Unlocking nature-based solutions through carbon markets in the USA

TECHNICAL REPORT

David Landholm
Felipe Bravo
Ivan Palmegiani
Charlotte Streck
Gabriela Martinez de la Hoz
Simon König
Melaina Dyck
Szymon Mikolajczyk

21 December 2022

CLIMATE FOCUS

Acknowledgments

This technical report is one in a series produced by Climate Focus and the Food and Land Use Coalition (FOLU). Since September 2021, Climate Focus and FOLU have been collaborating on a research project around financing strategies for terrestrial nature-based solutions (NbS) at a country and global level. The ultimate objective of the project is to enable public and private decision-makers to prioritize and deploy activities and investments that will unlock the potential of NbS for climate mitigation, adaptation, resilience, biodiversity and beyond. Our current report series includes the publication of country-based assessments in Kenya & Colombia, as well as global analyses focused on the voluntary carbon market. For more information about the project, please see below.

Authors: David Landholm, Felipe Bravo, Ivan Palmegiani, Charlotte Streck, Gabriela Martinez de la Hoz, Simon König, Melaina Dyck, Szymon Mikolajczyk

Design: Elisa Perpignan, Sara Cottle, Ivan Palmegiani

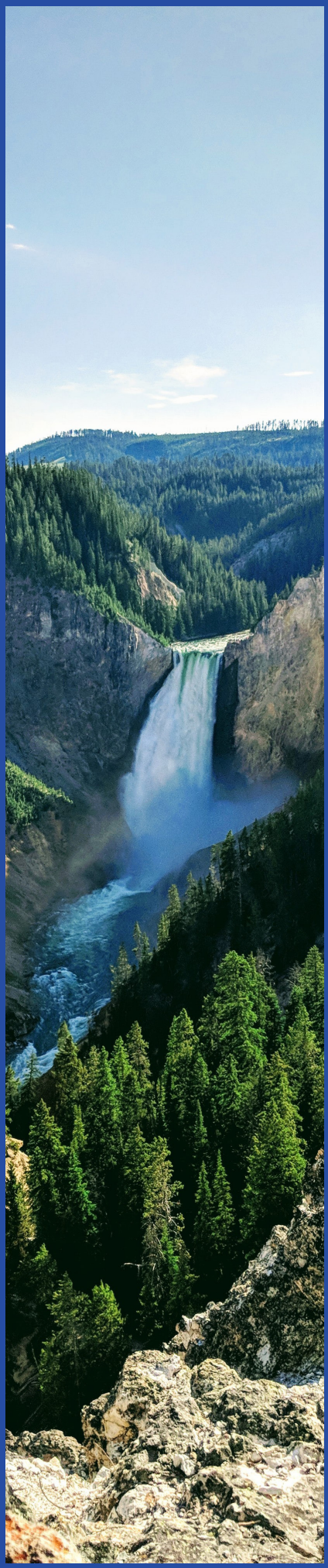
This report has received generous support from the Quadrature Climate Foundation.

Quadrature Climate Foundation

It has been produced in partnership with SYSTEMIQ.

SYSTEMIQ
Talia Smith
Scarlett Benson
Mitch Groves
Abel Hemmelder
Natasha Mawdsley
Alessandro Passaro
Alex Andreoli

Climate Focus would like to thank Stefanie Roe (WWF) for contributing time and energy to provide input on the model.



Acronyms

A/R Afforestation and Reforestation

AD Avoided Deforestation

AFOLU Agriculture, Forests and Other Land Use

AG Agriculture

BAU Business-as-usual

CEMP Cost Effective Mitigation Potential

FAO Food and Agriculture Organization

GHG Greenhouse Gas

IAM Integrated Assessment Model

IDEAM Instituto de Hidrología, Meteorología y Estudios Ambientales

IFM Improved Forest Management

MACC Marginal Abatement Cost Curves

MRV Measuring, Reporting and Verification

NBS Nature-Based Solutions

NDC Nationally Determined Contribution

PA Protected Areas

UNFCCC United Nations Framework Convention on Climate Change

VCM Voluntary Carbon Market

VCS Verified Carbon Standard

WL Wetlands

Introduction

An effective and efficient transition to low-carbon economies will be required over the next three decades to achieve the goals of the Paris Agreement and avoid the worst impacts of a changing climate. In addition to cutting greenhouse gas (GHG) emissions in half each decade, the global economy must also make significant investments in carbon removals to have a high probability of limiting warming to 1.5°C or 2°C by 2100.[1]

Nature-based solutions (NbS) – actions that protect and enhance carbon stored in natural ecosystems and reduce GHG emissions – are essential climate strategies, yet only receive a fraction of global finance. Although the global climate mitigation potential of terrestrial NbS has been estimated at 9-14 $GtCO_2e\ yr^{-1}$,[1,2,3] only 3% of public climate mitigation funding is allocated to NbS, compared to 38% to renewable energies alone.[4] At best, the current level of funding for forest protection, restoration, and enhancement only reaches 5% of the estimated total needed to align with the Paris Agreement's 1.5 °C targets,[5] indicating a drastic shortfall in climate finance for forests.

Markets for environmental services have a long history in the United States (U.S.), both voluntary markets and compliance markets such as cap-and-trade schemes. Examples of compliance markets include the U.S. Environmental Protection Agency (EPA)'s Acid Rain Program to reduce sulfur dioxide emissions for coal power plants launched under the 1990's amendments to the Clean Air Act,[6] and water quality trading managed by EPA and the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS).[7] Wetland mitigation banking under the Clean Water Act, in which agricultural and development activities purchase wetland credits to compensate for impacts on wetlands, is another important compliance market in the U.S. for environmental services.[8]

State and regional-level compliance carbon markets are active in the U.S. and are important reference points for existing forest and agriculture-related carbon credit trading. The cap-and-trade programs of the California Air Resources Board (CARB) and the Regional Greenhouse Gas Initiative (RGGI) allow the use of forest offsets:[9] CARB allows offsetting of up to 8% of allowable emissions and facilitates trading with the cap-and-trade programs in Quebec and Ontario. As of 2015, CARB had issued 7.2 million forest offset credits for voluntary early actions taken from 2004-2014. In the U.S., RGGI is the oldest mandatory, market-based greenhouse gas emissions reduction program. It permits 3.3% of obligations for each period to be offset with emission

---

1 This decarbonization roadmap translates to reducing global CO_2 emissions to 20 Gt $CO_2\ yr^{-1}$ by 2030, 10 Gt $CO_2\ yr^{-1}$ by 2030 and 5 Gt $CO_2\ yr^{-1}$ by 2050. Rockström, J., Gaffney, O., Rogelj, J., Meinshausen, M., Nakicenovic, N., & Schellnhuber, H. J. (2017). A roadmap for rapid decarbonization. *Science*, *355*(6331), 1269–1271.

2 Roe, S., Streck, C., Beach, R., Busch, J., Chapman, M., Daioglou, V., et al. (2021). Land-based measures to mitigate climate change: Potential and feasibility by country. *Global Change Biology*, *27*(23), 6025–6058.

3 To illustrate the scale of these numbers: the Climate Action Tracker estimated China's 2021 GHG emissions to be at 14.1 $GtCO_2e$, and the International Energy Agency estimated global transport emissions for 2019 at 8.5 $GtCO_2e$. Tracking Transport 2021. (2021). *IEA*. Retrieved July 26, 2022, from https://www.iea.org/reports/tracking-transport-2021.

4 Buchner, B., Baysa Naran, & de Aragão Fernandes, P. (2022). Global Landscape of Climate Finance 2021. *Climate Policy Initiative (CPI)*. Retrieved August 1, 2022, from https://www.climatepolicyinitiative.org/publication/global-landscape-of-climate-finance-2021/.

5 NYDF Assessment Partners. (2021). *Taking stock of national climate action for forests*. Retrieved August 1, 2022, from https://forestdeclaration.org/resources/taking-stock-of-national-climate-action-for-forests/.

6 Portney, P. R. (2003, republished 2020). Market-Based Approaches to Environmental Policy: A "Refresher" Course. Retrieved from https://www.resources.org/archives/market-based-approaches-to-environmental-policy-a-refresher-course/.

7 Ribaudo, M., Hansen, L., Hellerstein, D., & Greene, C. (2008). *The Use of Markets To Increase Private Investment in Environmental Stewardship* (No. 64). Retrieved from https://www.ers.usda.gov/webdocs/publications/46066/11941_err64_1_.pdf?v=4876.3.

8 Wetland Mitigation Banking Program. (n.d.). Retrieved from http://www.nrcs.usda.gov/wetland-mitigation-banking-program; Mitigation Banks under CWA Section 404. (2022). Retrieved from https://www.epa.gov/cwa-404/mitigation-banks-under-cwa-section-404.

9 Schultz, J. State Forest Carbon Incentives and Policies. *National Conference of State Legislatures*. Retrieved from https://www.ncsl.org/research/environment-and-natural-resources/state-forest-carbon-incentives-and-policies.aspx.

reductions from activities including reforestation, improved forest management (IFM), and avoided conversion.[10]

Carbon markets have significantly gained momentum over the last two years, particularly through a demand for NbS credits. This increase in demand is largely driven by companies relying on carbon markets to realize their mitigation commitments or to offset a portion of their emissions.[11,12] Although there is a lot of uncertainty, some estimates of the global carbon market demand reach 3-9.5 $GtCO_2e$ by 2050.[13]

Carbon markets provide an opportunity for the U.S. to channel finance into sustainable land use in the absence of comprehensive climate legislation. However, potential mitigation supply from carbon markets in the U.S., which covers a wide range of NbS, is currently unknown. Studies tend to focus on global demand, cover a limited set of NbS, and typically disregard other supply constraints other than price. In reality, carbon market investments face barriers across multiple dimensions that go beyond an economic dimension.

This technical report addresses these knowledge gaps and examines the role that carbon markets may play in the short and mid-term in the U.S. with regards to unlocking NbS mitigation potential. Specifically, the objectives of this report are fourfold:

1. to model what is the projected NBS mitigation potential supply of carbon markets in the U.S. over the 2021-2050 period;
2. to better understand the role that different feasibility barriers may play in relation to unlocking carbon markets' full mitigation potential;
3. to spatially identify the areas where the mitigation potential is concentrated in the U.S. across policy-relevant management units (i.e. at a state level); and
4. to determine what share of NbS potential is currently unlocked by carbon markets.

This report forms part of a series of technical country-specific reports.[14] The methodological approach piloted in these countries will be applied analogously at a higher scale in an upcoming global study to better understand how much NbS mitigation potential can be supplied from carbon markets.

[10] Nine states currently participate in RGGI. Schultz, J. (2021).

[11] Verra - Data and Insights VCS Quarterly Update on Q1/2020. (2020). *Verra*. Retrieved from https://verra.org/datainsights/april-2020/.

[12] Since 2017, carbon credits' issuance grew from 49 to 300 $MtCO_2e$ in 2021, amounting to a market value of 748 billion in the first eight months of 202. More than 53% of these credits derive from NbS projects, of which 72% comes from developing countries. Donofrio, S., Maguire, P., Zwick, S., & Merry, W. (2020). *Voluntary Carbon and the Post-Pandemic Recovery: A Special Climate Week NYC 2020 Installment of Ecosystem Marketplace's State of Voluntary Carbon Markets 2020 Report*. Retrieved from https://wecprotects.org/wp-content/uploads/2020/11/EM-Voluntary-Carbon-and-Post-Pandemic-Recovery-2020.pdf.; Verra - Data and Insights VCS Quarterly Update on Q4/2021. (2022). *Verra*. Retrieved August 1, 2022, from https://verra.org/datainsights/data-and-insights-january-2022/.

[13] Trove Research (2021). Future Demand, Supply and Prices for Voluntary Carbon Credits. Retrieved from https://trove-research.com/wp-content/uploads/2021/06/Trove-Research-Carbon-Credit-Demand-Supply-and-Prices-1-June-2021.pdf.

[14] As of November 2022, country reports have been released for Colombia and Kenya. Retrieved from https://climatefocus.com/publications/

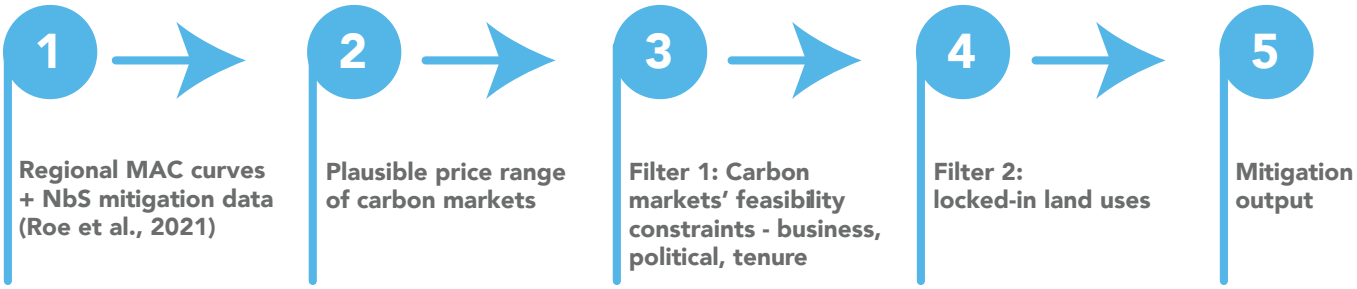
Methodological approach

To address the research gaps outlined above, we have developed a country-level model that explores how much mitigation potential can be unlocked by the NbS activities of Afforestation/ Reforestation (AR), Agriculture (AG)[15], the conservation and restoration of Wetlands (WL), and IFM, through the assessment of both economic and other country-specific constraints (**Figure 1**). The Avoided Deforestation activity is not considered.[16] Specifically, the model accounts for

1. the mitigation potentials of the four activities in the U.S.[17] and a wide range of carbon market price scenarios over time,
2. the feasibility barriers to implementation of these measures, related to ease of doing business, land tenure, and political factors, and
3. the on-the-ground restrictions posed by pre-existing land uses or areas that do not comply with additionality criteria (hereafter referred to as "locked-in land uses"). We consider mining concessions, oil and gas concessions, and protected areas. We assume here that protected areas in the U.S. already maximise the environmental return within its area and hence do not satisfy the additionality requirements of carbon standards. The country level estimates obtained through the model are further disaggregated at the State level based on secondary, spatially explicit data. These are used to determine the higher-priority areas for carbon market uptake in the U.S.

A visual overview of the methodology can be found in Figure 1, while a detailed description of the model and approach can be found in the Annex (Methodology). The methodology does not assess particular standards nor their historic performance, but rather estimates the available mitigation potential of these NbS activities for the overall market.

Figure 1: Schematic overview of the methodology applied to obtain the Nature-based Solutions (NbS) mitigation potential from carbon markets in the U.S.



[15] The "Agriculture" activity includes mitigation potential from activities that reduce emissions and/or remove CO_2 from the atmosphere and store it in the soil and biomass. Specifically, the following activities are considered: Enteric fermentation, manure management, improved rice production, nutrient management, soil carbon sequestration on grasslands, soil carbon sequestration on croplands, agroforestry, and biochar.

[16] The cost-effective mitigation potential from Avoided Deforestation in the U.S. is zero according to Roe et al. (2021), which is the reason why we don't consider this activity in the report. In practice, there are Avoided Deforestation projects that generate credits in the U.S. but their potential is limited and surrounded by controversy in relation to their additionality claims. This is discussed in more detail in the discussion section.

[17] Roe et al. (2021).

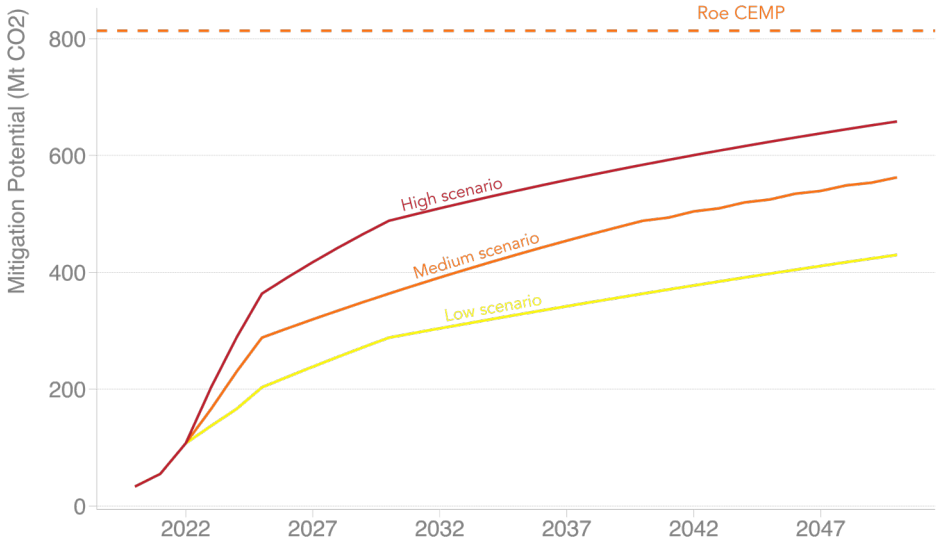
Results and discussion

Under current constraints, carbon markets hold the potential to unlock 37.9-61.1% of the mitigation potential of NbS in the U.S. over three decades (9.26 - 14.92 $GtCO_2e$ of 24.41 $GtCO_2e$ available after 30 years) (**Figure 2**). Carbon markets could unlock up to 137.2-203.1 $MtCO_2e\ yr^{-1}$ by 2023, 288.3-488.3 $MtCO_2e\ yr^{-1}$ by 2030 and reach 430.0-658.3 $MtCO_2e\ yr^{-1}$ by 2050. This represents only 16.9-25.0% of its available mitigation potential (813.5 $MtCO_2e$ yr-1) by 2023 and 52.9-80.9% by 2050 of their available mitigation potential.

As shown in Figure 2, there is a steep increase of carbon-market driven mitigation potential in the first half of the 2020 decade, followed by a second period where its growth continues following a more moderate trajectory. These broad dynamics are determined mainly by the regional Marginal Abatement Cost Curves (MACC), which reflect decreasing amounts of mitigation unlocked as prices increase beyond a certain threshold (an example is shown for the Agriculture activity in **Figure 5**, **Annex**). After accounting for the different constraints (price, implementation feasibility, and spatial location), the modeled available mitigation potential for all three scenarios is much lower than Roe et al. (2021)'s cost-effective mitigation potential (orange line in **Figure 2**).

In terms of activities, Agriculture dominates the carbon markets in the U.S., with 76% of the total potential, followed by Afforestation/Reforestation (16%), Improved Forest Management (7%) and the Conservation and Restoration of Wetlands (<1%) (**Figure 3**).[18]

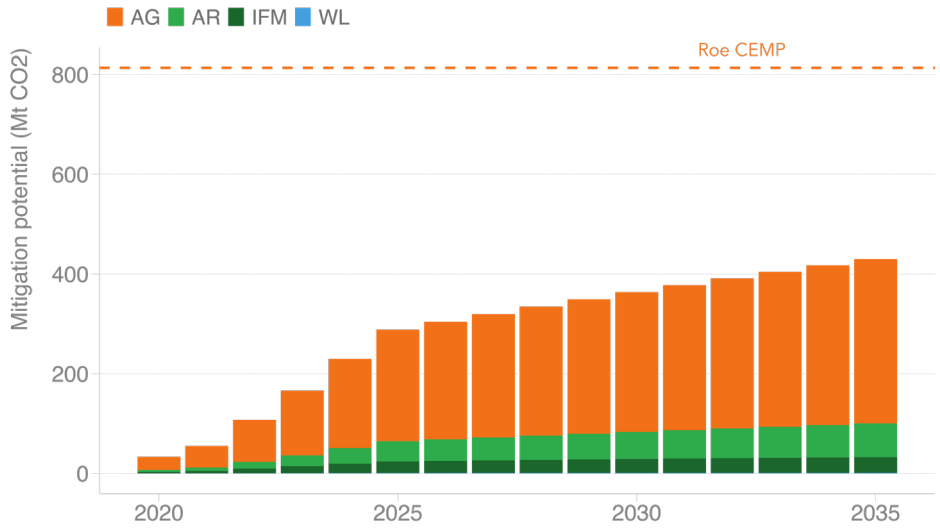
Figure 2: Carbon markets' mitigation potential for Nature-based Solutions (NbS) measures in the U.S. (Agriculture, Afforestation/Reforestation, Improved Forest Management, and the Conservation and Restoration of Wetlands) for three price scenarios (high, medium, low). Average cost-effective mitigation potential (CEMP) over the 2020-2050 period is shown for reference.[19]



[18] As mentioned in the methods section, the Avoided Deforestation activity is not assessed in this report. The cost-effective mitigation potential from Avoided Deforestation in the U.S. is zero according to Roe et al. (2021), which is the reason why we don't consider this activity in the report. In practice, there are Avoided Deforestation projects that generate credits in the U.S., but their potential is limited and surrounded by controversy in relation to their additionality claims. This is discussed in more detail in the discussion section.

[19] Roe et al., (2021).

Figure 3: Carbon markets' mitigation potential by Nature-based Solutions (NbS) measure in the U.S. (Agriculture, Afforestation/Reforestation, Improved Forest Management, and the Conservation and Restoration of Wetlands) for a medium price scenario. Average cost-effective mitigation potential (CEMP) over the 2022-2050 period is shown for reference.[20]



According to the model output, the available carbon market potential for Agriculture in the U.S. reaches 280.4 $MtCO_2e\ yr^{-1}$ by 2030 under the medium price scenario of USD 40 per tonne (low-high range, 223.6-371.9 $MtCO_2e\ yr^{-1}$). Using a combination of secondary datasets, and after filtering out locked-in land uses, the model estimates the potential for this activity to be largest for the states of Texas, Kansas, and Iowa with 5.7%, 4.6%, and 4.3% of the potential, respectively (see **Figure 4a** and **Annex Table 3**).

Carbon markets' available mitigation potential for Afforestation/Reforestation in the U.S. reaches 54.21 $MtCO_2e\ yr^{-1}$ by 2030 under the medium price scenario (40.65-81.31 $MtCO_2e\ yr^{-1}$). The available potential for this activity is most relevant for the states of Tennessee, North Carolina, and Missouri with 6.5%, 6.4%, and 5.9%, respectively (see **Figure 4b**).

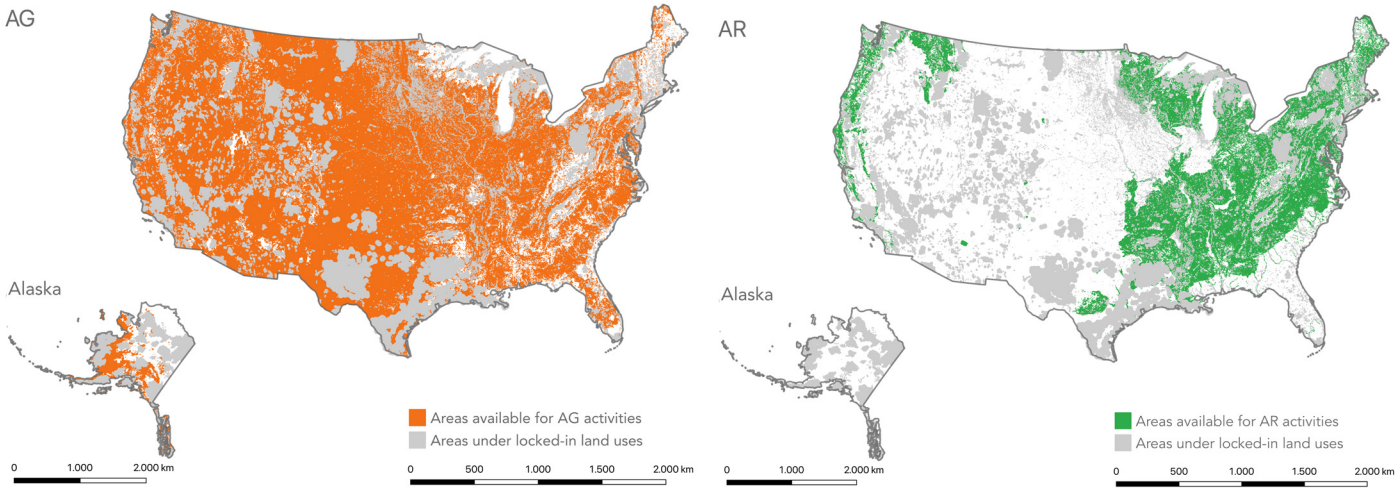
The mitigation potential for Improved Forest Management activities in the U.S. reaches 27.91 $MtCO_2e\ yr^{-1}$ by 2030 under the medium price scenario (23.14-33.68 $MtCO_2e\ yr^{-1}$). The carbon market potential for the Conservation and Restoration of Wetlands in the U.S. increases to 1.07 $MtCO_2e\ yr^{-1}$ by 2030 under the medium price scenario (0.86-1.4 $MtCO_2e\ yr^{-1}$). There is a lack of spatially explicit secondary data for mitigation potential of the Improved Forest Management and Wetland activities, which constitute 5.1% of the U.S. NbS potential. For these activities we only provide model results at the country level and do not attempt to disaggregate spatially by State.[21]

To generate all the results presented above, a relatively large amount of mitigation potential was discounted from the model due to overlaps with locked in land uses (oil and gas concessions, mining concessions, and protected areas). Specifically, these existing land uses overlapped with 21.2% and 11.1% of the Agriculture and Afforestation/Reforestation mitigation potential, respectively.

[20] Roe et al., (2021).

[21] For Improved Forest Management and Wetlands we discount the average percent (%) of overlap from the two other activities (Afforestation/Reforestation and Agriculture) with locked in land uses.

Figure 4: Distribution of mitigation potential in the U.S. for a) Agriculture (FAO, 2022) and b) Afforestation/ Reforestation (Cook-Patton et al., 2020; Griscom et al., 2017). Locked-in land uses such as protected areas, mining, and oil and gas concessions have been removed from the original datasets. The difference between the initial potential and final potential, after accounting for these areas removed, is recorded, and provides the second feasibility filter (%) that is applied to our country-level model estimates. **Table 3** *in the* **Annex** *presents the disaggregated potential by States.*



Currently, the voluntary carbon market (VCM) is unlocking around 1.5% of the available mitigation potential simulated in our model in the U.S.[22] To assess current projects and issuances in the U.S. we analyzed data from four leading standards, Verra's Voluntary Carbon Standard (VCS), Gold Standard (GS), American Carbon Registry (ACR), and Climate Action Reserve (CAR).[23] Together, all these standards globally account for over 90% of the transactions in the VCM.[24] This comparison is considering exclusively emission reductions occuring in the context of projects that are not eligible for compliance markets.[25]

For Agriculture, there are only five projects in the U.S. currently registered or completed in the VCM, located in the states of Arkansas, California, Iowa, Massachusetts, and Michigan. Nearly all of the carbon credit issuances to date (97%) come from the "Indigo U.S. Project No.1". Although this project is formally registered in Massachusetts, it focuses on promoting a range of agricultural management practice changes targeted at increasing soil organic carbon (SOC) storage and reducing net emissions of CO_2, CH_4, and N_2O from farms throughout the continental U.S., already reaching 21 states.[26] Other projects in this category include the N_2O reducton in corn crops and emission reductions in rice management systems. Projects in the Agriculture category have, on average, unlocked a negligible 0.002% of the annual mitigation potential available from this activity (i.e., 0.01 out of 309.7 $MtCO_2e\ yr^{-1}$) (**Table 2**).

[22] For context, in a forthcoming report that examines all countries with VCM projects, Climate Focus finds that VCM currently unlocks about 1% of NbS mitigation potential globally from the five activities examined.

[23] There are more carbon standards operating in the voluntary carbon markets with projects based in the U.S., e.g., City Forest credits (https://www.cityforestcredits.org/carbon-credits/carbon-registry/). However, given the small volumes issued by these standards (0.06 MtCO2e in the case of City Forest Credits) we focus our analysis on the pipeline of the four main carbon standards which represent over 90% of the transactions in the carbon markets globally.

[24] Voluntary carbon markets for NbS activities in the U.S. have developed largely outside of the major carbon standards overseeing VCMs globally (e.g., Verified Carbon Standard and Gold Standard). This is not surprising given the long history of environmental markets in the U.S. and focus of the major global VCM standards to drive emission reductions and removals in the Global South (to some degree, a legacy of the Clean Development Mechanism).

[25] The dataset we use (see https://climatefocus.com/initiatives/voluntary-carbon-market-dashboard/) doesn't consider compliance-eligible credits. When accounting for compliance-eligible credits, the overall mitigation potential currently unlocked by carbon markets – in the broader sense of the term – would be larger than the reported 1.5%.

[26] For more details of this project: The Reserve. (2018). CAR1459: Indigo U.S. Project No.1. Retrieved from https://thereserve2.apx.com/mymodule/reg/prjView.asp?id1=1459.

For Afforestation/Reforestation, 21 registered or completed projects have, on average, unlocked 4.4% of the annual mitigation potential suggested by the model (i.e., 2.87 out of 65.7 $MtCO_2e\ yr^{-1}$). Nearly half of the carbon credit issuances come from the "GreenTrees ACRE" project, located in the state of Arkansas, which uses tree planting to establish trees on lands that have been in continuous agricultural use and have not been in a forested state for ten years.[27] This project category represents 47% of average annual emissions reductions from the VCM in the U.S. since 2010.

For Improved Forest Management, 53 registered or completed activities have unlocked 10.7% of the annual mitigation potential calculated (3.08 of 28.7 $MtCO_2e\ yr^{-1}$). The largest project in terms of carbon credits issuances is the "Usal Redwood Forest" in the Mendocino County, California, with 30,5% of the carbon credits issuances for this category. The Redwood Forest Foundation is restoring the forest, planting redwoods and using sustainable harvesting practices that promote biodiversity, enhance carbon storage, and support local economies.[28] This project category represents 51% of average annual emissions reductions from the VCM in the U.S. since 2010.

Lastly, the 17 registered Wetlands projects, have unlocked, on average, 8.1% of the annual available mitigation potential suggested by our model for this activity (i.e., 0.11 out of 1.33 $MtCO_2e\ yr^{-1}$). Half of the issuances in this category come from three projects: "Prairie Pothole Avoided Conversion of Grasslands and Shrublands" located in North Dakota (21.6%), and "Blue Source – Pungo River Forest Conservation Project" (15.5%) and "Alligator River Avoided Conversion" (12.8%), located in North Carolina. This project category represents 2% of average annual emissions reductions from the VCM in the U.S. since 2010.

Since 2010, projects developed under ACR and CAR standards have dominated emission reductions in the U.S. with 76% and 22%, respectively (Table 2). The ACR and CAR standards have a long history and were developed primarily for application in the U.S. – most projects there issue credits under these standards. Overall, these standards have a good reputation in relation to well-known international standards and don't perform unfavorably in relation to quality controls, ensuring sound governance, permanence,[29] or the establishment of baselines.[30] In regard to activities covered by standards, 93% of emissions covered by CAR are Improved Forest Management activities, while, in contrast, 62% and 37% of emissions covered by ACR arise from Afforestation/Reforestation and Improved Forest Management, respectively. VCS only represents 3% of NbS emission reductions – all related to Improved Forest Management. The emission reductions achieved under Gold Standard projects has been negligible so far.[31]

[27] For more details of this project: American Carbon Registry. (2008). Project ID: ACR114. Retrieved from https://acr2.apx.com/mymodule/reg/prjView.asp?id1=114.

[28] For more details of this project: The Reserve (2007) Project ID: CAR730. (2007). Retrieved from https://thereserve2.apx.com/mymodule/reg/prjView.asp?id1=730 and The Usal Redwood Forest Company. (n.d.). About. *USAL Redwood Forest Company*. Retrieved from https://www.usalredwoodforestcompany.com/.

[29] For instance, both CAR and ACR have longer minimum periods for the monitoring for reversals than GS and VCS, and stronger requirements to compensate for reversals should they occur.

[30] CAR and ACR require adjusting baselines or withdrawing a project to reflect new policies and regulations as soon as they enter into force, while other standards typically don't.

[31] Gold Standard only presents one Afforestation/Reforestation activity. It's average annual emissions reductions amount to 0.13% of the total.

Table 1: Breakdown of Nature-based Solutions (NbS) mitigation potential and mitigation delivered by the voluntary carbon markets (VCM) per activity. The average annual emission reductions delivered by the VCM are calculated by averaging the verified emissions reductions of different monitoring periods for each project. Data includes until September 2022.

Activity type	Roe et. al. CEMP ($MtCO_2e$ yr-1)	CEMP ($MtCO_2e$ yr-1) (model output, after filters)[32]	Average annual ERs delivered by VCM ($MtCO_2e$ yr-1)[33]	% of CEMP unlocked by VCM[34]
AG	619.3	309.7	0.01	0.0%
AR	152.4	65.7	2.87	4.4%
IFM	39.6	28.7	3.08	10.7%
WL	2.2	1.3	0.11	8.1%
Total	813.5	405.3	6.06	1.5%

Table 2: Breakdown of average annual emission reductions delivered by the VCM by NbS activity (columns) and standard (rows). The average annual emission reductions delivered by the VCM are calculated by averaging the verified emissions reductions of different monitoring periods for each project. Data includes until September 2022.

Standard	ACTIVITY			
	Afforestation / Reforestation	Agriculture	Improved Forest Management	Wetlands
CAR	0	0,01	1,22	0,08
ACR	2,86	0,00	1,70	0,03
VCS	0	0	0,16	0
GS	0,01	0	0	0

Although Agriculture represents the activity with largest potential, in practice numerous barriers hinder the proliferation of agriculture carbon projects.[35] These barriers are not specific to the U.S. but affect the development of Agriculture projects generally. A major constraint is related to the need for cost-effective methods for measurement, reporting, and verification (MRV) of soil organic carbon stock changes from Agriculture projects.[36] Moreover, models which link interventions to SOC changes still require further development. In addition, permanence issues also represent a source of uncertainty with regard to unlocking carbon projects in agriculture. Although questions of permanence affect most removal activity categories, it is particularly challenging in the context of agriculture, where practices can change quickly on an annual basis. Finally, in addition to these technical barriers, there are numerous cultural challenges that need

[32] This is calculated by dividing the mitigation potential per activity type obtained with the medium scenario of our model for the period 2021-2050, divided by the length of the period (i.e., 30 years). The model's underlying methodology can be found in the Annex of this document.

[33] We assess current projects and issuances in the US from four leading standards: Verra's Voluntary Carbon Standard (VCS), Gold Standard (GS), American Carbon Registry (ACR), and Climate Action Reserve (CAR). The average ERs delivered by the VCM are calculated based on the vintage years of the issuances reported in the carbon standards databases. The databases include the corresponding vintage year for each carbon credit issuance. We calculate the average ERs delivered by averaging the issuances of each vintage year for each project and activity type.

[34] Average annual ERs delivered by VCM divided by CEMP (model output, after filters).

[35] Wongpiyabovorn, O., Plastina, A., & Crespi, J. M. (2022). Challenges to voluntary Ag carbon markets. *Applied Economic Perspectives and Policy*. Retrieved from https://onlinelibrary.wiley.com/doi/full/10.1002/aepp.13254.

[36] Villegas, D., Bastidas, M., Matiz-Rubio, Ruden, A., Rao, Hyman, et. al. (2021). *Soil carbon stocks in tropical pasture systems in Colombia's Orinoquía region: supporting readiness for climate finance - CCAFS Info Note*. Retrieved from https://cgspace.cgiar.org/bitstream/handle/10568/116231/2021%20Info%20Note%20SOC_WB_HSJ_Final_Nov_22.pdf.

to be overcome for farmers to change their practices – they will likely only do so if there is a clear business case and if these activities are strongly promoted.

Furthermore, the development of standards for Agricultural NbS activities are comparably recent in relation to methodologies for AR and IFM.[37] The lack of available methodologies applicable to Agriculture projects is another reason behind the relatively low number of projects in this sector. Until recently, the only regenerative agricultural carbon project opportunities were centered around grassland management and rotational grazing. For instance, the methodologies "Methodology for Improved Agricultural Land Management" and "Soil Enrichment Protocol" were published only by the end of 2020 under Verra's VCS and CAR, respectively.[38] To date, two projects in the US applying the methodology "Methodology for Improved Agricultural Land Management" are in the registration process with Verra, and two applying the methodology "Soil Enrichment Protocol" have been recently registered under CAR, with 0.02 $MtCO_2e$ issued until Q3 2022.[39] Although the methodology "Adoption of Sustainable Agricultural Land Management", developed by BioCarbon Fund (The World Bank) was published back in 2011 by Verra, it has not experienced a strong uptake and only presents three registered projects.[40]

Additionality concerns affect the development of carbon projects across multiple activities. Regarding Agriculture, not all carbon standards require farmers to change practices to comply with additionality requirements. Some merely require that practices in the field be different from common practices in the area, even if the same practices have been implemented for many years in the field under consideration.[41] This potential credibility concern, which is not specific to the U.S., may limit demand for Agriculture credits and hence affect supply. Regarding other activities in the U.S., numerous quality issues have been flagged in recent years, e.g., related to the additionality of avoided deforestation projects in forested regions that already enjoyed clear protection[42] or related to the systematic over-crediting of forest-based activities.[43] In regard to the former, this issue is largely resulting from the recent emergence of low-quality standards in the U.S.[44] Ultimately, the quality of an individual carbon project is determined, among other factors, by the differences on how standards deal with additionality, permanence, the establishment of baselines, or leakage. To inform buyers on the quality of projects across geographies numerous organizations have emerged[45] to provide ratings on the quality of individual carbon projects, which consider both the quality of the underlying standard and how a project is implemented.

---

[37] Taskforce on Scaling Voluntary Carbon Markets - Final Report. (2021). Retrieved October 11, 2022, from https://www.iif.com/tsvcm.

[38] Climate Action Reserve (2020) *Soil enrichment protocol development*. Retrieved from https://www.climateactionreserve.org/how/protocols/soil-enrichment/dev/ and Verified Carbon Standard (2020) *VM0042 Methodology for Improved Agricultural Land Management, v1.0.* Retrieved from https://verra.org/methodology/vm0042-methodology-for-improved-agricultural-land-management-v1-0/

[39] The VCS projects using this methodology are: (1) VCS3351 – "CIBO Initiative for Scaling Regenerative Agriculture" available at https://registry.verra.org/app/projectDetail/VCS/3351; and (2) VCS3331 – "Arva Carbon Ready USA" available at: https://registry.verra.org/app/projectDetail/VCS/3331. The CAR projects using this methodology are CAR1459 - "Indigo U.S. Project No.1" registered in June 2022, available at: https://thereserve2.apx.com/mymodule/reg/prjView.asp?id1=1459; and CAR1513 – "AgriCapture Soil Enrichment #1", registered in October 2022, available at https://thereserve2.apx.com/mymodule/reg/prjView.asp?id1=1513.

[40] Verified Carbon Standard (n.d.) *VM0017 Adoption of Sustainable Agricultural Land Management, v1.0,* Retrieved November 1, 2022, from https://verra.org/methodology/vm0017-adoption-of-sustainable-agricultural-land-management-v1-0/. The projects using this methodology are (1) VCS1704 - "Agricultural Land Management project in Beed District, India implemented by Godrej Properties Ltd." in India, Available at https://registry.verra.org/app/projectDetail/VCS/1704; (2) VCS1225 – "Kenya Agricultural Carbon Project" in Kenya, available at https://registry.verra.org/app/projectDetail/VCS/1225; and (3) VCS1532 – "COMACO Landscape Management Project" in Zambia, available at https://registry.verra.org/app/projectDetail/VCS/1532

[41] Wongpiyabovorn, O. et al. (2022).

[42] Elgin, B. (2020). These trees are not what they seem. How the Nature Conservancy, the world's biggest environmental group, became a dealer of meaningless carbon offsets. *Bloomberg*. Retrieved from https://www.bloomberg.com/features/2020-nature-conservancy-carbon-offsets-trees/.

[43] Badgley, G., Freeman, J., Hamman, J. J., Haya, B., Trugman, A. T., Anderegg, W. R. L., & Cullenward, D. (2022). Systematic over-crediting in California's forest carbon offsets program. *Global Change Biology*, 28, 1433– 1445. https://doi.org/10.1111/gcb.15943

[44] As discussed earlier, both ACR and CAR are broadly above par in relation to international standards.

[45] To illustrate, see e.g. Calyx Global (https://calyxglobal.com/), Sylvera (https://www.sylvera.com/), or BeZero (https://bezerocarbon.com/ratings/).

Despite the challenges, the alignment of several factors offers a positive outlook for unlocking agriculture mitigation potential through carbon markets. Firstly, as maturing technological advancements provide information on how soil responds to a myriad of practices in different regions models may reduce uncertainty and bring down the costs associated to MRV.[46] Secondly, the agriculture sector offers a diversified range of activities that can both reduce emissions and sequester carbon,[47] which are of interest to a wide range of actors, including NGOs that have experience working with local communities. Finally, a lot of political momentum is targeting emissions reductions and removals in the agricultural sector. To illustrate, at least five declarations were made as part of the 2021 Glasgow UN climate conference that mention widely emission reductions and removals from the agricultural sector, most of which were supported by the U.S.[48]

Policy changes in the U.S. may interact with carbon markets for agricultural and forest projects in the US – some might stimulate carbon market growth while others might inhibit growth if certain GHG reduction or removal practices are mandated or incentivized. The 2022 Inflation Reduction Act (IRA) provides over USD 18 billion to four existing environmental incentives programs: the Environmental Quality Incentives Program (EQIP), Regional Conservation Partnership Program (RCPP), Conservation Stewardship Program (CSP), and Agricultural Conservation Easement Program (ACEP).[49] This IRA funding far exceeds private finance generated through the purchase of carbon credits under soil sequestration and conservation VCM programs in the U.S. (e.g., Truterra, Bayer Carbon, Agoro Carbon Alliance, and Carbon by Indigo). Meanwhile, the USDA climate-smart commodities program is encouraging market-based, voluntary adoption of climate-smart agricultural approaches and has committed to providing USD 3 billion to 70 projects covering over 50,000 farms in the first two pools of the Partnerships for Climate-Smart Commodities.[50] The impact of these public programs on VCMs in the U.S. is not yet known but would merit further analysis. In November 2022, the U.S. announced on the sidelines of COP27 strategic plans for advancing NbS, referencing support for a "NbS solutions roadmap" with over USD 25 billion from new and recent interagency commitments. The roadmap outlines five strategic areas of focus: updating policies, unlocking funding, leading with federal facilities and assets, training the NbS workforce, and prioritizing research, innovation, knowledge, and adaptive learning. The roadmap is designed to leverage investments made under the infrastructure bill and the IRA.[51]

Finally, there are other policy proposals in the U.S. that, if made law, would likely support the growth of carbon markets for agricultural and forestry activities. The Growing Climate Solutions Act, which was passed by the Senate in 2021 but has not been passed by the House of Representatives, would authorize the USDA to create a certification program for third-party verifiers and provide technical assistance to farmers, ranchers, and forest owners to participate in

---

[46] European Commission, Directorate-General for Climate Action, Radley, G., & Keenleyside, C. (2021). *Technical guidance handbook: setting up and implementing result based carbon farming mechanisms in the EU*. Retrieved from https://data.europa.eu/doi/10.2834/12087.

[47] Roe, S. et al. (2021). Land-based measures to mitigate climate change: Potential and feasibility by country. *Global Change Biology*, 27, 6025– 6058.

[48] The Glasgow Leaders' Declaration on Forests and Land Use, the Glasgow Food and Climate Declaration, the Agriculture Innovation Mission for Climate pledge, the methane pledge, where over 100 countries agreed to reduce methane emissions to 30% of 2020 levels by 2030, and, finally, the Policy Action Agenda for a Just Transition to Sustainable Food and Agriculture. The US participates from the first four processes.

[49] Du, Z., Feng, H., & Moore, L. S. (2022). Conservation Investment and Carbon Payments in US Agriculture: Implications of the Inflation Reduction Act of 2022. *Agricultural Policy Review, Center for Agricultural and Rural Development, Iowa State University*. Retrieved from https://www.card.iastate.edu/ag_policy_review/article/?a=146.

[50] U.S. Department of Agriculture. (2022) Biden-Harris Administration Announces an Additional $325 Million in Pilot Projects through Partnerships for Climate-Smart Commodities, for Total Investment of $3.1 Billion**.** Retrieved from https://www.usda.gov/media/press-releases/2022/12/12/biden-harris-administration-announces-additional-325-million-pilot.

[51] The White House. (2022, November 8). Biden-Harris Administration Announces Roadmap for Nature-Based Solutions to Fight Climate Change, Strengthen Communities, and Support Local Economies. *The White House*. Retrieved from https://www.whitehouse.gov/briefing-room/statements-releases/2022/11/08/fact-sheet-biden-harris-administration-announces-roadmap-for-nature-based-solutions-to-fight-climate-change-strengthen-communities-and-support-local-economies/.

voluntary markets.[52] The Rural Forest Markets Act, which has not been passed by either Chamber, would direct the USDA to provide finance to facilitate the sale of forest carbon offsets.[53] Advisors in the Biden administration have proposed the creation of a USDA Carbon Bank that would use finance allocated under the Commodity Credit Corp – set up to assist farmers impacted by the "tariff war" with China under the Trump administration – to guarantee prices for farmers or producers engaging in approved carbon conservation activities.[54] There is support for these bills and proposals among producer and environmental organizations,[55] but it is not clear if or how they will be taken up.

Conclusions

With these findings, it is clear that carbon markets can play an important role in supplying mitigation potential in the U.S., up to 288.3-488.3 $MtCO_2e\ yr^{-1}$ by 2030 and 430.0-658.3 $MtCO_2e\ yr^{-1}$ by 2050. However, carbon markets should not be treated as a silver bullet. The estimations of available mitigation potential provided in this report suggest that, even when measures are taken to facilitate carbon market investments, markets alone are insufficient to fully deliver the U.S.' NbS mitigation potential of 813.5 $MtCO_2e\ yr^{-1}$ over the next three decades.[56] As a result, it is important to leverage other financial instruments and policy interventions in parallel.

Voluntary carbon markets in the U.S. currently unlock 6.1 $MtCO_2e\ yr^{-1}$, which constitutes only 1.5% of the modelled mitigation potential that is available to carbon markets (405.3 $MtCO_2e\ yr^{-1}$ over the next three decades). Therefore, there is a large growth potential if current barriers are addressed, particularly for Agriculture. This project category presents the largest potential but faces multiple challenges related to developing cost-effective MRV systems and to addressing permanence and additionality concerns. Furthermore, another source of uncertainty relates to how U.S. policy changes may interact with carbon markets.

This study exemplifies the risks of approaching the supply of NbS mitigation potential from a price-centric perspective alone. Supply studies should attempt to capture, on the one hand, the different political, economic, social, and legal barriers which limit the leverage of NbS mitigation potential via carbon markets. On the other hand, it is important to capture spatial restrictions in the form of locked-in land uses, which outline the areas that may not be accessible to carbon markets. The latter restrictions were relatively significant for some activities in the U.S. and have been found to be very important for other countries.[57] The methodological approach presented in this report is a first endeavor to reflect more realistically the on-the-ground limitations faced nowadays by project developers.

---

[52] Braun, M. (2021). S.1251 - 117th Congress (2021-2022): Growing Climate Solutions Act of 2021 [Legislation]. Retrieved from https://www.congress.gov/bill/117th-congress/senate-bill/1251#:~:text=This%20bill%20authorizes%20the%20Department,ranchers%2C%20and%20private%20forest%20landowners.

[53] Stubbs, M., Hoover, K., & Ramseur, J. (2021). *Agriculture and Forestry Offsets in Carbon Markets: Background and Selected Issues*. Retrieved from https://crsreports.congress.gov/product/pdf/R/R46956.

[54] Maixner, E., & Brasher, P. (2020). Carbon markets lure farmers but are benefits enough to hook them? *AgriPulse*. Retrieved from https://www.agri-pulse.com/articles/14880-carbon-markets-lure-farmers-but-are-benefits-enough-to-hook-them.

[55] Stubbs, M., Hoover, K., & Ramseur, J. L. (2021).

[56] As reference, according to UNFCCC data, annual GHG emissions of the U.S. (without LULUCF) amounted to 5.98 Gt CO_2e in 2020. UNFCCC. (n.d.). GHG Data. Retrieved November 10, 2022, from https://unfccc.int/topics/mitigation/resources/registry-and-data/ghg-data-from-unfccc.

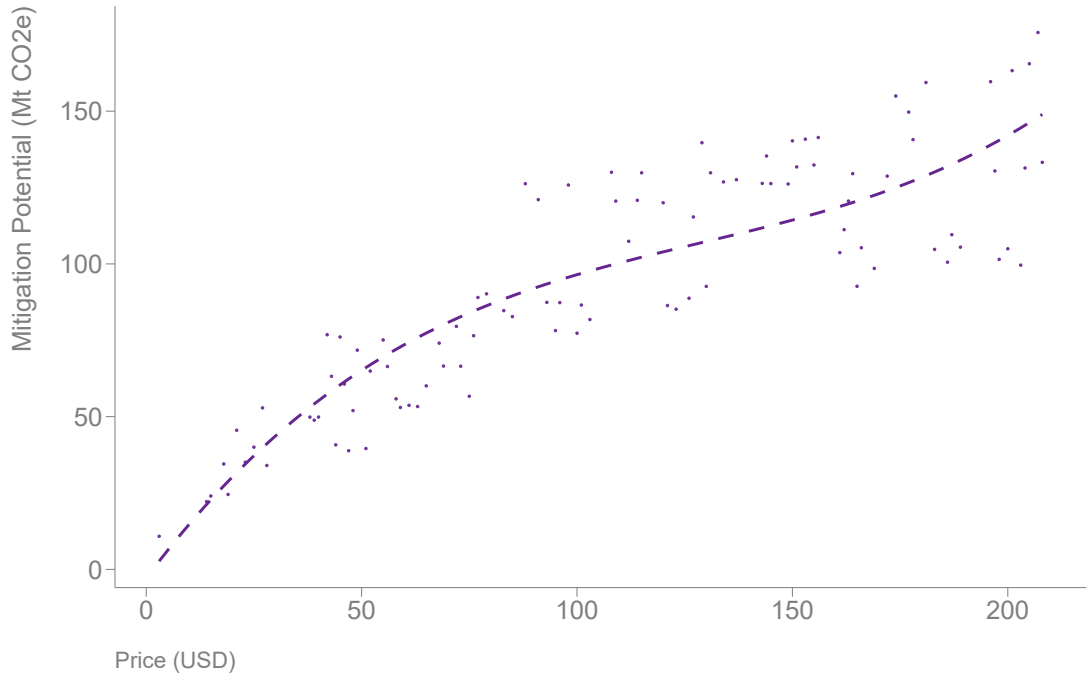
[57] Streck, C., Martinez, G., Landholm, D., Bravo, F., Castro, J. P., Cote, L., et al. (2022). Unlocking nature-based solutions through carbon markets in Colombia. Climate Focus. Retrieved from https://climatefocus.com/publications/unlockingnaturebasedsolutions-through-carbon-markets-in-colombia/.

Annex

Methodology

To estimate how much mitigation potential can be unlocked by carbon markets, this analysis combined unpublished IPCC regional Marginal Abatement Cost Curves (MACC), produced by MESSAGE-GLOBIOM, an integrated assessment model (IAM), with the latest country data on Nature-based Solutions (NbS) mitigation potential from Roe et al. (2021). This paper provides available mitigation estimates ("cost-effective mitigation") for 20 different NbS (USD100/tCO_2e). For each of the four considered activities (Afforestation/Reforestation, Agriculture[58], the Conservation and Restoration of Wetlands, and Improved Forest Management), we fitted a function to the MACC output of MESSAGE-GLOBIOM model. The output of this model provides how much mitigation is unlocked for different prices (see example of Agriculture for OECD+EU in **Figure 5**). The analysis uses the shape of the regional MACC and applies it to the Roe et al. (2021)'s country-level mitigation data estimate (USD100/tCO_2e) to extract how much can be unlocked at lower prices.

Figure 5: Example of a fitted function for a Marginal Abatement Cost Curve (MACC) based on MESSAGE-GLOBIOM's integrated assessment model (IAM). This curve refers to the Agriculture activity for developed countries (OECD90+EU).

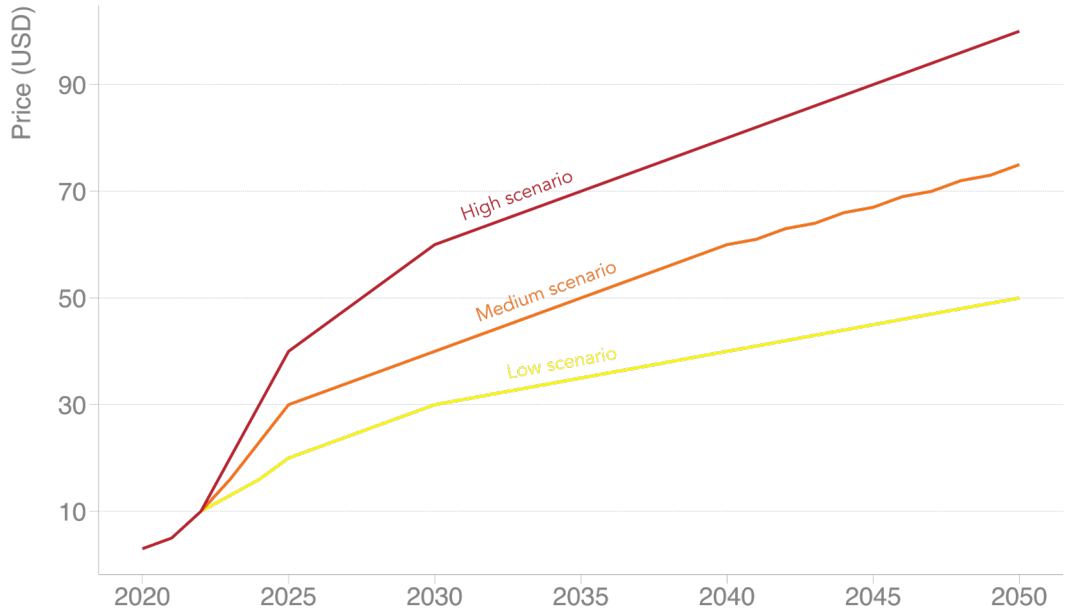


Next, we considered a wide range of price scenarios (Figure 6). Given the long timeframe considered (until 2050), a simple and transparent scenario-based approach is preferred over modeling specific price forecasts, which is particularly complex in the very uncertain carbon market environment. Combining these wide price projection ranges with the information above, the model obtained a first estimate of how much mitigation potential can be unlocked in the U.S. for each

[58] The Agriculture activity includes mitigation potential from activities that reduce emissions and/or remove CO_2 from the atmosphere and store it in the soil and biomass.

of the five activities, which considers both available NbS mitigation potential and possible price scenarios.

Figure 6: Price projections considered (low, medium, high).



Filter 1: Feasibility factors

In practice, the implementation of NbS projects does not solely consider costs, but numerous other, typically ignored dimensions also act as barriers for the uptake of projects. Political, institutional, social, and technological dimensions are also important. The analysis found that there is a significantly positive correlation between Roe et al. (2021)'s NbS country feasibility scores, which includes many of these dimensions, and project uptake59 across all countries engaged in VCM.

We develop a tailored feasibility scoring system that specifically reflects three distinct carbon market investment and implementation barriers. Specifically, we use the business and investment freedom indexes from the Heritage Foundation as a proxy of "ease of doing business", reflecting the need for countries to remove barriers to external investments. In addition, the findings consider the same political feasibility factors used in Roe et al. (2021). Political feasibility includes World Bank indicators of Voice and Accountability, Political Stability and Absence of Violence/Terrorism, Government effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption. Finally, for land tenure security we used the International Property Rights Index.[60]

We combined the three parameters described above (i.e., ease of doing business, political and land tenure) to calculate a feasibility score for each of the 214 countries in the dataset per year.[61] We used historic data from 2013 to 2020 to estimate how feasibility factors may evolve in the future. For this purpose, we divided the countries into 43 groups of 5 to 6 countries, calculated the feasibility factors for each country and year and then average the yearly score among countries in each group. We then sorted the country groups according to their average score in 2013 and

[59] Climate Focus measured project uptake as *project*years*, i.e., the number of VCM NbS projects a given country times the number of years each project has been running.

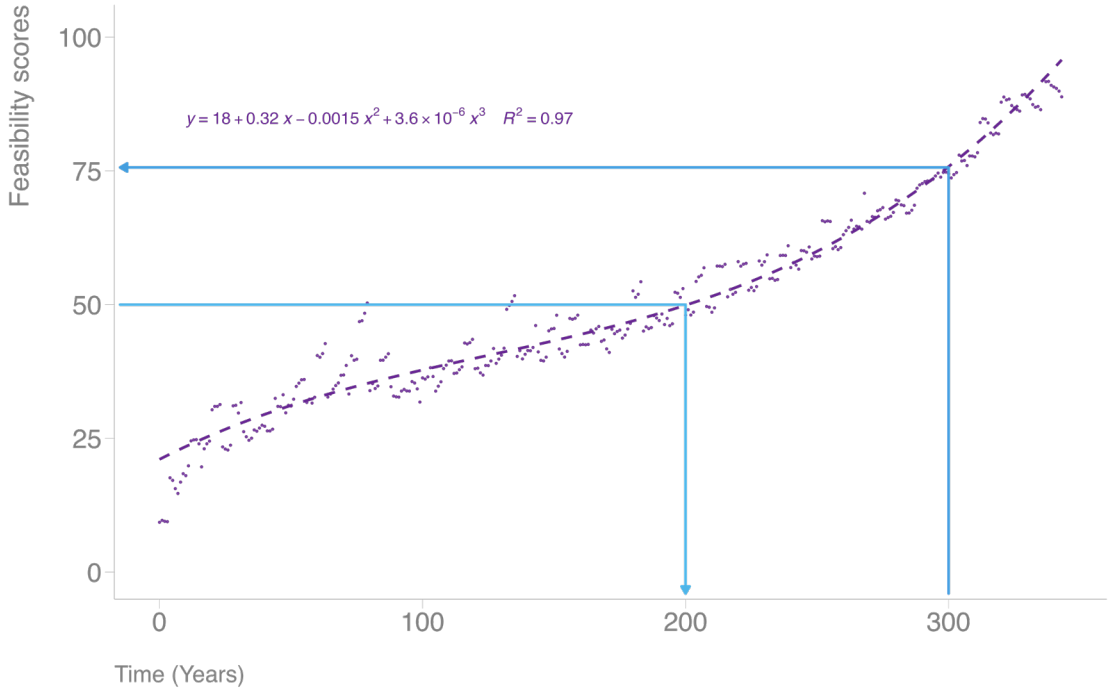
[60] Property Rights Alliance. (2021). International Property Rights Index. Retrieved from http://www. internationalpropertyrightsindex.org.

[61] Individual feasibility scores are first normalized (0-100), then averaged across the three variables to obtain a final feasibility score.

values in each group according to year. We obtain a sequence of 344 scores (i.e. 43 groups by 8 years per group), indexed from 0 to 343.

Figure 7 displays how the average feasibility scores of these groups (y axis) change over time (x axis), i.e. the 344 data points. Based on historic data, as observed, feasibility scores are expected to gradually increase over time, albeit at different rates depending on where a country starts on the development pathway curve.

Figure 7: Modelled evolution of feasibility scores over time. Y axis represents feasibility scores, x axis years. Green lines (with arrows) highlight the process: we have the initial feasibility score for the U.S. (74.4), obtain the initial time value (x axis); then we return x+30 years to the equation to obtain the feasibility factor in 2050 (87.6).



To obtain the feasibility score in 2050 for an individual country, we proceed as follows along the fitted function shown in **Figure 7**: we consider the starting feasibility score of the country at present day (2020), e.g. the U.S. (74.4), and derive the corresponding time index on the x axis. We then obtain the final feasibility score as the y value corresponding to x+30, which for the U.S. is 87.6. It therefore experiences a growth of 17.7% in their feasibility score over this time period.

The final step is to transform the calculated feasibility scores into percentage values, which are used as filters to reduce the mitigation potential of each country. This was done by assigning scores from 0 to 100 to each country for every year (i.e., the lowest scoring country receives 0 and the highest 100). Under this assumption the top scoring feasibility country (100%) has no barriers, and no mitigation potential is discounted in the model. In contrast, the worst scoring country receives 0%, i.e. no mitigation is unlocked in this country due to high barriers.

In the case of the U.S., the feasibility filter goes from 99.6% in 2020 to 100% in 2050. This means 0.4% and 0% are discounted from the U.S.'s NbS mitigation potential in 2020 and 2050, respectively. The three barriers included in the model do not play a critical role for the U.S. but affect strongly other countries.[62]

[62] See Colombia technical report: Landholm, D., Bravo, F., Streck, C., Martinez, G., Castro, J. P., Cote, L., et al. (2022). Unlocking nature-based solutions through carbon markets in Colombia - Technical Report. *Climate Focus*. Retrieved October 11, 2022, from https://climatefocus.com/wp-content/uploads/2022/09/Unlocking-Nature-based-Solutions-Colombia-Technical-Report-V1.1.pdf.

Filter 2: Spatially explicit mitigation potential maps

In a final step, we consider areas where it is very difficult to develop carbon market projects, due to existing on-the-ground limitations. These are referred to as "locked-in land uses". For the U.S., this analysis considers mining concessions, oil and gas concessions, and protected areas, and assume that investors and project developers will prefer to invest elsewhere in areas with fewer barriers. We use existing spatially explicit maps on mitigation potential per activity for Afforestation/Reforestation and Agriculture to estimate what percentage of the potential falls within these locked-in areas. This percentage is then applied to the country-level model output to provide a conservative estimate on what is realistically available for NbS mitigation via carbon markets. The final maps are also used to highlight where the potential for different activities lies in the U.S. (**Figure 4**).

For Afforestation/Reforestation potential, we consider carbon accumulation potential from natural forest regrowth in reforestable areas. This model uses data from Cook-Patton et al. (2020) filtered to include only reforestable areas as defined by Griscom et al. (2017).[63] This map is not specific to carbon markets, but presents overall potential for the activity. Finally, for Agriculture potential this model uses the recently released Global Soil Sequestration Potential (GSOCseq) Map (FAO, 2022)[64]: the analysis uses scenario 3 and compares it to the business as usual (BAU) scenario. Using a more pessimistic scenario (e.g., scenario 1) would reduce slightly the values presented in the map but does not affect the distribution of where the potential is. Similar to Afforestation/ Reforestation, this map is not specific to carbon markets, but presents the overall distribution potential for the activity.

All three potential maps are then processed to account for locked-in land uses where leveraging carbon markets is deemed difficult. This provides not only a final map of where the activity may be developed, but also the second feasibility filter (%) that is applied to the country model. After accounting for economic, feasibility, and land tenure barriers, the model then accounts for locked-in land uses by applying a percentage reduction that is informed by these spatially explicit maps.

Table 3: Breakdown of Nature-based Solutions (NbS) mitigation potential by State for AR, and AG.

State	Mitigation potential (% of country total)	
	AR	AG
Alaska	0,0%	19,5%
Alabama	5,4%	0,6%
Arkansas	5,1%	1,1%
Arizona	0,1%	1,5%
California	2,2%	3,2%
Colorado	0,0%	1,8%
Connecticut	0,1%	0,0%
District of Columbia	0,0%	0,0%

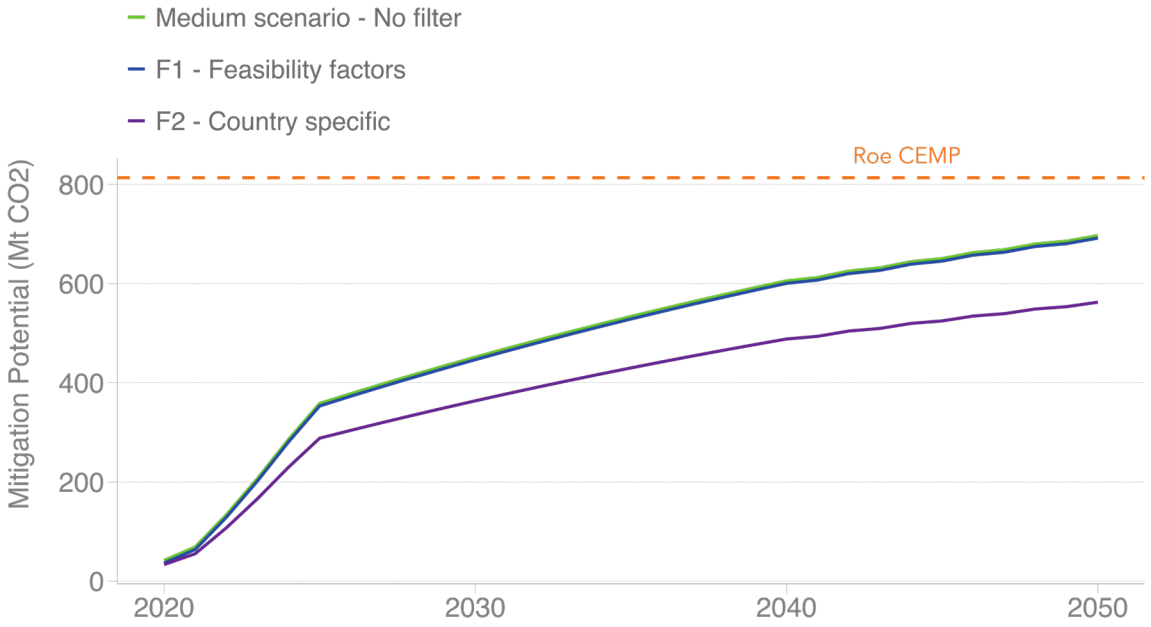
[63] Cook-Patton, S. C., Leavitt, S. M., Gibbs, D., Harris, N. L., Lister, K., Anderson-Teixeira, K. J., et al. (2020). Mapping carbon accumulation potential from global natural forest regrowth. *Nature*, *585*(7826), 545–550.

Griscom, B. W., Adams, J., Ellis, P. W., Houghton, R. A., Lomax, G., Miteva, D. A., et al. (2017). Natural climate solutions. *Proceedings of the National Academy of Sciences*, *114*(44), 11645–11650.

[64] FAO. (2022). *Global soil organic carbon sequestration potential map (GSOCseq v1.1).* Retrieved from http://www.fao.org/documents/card/en/c/cb2642en.

Delaware	0,4%	0,1%
Florida	0,0%	1,8%
Georgia	3,0%	0,6%
Hawaii	0,0%	0,0%
Iowa	0,4%	4,3%
Idaho	1,0%	2,0%
Illinois	2,8%	3,9%
Indiana	2,3%	2,3%
Kansas	1,7%	4,6%
Kentucky	5,3%	1,0%
Louisiana	1,6%	0,6%
Massachusetts	0,2%	0,0%
Maryland	1,4%	0,2%
Maine	1,1%	0,2%
Michigan	4,4%	1,8%
Minnesota	5,3%	3,9%
Missouri	5,9%	2,9%
Mississippi	4,9%	0,8%
Montana	0,8%	3,9%
North Carolina	6,4%	1,3%
North Dakota	0,1%	3,6%
Nebraska	0,0%	3,4%
New Hampshire	0,3%	0,0%
New Jersey	0,4%	0,1%
New Mexico	0,0%	1,7%
Nevada	0,0%	1,5%
New York	3,8%	0,9%
Ohio	3,1%	1,8%
Oklahoma	2,8%	2,5%
Oregon	1,9%	3,0%
Pennsylvania	3,2%	0,5%
Rhode Island	0,0%	0,0%
South Carolina	1,8%	0,3%
South Dakota	0,0%	3,8%
Tennessee	6,5%	0,8%
Texas	0,9%	5,7%
Utah	0,0%	1,3%
Virginia	4,3%	0,3%
Vermont	0,5%	0,1%
Washington	2,4%	1,9%
Wisconsin	5,3%	1,6%
West Virginia	0,7%	0,1%
Wyoming	0,0%	1,3%

Figure 8: Visual description of methodological process displaying a medium price scenario (orange). After considering feasibility and locked-in land use constraints the mitigation available is represented by the grey and yellow lines, respectively.



Limitations

Forecasting carbon markets' potential over a long timeframe for a varied set of NbS is fraught with challenges that reflects on some limitations of this analysis.

First, the defined price trajectories, the used MACCs, and the filters (feasibility and locked in land uses) do not capture some additional activity-specific constraints. For instance, our model shows Agriculture as the activity with most potential; however, important technical barriers related to measuring, reporting and verification (MRV) need to be overcome for carbon markets to leverage Agriculture's full potential. A lot of effort is currently placed on solving these barriers, but the outcome is yet unclear.[65] It is also unclear how future changes in carbon market standard rules will affect these estimates. For instance, renewable energy projects used to represent a large share of carbon markets but are no longer considered additional and have been excluded by some carbon market standards (except for Least Developed Countries).

Second, this model uses regional MACCs derived from IAMs for 5 different NbS activities. The model takes the shape of the regional MACC and applies it to the country-specific mitigation potential presented by Roe et al. (2021), i.e., the cost-effective mitigation potential unlocked at USD100/tCO_2e. Although this approach is not expected to deviate substantially from an approach that gathers country-level costs, the accuracy can certainly be improved in the future by using local data.

Third, proving additionality is an important element for the development of carbon projects. Although additionality is not explicitly treated in this model, the underlying NbS mitigation potentials used as a starting point from Roe et al. (2021) do cover it implicitly at a country scale. Namely, the underlying studies where this mitigation is calculated from (see **Table 1** in Roe et

[65] For an overview of technical challenges related to measuring, monitoring, and verifying soil organic carbon changes, see: European Commission et al. (2021).

al., 2021) typically consider the mitigation potential in relation to the continuation of business-as-usual activities. Hence, although it would be preferable to have a gauge of carbon market-specific additionality of these activities, and how they vary across activities, the additionality restriction is likely covered to a large extent.

Fourth, the implementation of new country policies interact with carbon markets, either by stimulating carbon market growth or by inhibiting growth if certain GHG reduction or removal practices are mandated or incentivized. These aspects are not considered in the model but are important to consider.

Fifth, the estimation of the portion of area occupied by locked-in land uses is unlikely to perfectly match the shape and size of mining, oil, and gas concessions in the country. As spatially explicit information becomes available on these land uses, the accuracy of the model outputs can be improved. However, at a country scale, this is expected to be a minor source of uncertainty.

Finally, carbon market prices will evolve over time as a function of supply and demand. Regarding the latter, however, there are still a lot of uncertainties regarding how many companies will go beyond net-zero targets. The volume of credits generated by neutrality claims may be even larger than target-year net-zero claims. Hence, until this becomes clearer the uncertainty around demand will be very large over a 30-year forecasting period. Here, we preferred to lay a wide range of price scenarios to gauge the effect under different scenarios. What is expected at the moment is that demand will quickly outpace supply, and therefore addressing country supply barriers is urgently needed.

Climate Focus is an independent expert in international and national climate law, policies, project design and finance. We have been pioneering carbon markets ever since their inception. We aim to find a creative and unique solution for every single client, ranging from the development of policies to protect the rainforest to structuring greenhouse gas mitigation projects in the energy sector. Our advice is rooted in a profound knowledge of climate change policies, emission trading schemes and project development.

Climate Focus has offices in Amsterdam, Rotterdam, Washington DC, Berlin, and Bogotá. Our core team is complemented by a broad network of in-country and specialized partners.

CONTACT US

GLOBAL HEAD OFFICE
AMSTERDAM, THE NETHERLANDS
Climate Focus, B.V.
Van Diemenstraat 170
1013CP Amsterdam,
The Netherlands
T +31 20 262 10 30

ROTTERDAM, THE NETHERLANDS
Het Industriegebouw
Goudsesingel 52-214
3011 KD Rotterdam
The Netherlands
T +31 20 262 10 30

WASHINGTON, DC, USA
Climate Focus North America, Inc.
1701 Rhode Island Ave NW
Washington, DC 20036, USA
T +1 202 540 22 73

BERLIN, GERMANY
Climate Focus Berlin GmbH
Schwedter Str. 253
10119 Berlin, Germany
T +49 30 24637919

BOGOTÁ, COLOMBIA
Carrera 14 #89-48, 305
Bogotá, Colombia
T +57 1 322 73 54