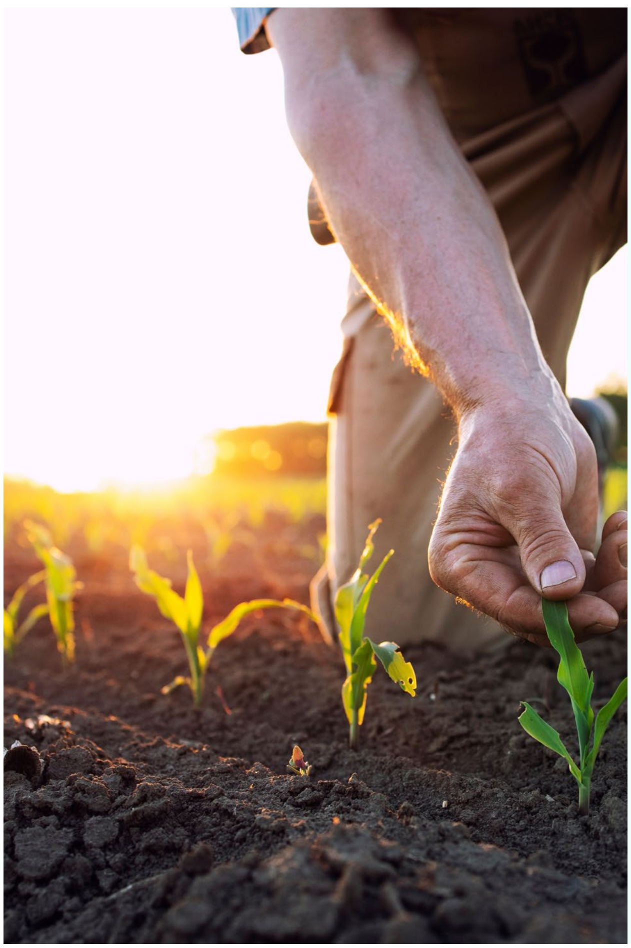
Demand support for carbon removal and ERW will be needed in the medium- to long-term. A market for carbon removal cannot exist without demand or buyers willing (or required) to pay for carbon removal credits. Globally, demand-side policies could increase durable CDR demand to cover up to 30% of global residual emissions.[xvii] Government procurement—such as DOE's CDR Purchase Pilot Prize—is one example of a demand-side policy. Opportunities to create long-term demand signals include: longer-term procurement policies on the order of 10 years or more, procurement requirements as part of countries' Nationally Determined Contributions (NDCs), and procurement policies that have a 'sunset date' when specified market conditions are met.

ENSURING DATA TRANSPARENCY AND ACCESSIBILITY

Irrespective of the funding avenue, government-supported ERW projects can accelerate learning for the field through transparent and accessible data sharing. For example, DOE's CDR Purchase Pilot Prize could require finalists to share their environmental impact data publicly. Cascade's ERW Data Quarry provides an example of how to encourage data sharing while also ensuring farmer and commercial privacy protection. Government programs should also encourage project developers to adhere to Ag Data Transparent core principles where applicable to protect farmers' data privacy rights.

Encourage farmer adoption through new and existing programs

The long-term success of ERW will depend on significant farmer and agriculture industry buy-in. This will require new business models that move beyond the carbon market paradigm and value the agronomic and environmental benefits ERW provides in addition to carbon removal. Many farmers face economic and logistical challenges in adopting new practices. Governments should explore policies that support farmer adoption of ERW outside of the VCM such as "pay-for-practice" programs that compensate farmers directly for implementing new practices. Existing agricultural pay-for-practice programs in the U.S. are run by the USDA and offer both financial and technical assistance to farmers adopting practices that provide conservation (e.g., soil health, water quality, climate, etc.) benefits.[xviii] The eligibility of these programs could be expanded to include ERW through a new Conservation Practice Standard. Similarly, under the EU's Common Agricultural Programme, farmers can receive payments to adopt sustainable practices through voluntary "eco-schemes". Note that these programs require a strong evidence base that ensures the practice will deliver the desired outcome, as there are minimal post-adoption measurement requirements.



SUPPORTING FARMER ADOPTION OF ERW THROUGH USDA CONSERVATION PROGRAMS

One of USDA's largest conservation programs, the Environmental Quality Incentives Program (EQIP), provides up to a 75% cost-share for farmers to implement a new conservation practice. For farmers to access this funding, there must be a federal Conservation Practice Standard that has been adapted and modified by the state in which the farmer is applying for funding.[xix] There is currently an interim Conservation Practice Standard for amending soils with agricultural lime (iCPS 805). If adopted at the federal level, states may have the opportunity to adopt a modified version that includes other ERW feedstocks such as silicates. Farmers would then be able to apply for EQIP funding to implement ERW.

Increase Confidence in Carbon Markets

While a shift towards greater public support for ERW is expected in the coming years, private-sector carbon financing will be the primary driver of ERW projects in the near term. However, prospective carbon removal buyers and investors have shown hesitancy in entering the market due to uncertainty around the durability and credibility of carbon removal credits, a lack of regulatory clarity, and overall market immaturity. Governments can help increase carbon removal buyers' and investors' confidence in the market through non-financial market levers that help address concerns around a lack of rigor and regulatory clarity.

Identify or develop high-rigor standards

The voluntary carbon market has seen numerous challenges around rigor and efficacy in recent years, and some governments recognizing the value of a functioning VCM have intervened to provide support. The level of intervention has varied depending on the jurisdiction (Figure 5); for example, the EU is exploring a regulatory framework for CDR credits through its Carbon Removal and Carbon Farming (CRCF) regulation in which the EU will develop standards for various CDR pathways and set up an EU registry for CDR units, while the U.S. has taken a more hands-off approach. USDA has recently created a program authorized by the bipartisan Growing Climate Solutions Act to review VCM protocols for agriculture and forestry practices. Whether developing new standards or approving existing ones, governments have a role in clearly defining what constitutes "high-quality" to improve market integrity and certainty.

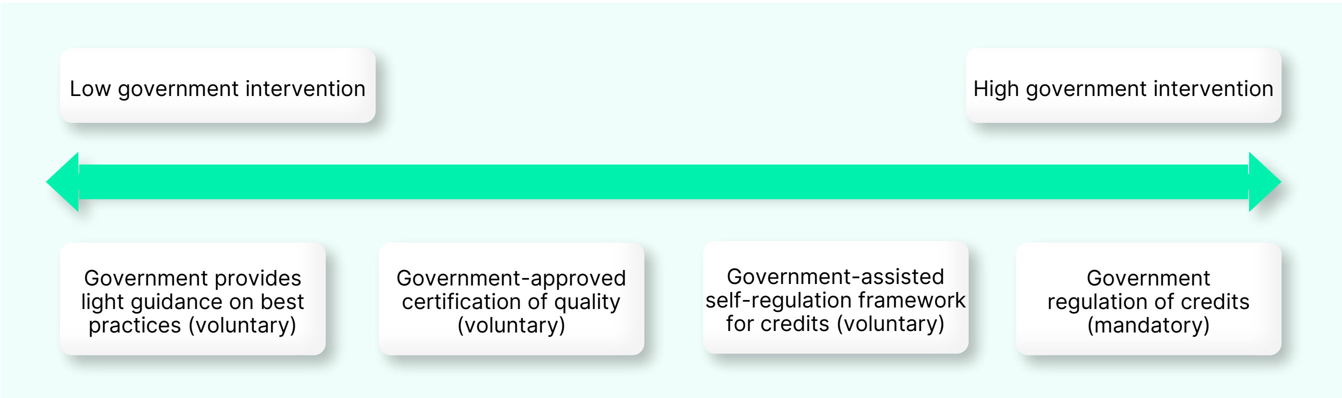


Figure 5. Spectrum of government intervention in carbon markets.
Adapted from Table 2 in the Bipartisan Policy Center and Carbon Direct's Government Intervention in Support of Quality Carbon Credits report available at: https://bipartisanpolicy.org/report/carbon-credit-report/.

Clarify accounting of ERW in jurisdictional frameworks

Various jurisdictions are exploring how to best account for carbon removals in existing and proposed policies. For example, there are ongoing discussions around creating a separate target for carbon removals as part of the EU's 2040 climate target. Some jurisdictions may consider incorporating all land-based carbon removals—including ERW—as part of the land use, land use change, and forestry (LULUCF) sector, rather than in a separate removals section. When evaluating the best approach for accounting of carbon removals from ERW, jurisdictions should ensure clarity, avoid discouraging action on climate mitigation (e.g., mitigation deterrence), and consider interoperability with other policies. The clarity provided by separate targets for carbon removals and LULUCF can spur new CDR demand.

Set clear regulatory timelines

It can take years to create and implement new regulations because of the nature of bureaucratic processes. For example, the EU Commission has indicated that the first CDR units through the CRCF Regulation are expected in 2026 and 2027, with a registry expected by 2028. While this is a great first step at providing transparency, the Commission should consider going a step further in providing a clear timeline for each CDR pathway (even if estimated), so buyers and project developers are better able to plan around when an EU methodology and EU-minted units will be available. Cascade has made the case that rigorous ERW MRV methodologies are needed now to support the deployment led learning cycle. The EU Commission should consider ERW as part of the next wave of methodologies they develop under the EU CRCF process.

Comparison of the EU and U.S. Flagship CDR Programs

The U.S. and EU have both been leaders in CDR policy, but have taken differing approaches: the EU has focused on regulatory and compliance policies, while the U.S. government has placed greater emphasis on funding innovation and deployment of CDR.

	EU Carbon Removal and Carbon Farming Regulation	U.S. DOE CDR Purchase Pilot Prize
Description	The EU Carbon Removal and Carbon Farming regulation is a precedent-setting voluntary regulatory framework to certify carbon removals and create an EU-wide registry.	DOE's CDR purchase pilot prize program is the first effort by a government to purchase CDR credits directly from project developers.
CDR Pathways Included	Inclusive of carbon farming (e.g., practices that enhance carbon sequestration and storage in forests and soils), temporary storage in long-lasting products, and permanent carbon removal. ERW is categorized as a permanent carbon removal pathway, rather than a carbon farming technique.	Inclusive of Direct Air Capture (DAC), biomass carbon removal and storage (BiCRS), enhanced geological weathering or ERW, and alternative or managed carbon sinks. Three ERW projects are semi-finalists in Round 1.
Approach to MRV	MRV standards are developed by the EU Commission with support from a designated "Expert Group".	MRV plans are developed and implemented by project developers and their designated MRV implementation partner. Plans are evaluated by the DOE and contracted expert reviewers.
Funding Amount	No project funding is available through the regulation, but the EU is exploring other avenues to publicly fund CDR.	$35 million for Round 1.
Timeline	The first methodologies will be completed by 2026, with the first units expected to be generated by 2026/2027. A registry will be set up by 2028.	Round 1 winners are anticipated to be announced in December 2025. A Round 2 is expected, but has yet to be announced.
How can "Foundations" be used to support this program?	The EU Commission can use "Foundations" as a reference in the development of the initial technical scoping paper for ERW and any further methodology development efforts.	DOE can use "Foundations" as a reference when evaluating MRV plans in ERW project proposals and the implementation of those plans.

Conclusion

Enhanced Rock Weathering (ERW) provides a transformative opportunity to simultaneously tackle global soil health challenges while delivering durable carbon removal at scale. By addressing soil acidification and reducing input costs, ERW has potential to not only improve agricultural productivity, but also to support farmer livelihoods.

However, realizing this dual potential requires concerted policy action and investment to answer remaining priority R&D questions, address barriers to scale, and increase carbon removal buyer and investor confidence in the market. This government support can start a virtuous learning-by-doing cycle, driving down costs, improving MRV methods, and supporting responsible adoption across diverse agricultural landscapes.

Ultimately, a well-supported ERW field has the potential to play a critical role in achieving global carbon removal targets while ensuring resilient and sustainable food systems for future generations.

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