Originally published as Carbon Direct, which is now Relae. Learn more at relae.co

Carbon Direct

Carbon Dioxide Removal and Environmental Justice in the United States

A landscape analysis of race, class, and environmental burden metrics

June 2025 • In collaboration with McKNIGHT FOUNDATION



Originally published as Carbon Direct, which is now Relae. Learn more at relae.co

TABLE OF CONTENTS

Report overview 3

- Acronyms and abbreviations 3
- Executive summary 4
- Introduction 5
- Environmental justice 6

Setting the stage 7

- What is the VCM? 8
- What are the main types of CDR? 9
- What does not qualify as CDR? 10
- Research approach 11

General trends 16

- Nature-based CDR trends 19
- Hybrid CDR trends 20
- Engineered CDR trends 21

Case studies 22

- Nature-based removals 23
- Hybrid removals 26
- Engineered removals 29

Conclusion 32

- Major takeaways 33
- Additional insights 34

Appendices 35

- Appendix A: Data and methods 36
- Appendix B: Glossary 38

Acknowledgements 39

Originally published as Carbon Direct, which is now Relae. Learn more at relae.co

Report overview

Acronyms and abbreviations

ACR: American Carbon Registry

ARR: afforestation, reforestation, and revegetation

BCR: biochar carbon removal

BECCS: bioenergy with carbon capture and storage

CAR: Climate Action Reserve

CCS: carbon capture and storage

CCUS: carbon capture, utilization, and storage

CDR: carbon dioxide removal

CO_2: carbon dioxide

DACS: direct air capture and storage

EJ: environmental justice

EPA: Environmental Protection Agency (United States)

IEACCUS: International Energy Agency's Carbon Capture, Utilization, and Storage

IFM: improved forest management

IPCC: Intergovernmental Panel on Climate Change

NBS: nature-based solutions

NO_2: nitrogen dioxide

VCM: voluntary carbon market

Executive summary

Meeting the goals of the Paris Agreement will require removing 10 billion tonnes[1] of carbon dioxide annually by 2050—a significant gap that must be closed within the next two decades. Carbon dioxide removal (CDR) will need to scale at a rapid pace, increasing the current rate of removals by four to five times.[2] As CDR scales, it is important to remember that projects have specific, place-based dimensions. Some of these have impacts on, and provide benefits for, frontline communities. Yet, no study currently exists that examines where CDR projects are located in relation to these communities, much less how these dimensions can inform the rapidly growing CDR market to advance environmental justice.

In this report, Carbon Direct and the McKnight Foundation publish a first-of-its-kind study. Carbon Direct analyzed the demographic profiles and environmental burden indicators for communities living in proximity to carbon projects. Our study focused on projects from seven major registries across the voluntary carbon market (VCM) in the United States (US), with a particular focus on CDR projects. We combined these project data with EJScreen data from the US Environmental Protection Agency (EPA) to explore the question: are CDR projects disproportionately located in frontline communities in the US?

As CDR is still nascent within the broader VCM, these findings serve as an important baseline to inform CDR project developers and investors as they consider new project design and siting. **Future research should continue to focus on exploring the impacts of CDR on frontline communities.**

This analysis yielded three key findings:

1. **There are currently no correlations between CDR project locations and frontline communities.** Carbon Direct found that CDR projects in the US are not disproportionately located in low-income communities of color. In addition, CDR projects are not located in areas with significantly higher pre-existing environmental burdens. The lack of a pattern, although not statistically significant, is noteworthy.
2. **Some CDR projects *do* exist near frontline communities with higher environmental burden.** On a case-by-case basis, some CDR projects fall within proximity to frontline communities. We posit that this may be related to one or more factors:
    - Current carbon dioxide infrastructure locations, or
    - General patterns of economic development.
    - We cannot determine the “why” through this study.
3. **CDR projects are still nascent within the broader VCM.** CDR is expected to scale over the next decade. As such, the bulk of known CDR projects have not yet been registered. While CDR currently makes up about 37% of all projects in the VCM, the bulk of the removal credits have yet to be delivered.
    - CDR project developers have an opportunity to advance restorative justice as CDR scales.
    - Equitable engagement plans and community benefits mechanisms will be crucial to advance environmental justice.

1. Read “Negative Emissions Technologies and Reliable Sequestration: A Research Agenda” at NAP.edu. [accessed 2025 Mar 31]. https://nap.nationalacademies.org/read/25259/chapter/2.
2. Carbon Direct. 2024. 2024 State of the Voluntary Carbon Market. [accessed 2025 Mar 31]. https://www.carbon-direct.com/research-and-reports/state-of-the-voluntary-carbon-market-2024.

Introduction

The 2015 Paris Agreement aims to limit global warming to 1.5°C above industrial levels.[3] To achieve this goal, emissions must peak by this year (2025) and then decline rapidly. By 2030, emissions must decline by 43%. By 2050, they must decline by 90%. This means it is critical to remove as much existing carbon dioxide (CO_2) from the atmosphere as possible. Approximately 10 billion tonnes of CO_2 removal per year is needed by 2050. Currently, only two billion tonnes of CO_2 are removed annually.

As society moves quickly to scale CDR, we must also move equitably. While CDR is essential as a global solution, it will have hyperlocal impacts and has the potential to positively benefit local communities. By ensuring environmental justice (EJ) principles are central to climate objectives, CDR projects can work toward reducing emissions while also preventing harm, creating benefits, and addressing the legacy of systemic environmental injustices in the US.

This report draws on the approach used in the landmark 1987 report *Toxic Wastes and Race in the United States*,[4] which demonstrated a concerning pattern in the US of siting hazardous waste facilities in low-income communities of color. Similarly, the goal of this report is to understand if CDR projects are disproportionately located in low-income communities, communities of color, and other disadvantaged communities.

The CDR market is growing. US companies and project developers are global leaders in CDR deployment. Therefore, the potential for influencing and shaping CDR both domestically and globally stem from understanding CDR projects within a US context with a climate equity and EJ lens. To date, landmark legislation, market signals, and private investment have provided momentum for the US to become a leader in CDR development. However, this momentum may face challenges under the current Federal administration, particularly around funding related to frontline communities. Although this momentum may face challenges under the current federal administration, particularly around funding related to frontline communities, there is still an important nexus between carbon removal and environmental justice.



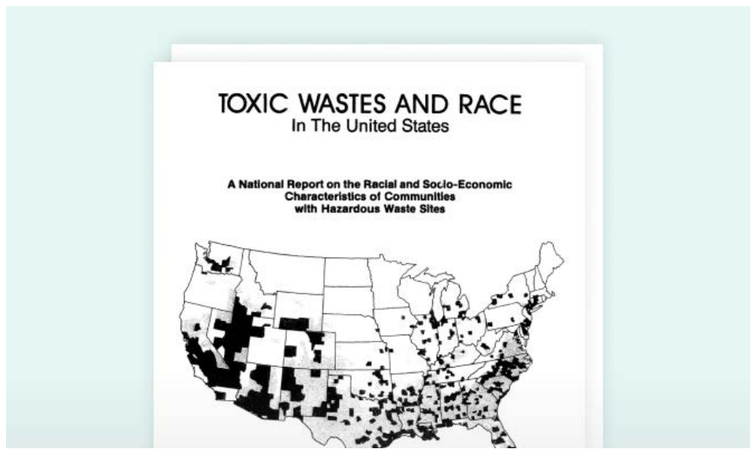
Source: Li-An Lim on Unsplash.

3. United Nations. 2015. Paris Agreement. [accessed 2025 Mar 31]. https://unfccc.int/sites/default/files/english_paris_agreement.pdf.

4. Commission for Racial Justice United Church of Christ. 1987. Toxic Wastes and Race in the United States: A National Report on the Racial and Socio-Economic Characteristics of Communities with Hazardous Waste Sites. [accessed 2025 Mar 31]. https://www.ucc.org/wp-content/uploads/2020/12/ToxicWastesRace.pdf.

Environmental justice

Over the late 20th century, EJ focused on pollution exposure burden for historically marginalized communities in the US. As the 1987 report *Toxic Wastes and Race in the United States* shows,[5] these communities are disproportionately exposed to hazardous waste and pollution, revealing structural inequality at the intersections of environmental law, policy, and economic development. Race is still the top indicator for exposure to toxic waste in the US.[6] Since 1987, the EJ movement has grown in scope and influence in the US, becoming a major framework for climate policy. Today, the EJ movement is global.



In this report, we use the term "frontline communities" to describe people who live with comparatively higher degrees of climate vulnerability and environmental justice challenges. In the US, activists, advocates, policymakers, and scholars use the terms "frontline communities" or "EJ communities" interchangeably. These terms are used to describe people who experience the double exposure[7] of climate change and environmental pollution burden that results from patterns of inequitable economic development and systemic marginalization. Equitable and just climate solutions work to address both climate vulnerability as well as historic environmental injustices.

The Intergovernmental Panel on Climate Change (IPCC) recommends a **just transition with equitable climate solutions** as the most effective way to mitigate greenhouse gas emissions. If implemented with climate equity in mind, CDR projects can have a net positive benefit for frontline EJ communities.

Yet, EJ advocates remain generally skeptical of CDR and carbon management. This skepticism likely emerges from (1) a legacy of environmental injustices in the US stemming from inequitable economic development in frontline communities, and (2) a lack of access to data, information, or deep community engagement on CDR project development—including information on how these projects impact community health and safety. Such skepticism often leads to frontline communities resisting the introduction of carbon crediting projects in their communities. Common EJ critiques of carbon projects tend to focus on the credibility and durability of credits, failure to recognize pre-existing community priorities, and the potential for projects to distract from efforts to phase out fossil fuel use enabling a business-as-usual mindset—often referred to as a "moral hazard" risk.

Many EJ advocates continue to push for a total systems-change approach. Within this systems-change framework, CDR is meant to serve as a complimentary tool in meeting our climate targets for holistic societal decarbonization. It is not meant to be a replacement for reducing or avoiding greenhouse gas emissions. If implemented effectively, CDR investors and developers can leverage the multiple co-benefits of CDR projects to improve community engagement, create meaningful benefits for communities, and ensure a safer and healthier quality of life for all.

5. Commission for Racial Justice United Church of Christ. Toxic Wastes and Race in the United States.

6. Mascarenhas M, Grattet R, Mege K. 2021 Sep 1. Toxic Waste and Race in Twenty-First Century America. doi:10.3167/ares.2021.120107. [accessed 2025 Mar 31]. https://www.berghahnjournals.com/view/journals/environment-and-society/12/1/ares120107.xml.

7. O'Brien KL, Leichenko RM. 2000. Double exposure: assessing the impacts of climate change within the context of economic globalization. Global Environmental Change. 10(3):221–232. doi:10.1016/S0959-3780(00)00021-2.

Originally published as Carbon Direct, which is now Relae. Learn more at relae.co

Setting the stage

First, a brief primer on the VCM and the place of CDR in the broader carbon market.

What is the VCM?

The VCM is a mechanism that allows companies, organizations, and individuals to offset their greenhouse gas emissions by purchasing carbon credits. The VCM is important because it creates a system to advance climate action through the mobilization of capital for climate projects and technologies that might not otherwise be feasible. There are two main categories of carbon credits: **avoidance or reduction** and **removal**.

Avoidance or reduction

Projects that prevent potential carbon-emitting activities from occurring or decrease emissions compared to prior practices. For instance, implementing renewable energy projects to replace fossil fuel energy sources helps to avoid future emissions. Other examples include improving fuel efficiency, reducing methane emissions from waste processing, or carbon capture and storage (CCS) projects that capture emissions before they enter the atmosphere.

Removal

Projects that extract CO_2 from the atmosphere and sequester it for extended periods. This can be achieved through nature-based solutions, engineered solutions, or a combination of both known as hybrid solutions. For the purposes of this study we will be focusing on the **removals** category of carbon credits, or CDR.



Source: Nora Jane Long on Unsplash.

What are the main types of CDR?

There are various ways to remove CO_2 from the atmosphere. At Carbon Direct, we organize the range of CDR projects into three approaches: **nature-based solutions**, **hybrid solutions**, and **engineered solutions**. Approximately 4% of all credits in the VCM (both US and globally) come from CDR projects. Of these, over 95% of credits come from nature-based projects. **Table 1** lists types of CDR projects categorized by approach and **figure 1** provides a visual diagram of CDR projects in the VCM, also categorized by approach.

Table 1. Types of carbon dioxide removal projects in the voluntary carbon market, categorized by approach

Approach	Project types
Nature-based	• Afforestation, reforestation, and revegetation (ARR) • Improved forest management (IFM) • Soil carbon • Peatland restoration • Blue carbon (e.g., wetlands marshes, seagrass beds)
Hybrid	• Biomass-based pathways such as biochar • Bioenergy with carbon capture and storage (BECCS) • Biomass carbon removal and storage (BiCRS)
Engineered	• Carbon mineralization • Direct air capture (DAC)

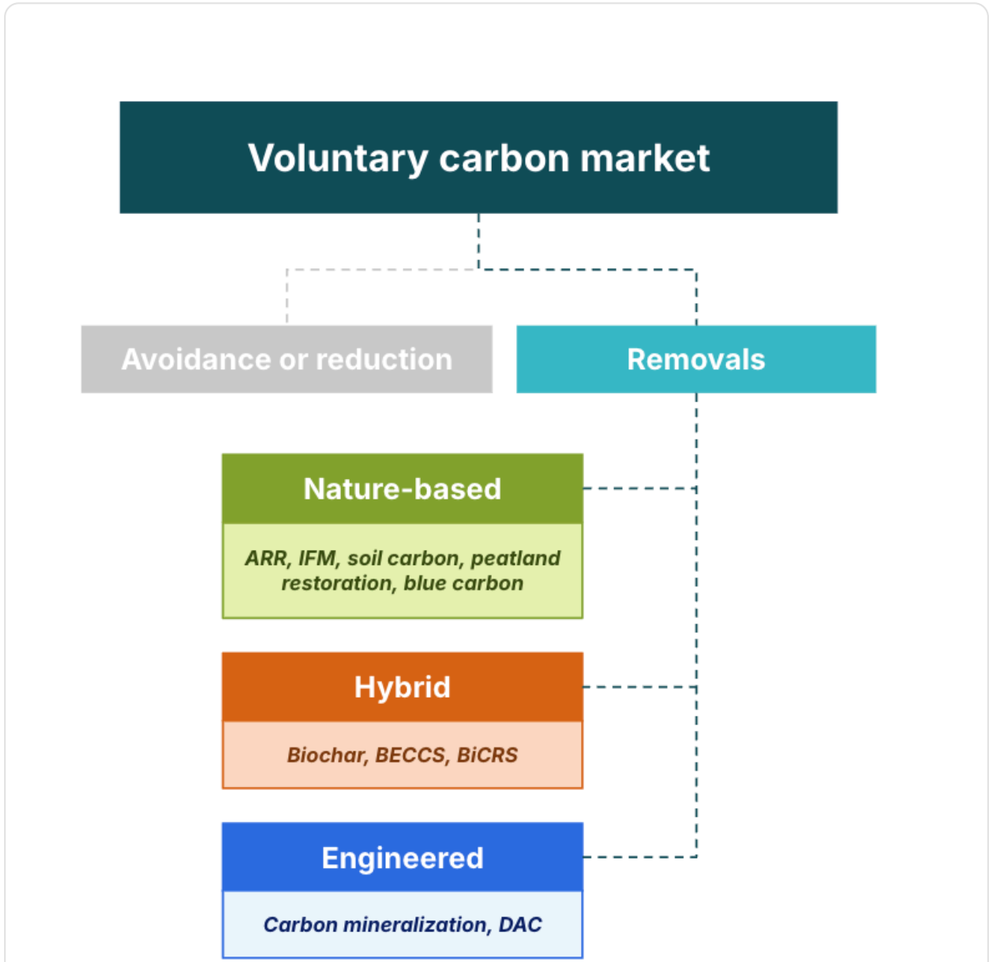


Figure 1. Types of carbon dioxide removal (CDR) projects in the voluntary carbon market, categorized by approach. Source: Carbon Direct.

What does not qualify as CDR?

Often, policymakers and EJ advocates conflate CDR projects (removals) with reduction or avoidance projects. For example, a common misconception is that CCS projects fall under the same category as CDR projects. Rather, CCS is a **reduction** technology that captures and stores CO_2 emissions before they enter the atmosphere, unlike CDR projects which **remove** and store CO_2 that is already in the atmosphere. Likewise, **avoidance** projects such as renewable energy meant to replace the use of fossil fuels cannot be categorized as CDR. This is because, while they avoid emitting CO_2 to the atmosphere, they do not directly remove CO_2 that is already in the atmosphere (**table 2**).

Table 2. Examples of removal versus other projects types in the voluntary carbon market

	Avoidance or reduction	Removal (CDR)
Nature-based	Reducing emissions from Deforestation and Forest Degradation, plus the role of conservation, sustainable management of forests (REDD+) and *some* IFM projects	Afforestation, reforestation, and revegetation (ARR) and *some* IFM projects
Hybrid	Cookstoves	Bioenergy with carbon capture and storage (BECCS)
Engineered	Gas destruction (e.g., methane landfill gas capture), renewable energy projects to replace fossil fuel energy sources (helps to avoid future emissions), improved fuel efficiency, and carbon capture and storage (CCS)	Direct air capture (DAC)



Source: Natalia Blauth on Unsplash.

Research approach

Carbon Direct compiled carbon credit project data from seven major registries in the VCM:

We only included projects in this analysis for which registries have issued or retired carbon credits. Carbon Direct has market insights into future carbon credit projects through offtake agreements, but chose to not include them in this study due to market uncertainties. After cleaning the data and removing duplicates, we analyzed 937 total VCM projects (**figure 2**). Of these projects 342 (37%) are CDR projects representing removals (**figure 3**).

For EJ analyses, Carbon Direct integrated the US EPA's EJScreen data with registry data and drew on the following indicators for analyses:

- People of color (race)
- Low-income (socioeconomic status)
- Demographic index (composite of people of color and low-income)
- Environmental burden indicators (pollution burden)

EJScreen data is based on US Census data, and organized by percentile thresholds at the census tract level.

For the purposes of this study, any indicator that **crossed the 80th percentile threshold** was flagged as an **indicator of concern**, suggesting either significant presence of minority or marginalized communities and/or a high threshold for environmental burden. When a study area had **three or more environmental burden indicators** crossing the 80th percentile, Carbon Direct considered the communities in that study area as living with a high pollution burden.



Source: Chris Boswell on iStock.

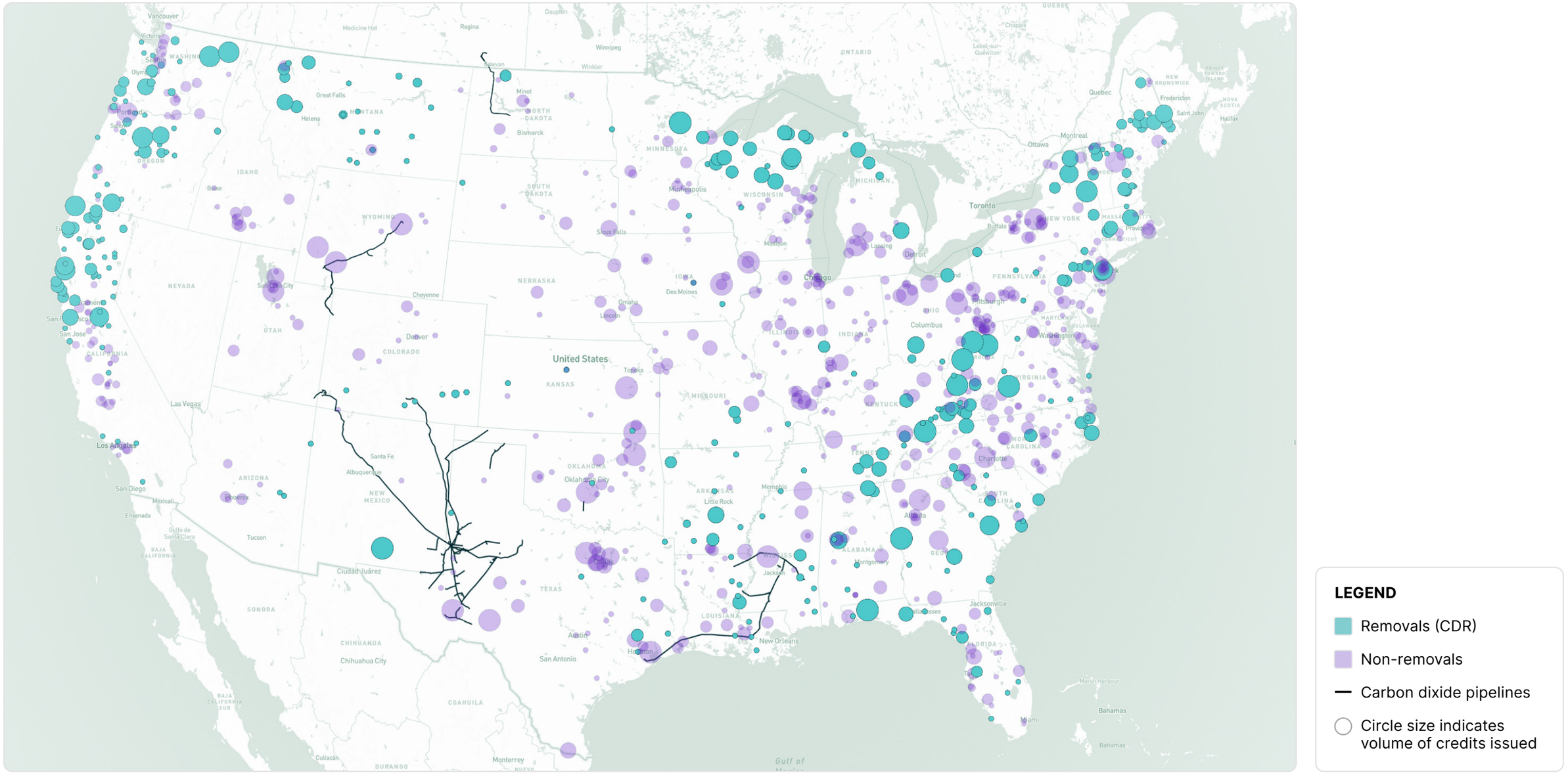


Figure 2. Map of all voluntary carbon market projects from major carbon market registries located in the United States. The size of the circles represents the volume of credits issued (larger circles = more credits issued). The purple circles represent non-removals and the teal circles represent removals. Source: Carbon Direct.

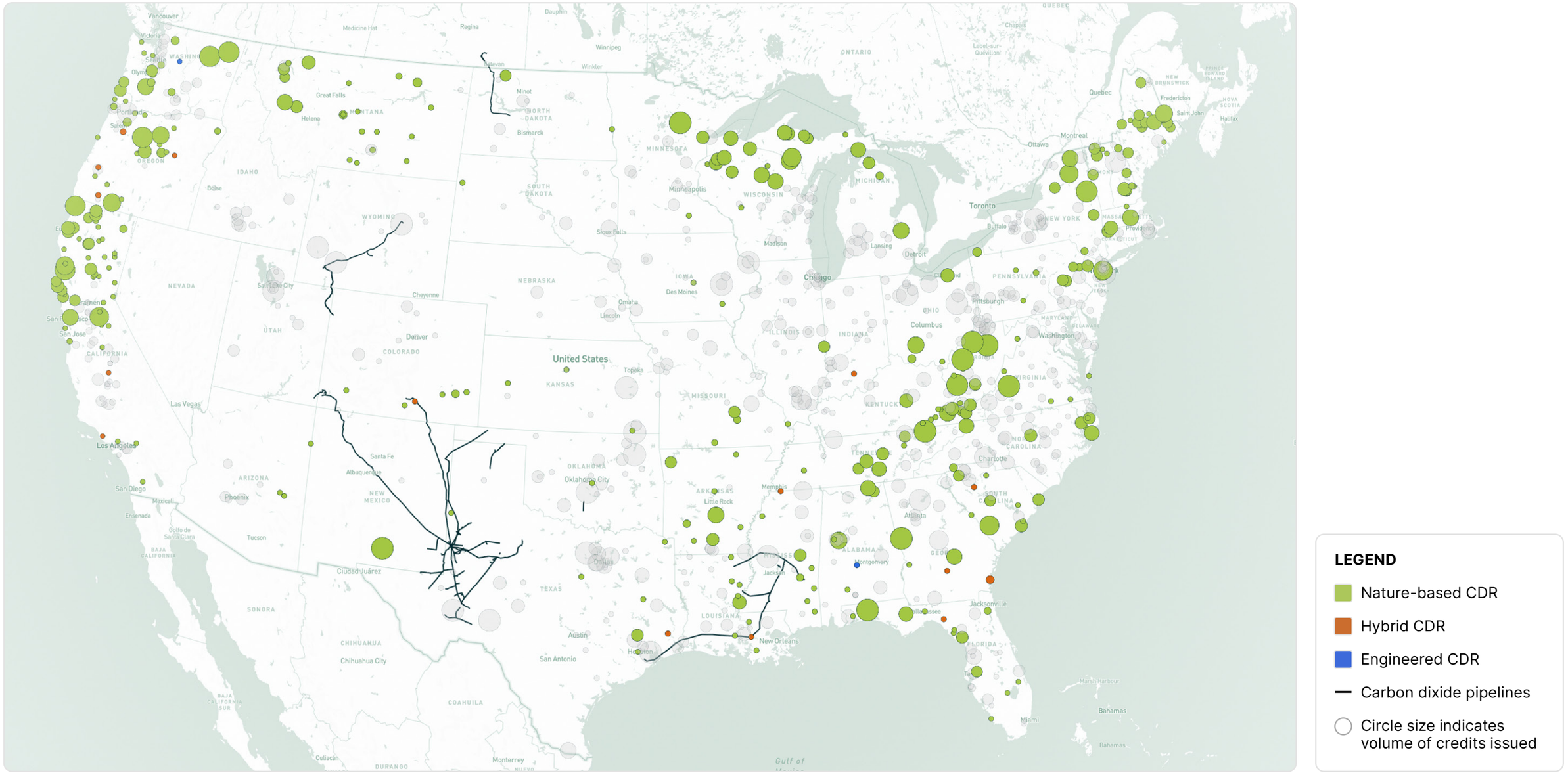


Figure 3. Map of all carbon dioxide removal (CDR) projects from major carbon market registries located in the United States. The size of the circles represents the volume of credits issued (larger circles = more credits issued). The color of the circles correspond to their respective removal pathway (nature-based = green, hybrid = orange, engineered = blue). Source: Carbon Direct.

Radar charts

We used radar charts to visualize across multiple dimensions and give a comprehensive view of one entity or group (**figure 4**). Higher values (closer to the outer ring) indicate greater potential EJ concerns. Lower values (closer to center) suggest fewer impacts on vulnerable communities.

At/above 50th percentile: rates at or above 50% of national average

Below 50th percentile: rates below 50% of national average (better)

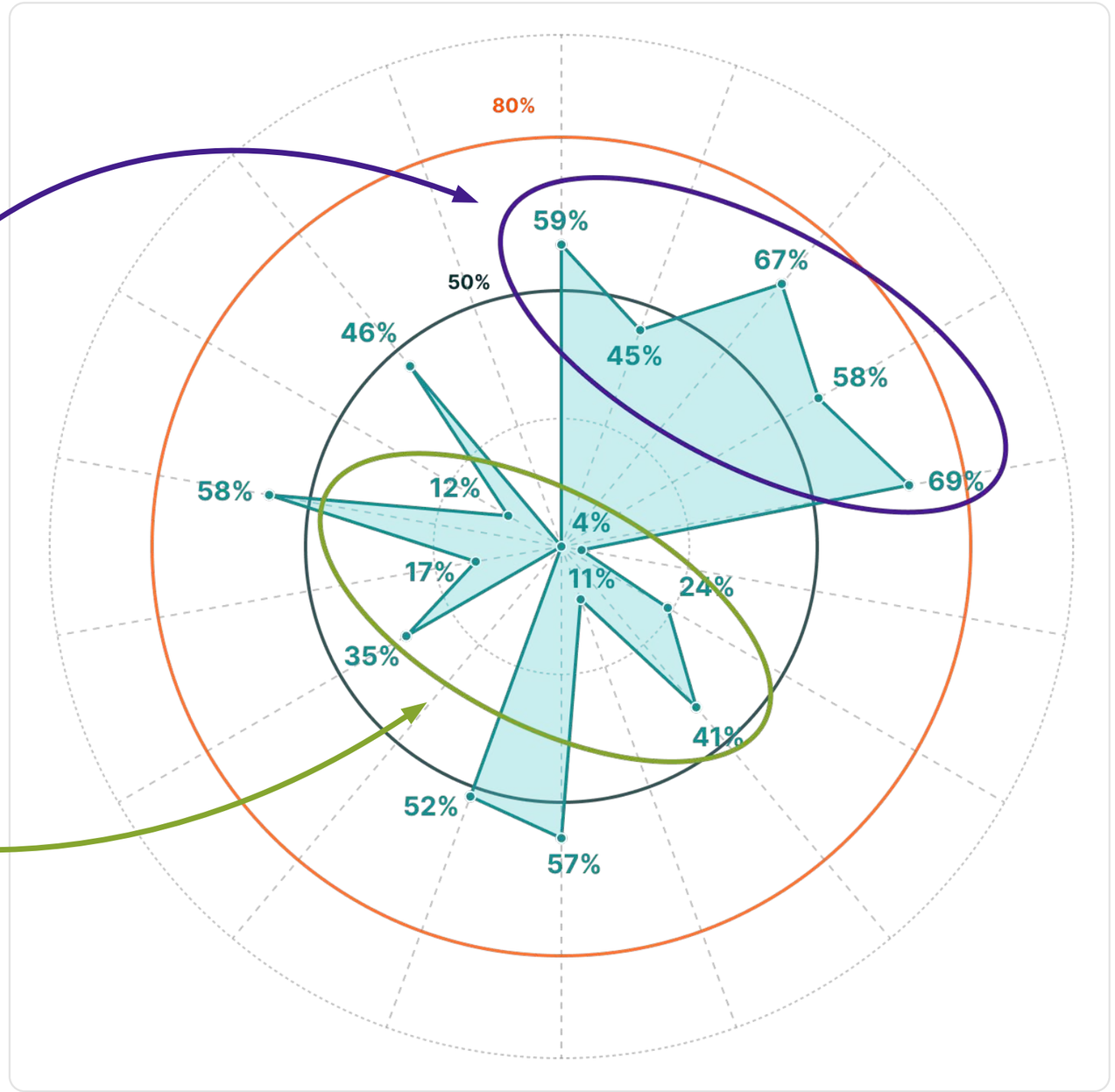


Figure 4. Example of a radar chart visualizing multiple dimensions of environmental justice. Source: Carbon Direct.

Violin charts

We used violin charts to display the population distribution for a group, plotted horizontally—circles indicate plotted data points (**figure 5**). Wider areas of the violin are values that occur more frequently in the included population. A wide base or top implies skewed distribution in that direction. A generally uniform shape implies generally equal distribution.

For a more detailed description of the data and methods used for our research, please see Appendix A: Data and methods.

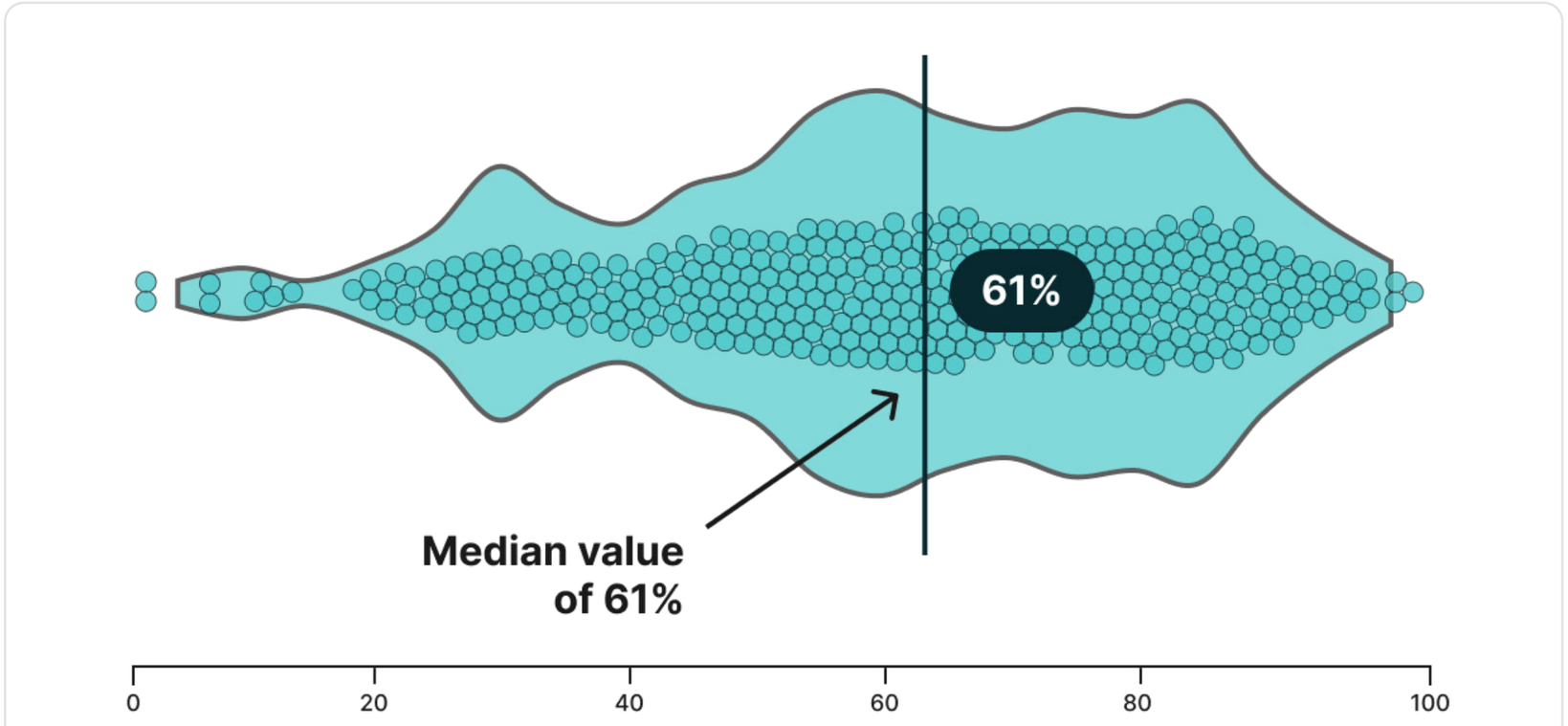


Figure 5. Example of a violin chart visualizing the population distribution for a group. Source: Carbon Direct.

General trends

At the highest level of interpretation, there is no consistent pattern or relationship between EJ metrics and the presence of CDR projects.

This means that CDR projects are not disproportionately located in low-income communities, communities of color, or other minority or historically marginalized communities (**figure 6** and **figure 7**). This lack of a pattern is itself a noteworthy result.

Unlike hazardous waste facilities in the US, CDR projects do not show a pattern of co-location with frontline communities. More research is needed to understand how CDR differs from other kinds of economic and industrial development and how the emerging carbon market might diverge from the legacy carbon market, as CDR rapidly scales.

However, there are still EJ trends worth exploring. Results become more interesting with disaggregation and deeper analysis into specific results and metrics. The results demonstrate that nuance and case-by-case assessment are required for interactions between CDR projects and EJ communities. For many projects in the dataset, project-level median metrics track fairly closely with national medians, which are at 49th or 50th percentile. However, there are some interesting trends at the pathway level (**nature-based**, **hybrid**, or **engineered**).



Source: Kali9 on iStock.

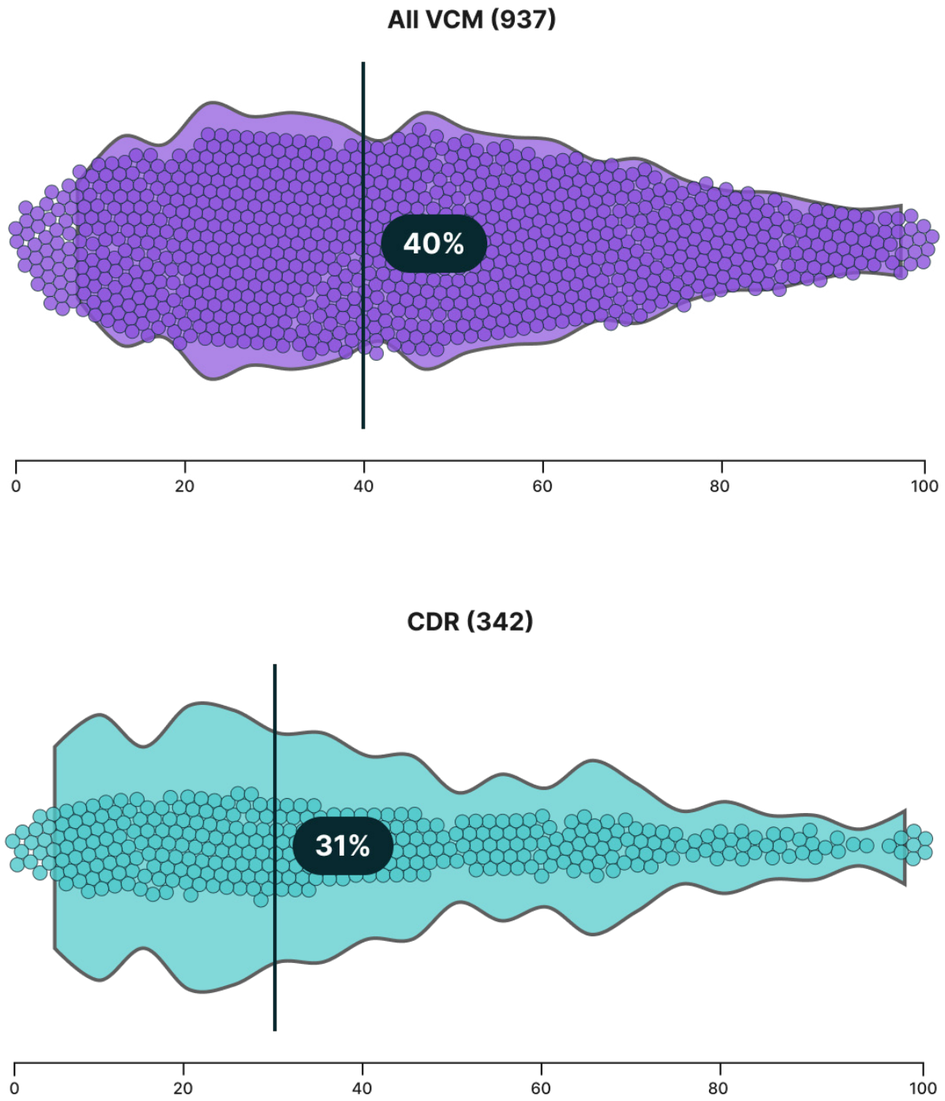


Figure 6. Violin charts of the people of color variable for all voluntary carbon market (VCM) projects (purple) and for only carbon dioxide removal (CDR) projects (teal) in a three-mile study area. There is a relatively regular distribution and the median percentile falls at the 40th percentile for all VCM projects and at the 31st percentile for only CDR projects. Source: Carbon Direct.

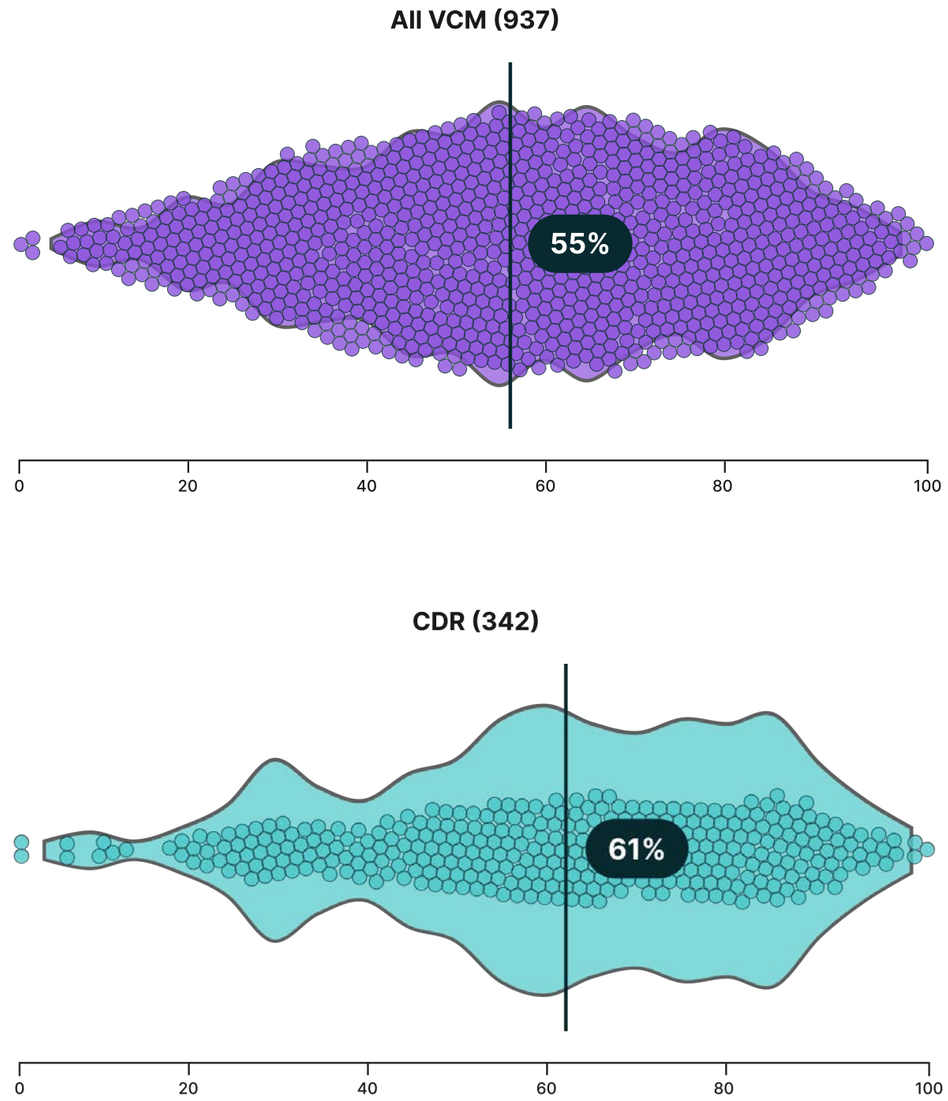
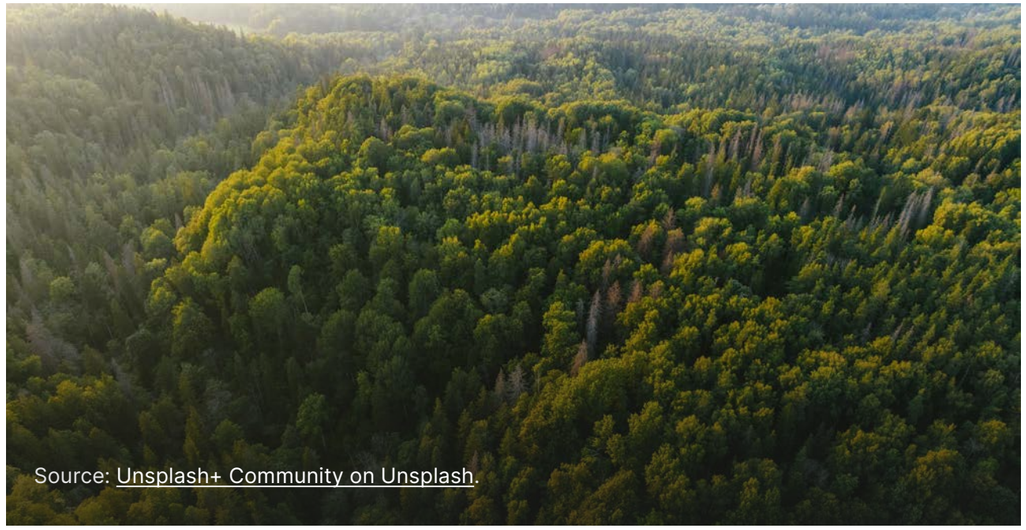


Figure 7. Violin charts of the low-Income variable for all voluntary carbon market (VCM) projects (purple) and for only carbon dioxide removal (CDR) projects (teal) in a three-mile study area. This is a somewhat skewed distribution, suggesting that there are generally more low-income communities in the US than there are communities of color. The median percentile falls at the 55th percentile for all VCM projects and at the 61st percentile for only CDR projects, somewhat higher than the people of color variable. Source: Carbon Direct.

Nature-based CDR trends

For nature-based CDR projects (**table 1**), the medians are generally close to the national median, but show more variation. This reflects a broader and more diverse set of projects—enabled by the larger number of nature-based initiatives overall. Nature-based projects make up the lion's share (95%) of the CDR market currently registered in the VCM. In general, nature-based projects also track closely with national trends and do not show correlations with EJ metrics (**figure 8**). The radar chart illustrates that most environmental burden indicators, for all nature-based projects in the VCM (n = 325), are near or below the 50th percentile, with the highest percentile at 61% for low-income households. The environmental burden indicators for all nature-based CDR projects follow a similar pattern. Most medians fall around the 50th percentile with low-income households, unemployment, and life expectancy falling slightly above the median.



Source: Unsplash+ Community on Unsplash.

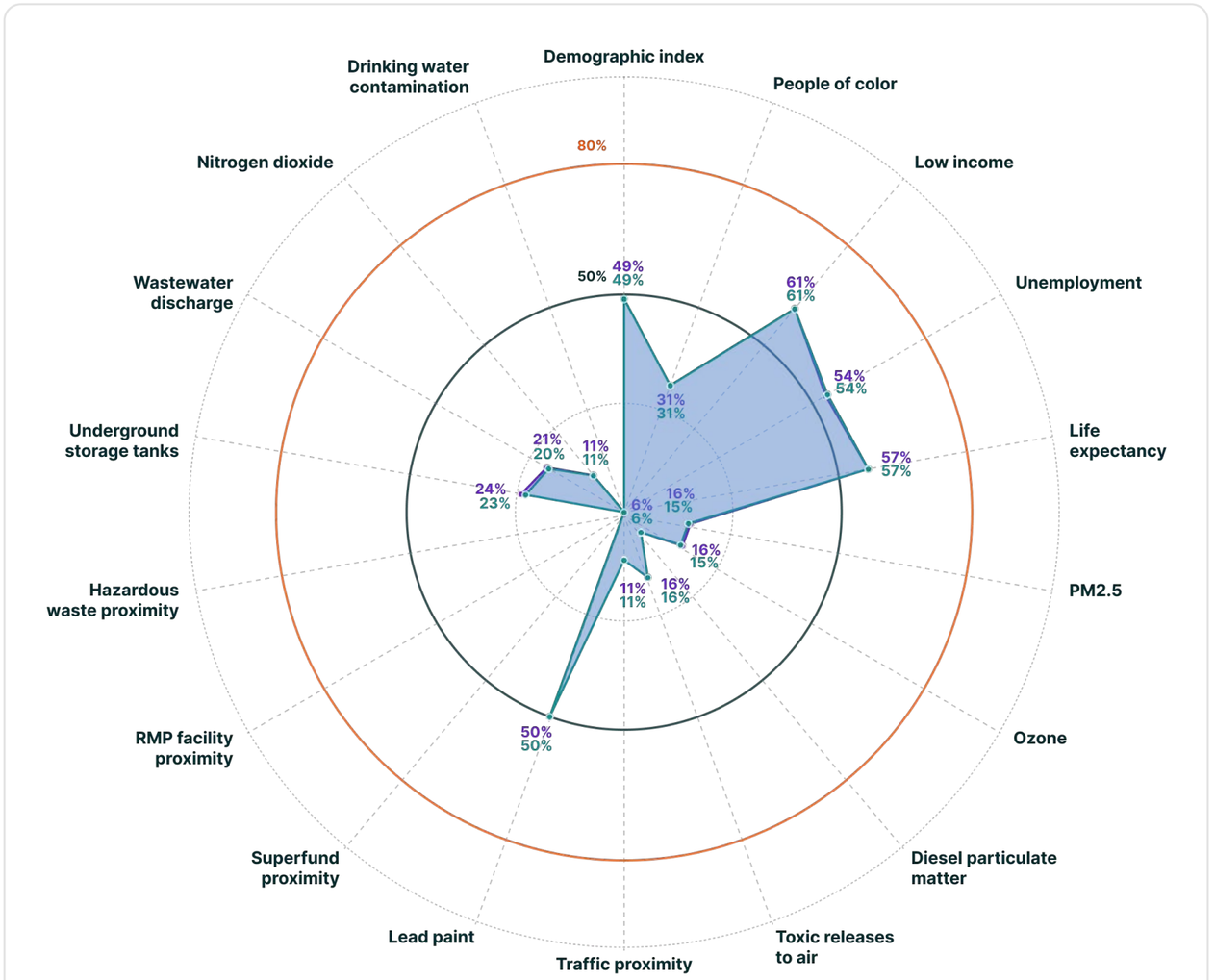


Figure 8. Radar chart for all nature-based projects in the voluntary carbon market (purple) and nature-based carbon dioxide removal projects (teal) by environmental burden indicators (e.g., superfund proximity, hazardous waste proximity). For nature-based projects, the median for all indicators does not cross the threshold of concern at 80th percentile, which suggests that nature-based projects are not disproportionately located near frontline communities. Source: Carbon Direct.

Hybrid CDR trends

For hybrid projects (**table 1**), the medians are slightly higher than the national median, but not substantially so (**figure 9**). The median hybrid CDR project does not show correlations with EJ metrics. Environmental burden indicators for all hybrid projects in the VCM (median represented in purple) are near the 50th percentile. With the highest percentile at 63% for "wastewater discharge."

We analyzed 16 hybrid CDR projects for this assessment, and the median value of those projects is represented in teal. Most environmental burden indicator medians fall near the 50th percentile. There are no major differences between hybrid projects in the VCM and hybrid CDR projects, according to environmental burden indicators—one exception is that, for VCM projects, wastewater discharge is noticeably higher than for CDR projects.



Source: Toni Jardon on iStock.



Figure 9. Radar chart for all hybrid projects in the voluntary carbon market (purple) and hybrid carbon dioxide removal projects (teal) by environmental burden indicators (e.g., superfund proximity, hazardous waste proximity). For hybrid projects in general, the median for all indicators do not cross the threshold of concern at 80th percentile, which suggests that hybrid projects are not disproportionately located near frontline communities. Source: Carbon Direct.

Engineered CDR trends

For engineered projects (**table 1**) there are no EJ correlations. This is mostly due to the small sample size. There are only **two** engineered CDR projects in the current registries (**figure 10**). Most environmental burden indicators for all engineered projects in the VCM (median represented in purple) are at or below the 50th percentile.

We analyzed the two CDR projects for this assessment (median represented in teal). Most environmental burden indicators for both CDR projects fall near the 50th percentile.

“Drinking water contamination” was the highest environmental burden indicator for CDR projects, ranking in the 83rd percentile. Sample sizes for most CDR pathways that are not forestry related are limited. Engineered CDR technology, such as DACS, is still early-stage, so the limited sample size analysis should not necessarily be treated as a pattern or indicative of future trends.



Source: Climeworks.

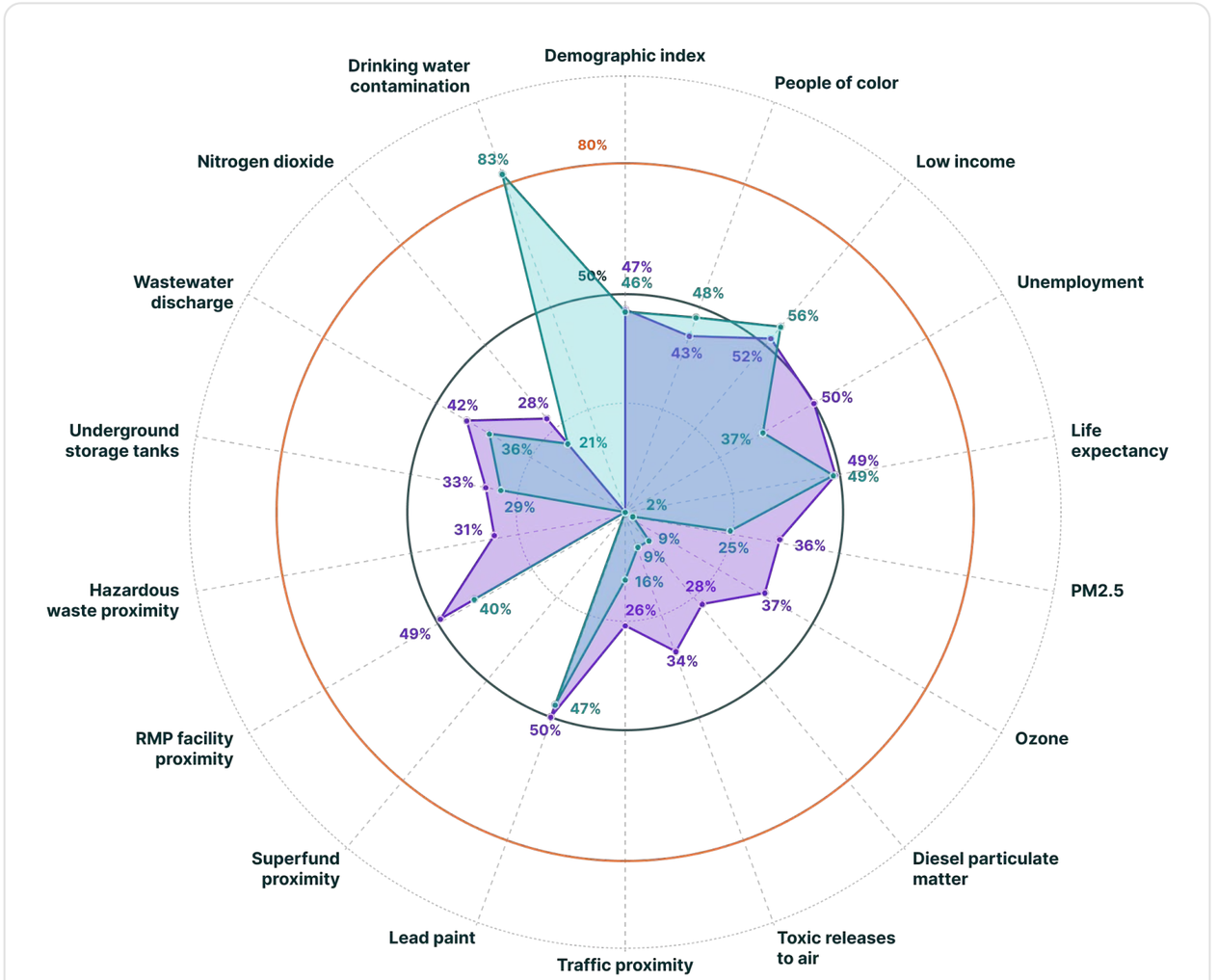


Figure 10. Radar chart for all engineered projects in the voluntary carbon market (purple) and engineered carbon dioxide removal projects (teal) by environmental burden indicators (e.g., superfund proximity, hazardous waste proximity). Source: Carbon Direct.

Case studies

To ground our findings, we chose to break them down by CDR pathway (nature-based, hybrid, and engineered removals). Within each pathway, we chose to focus on a specific case study to illustrate what the project-level data look like and how CDR practitioners and EJ advocates can use these findings. The case studies are useful for illustrating place-based dynamics rather than high-level patterns.

For each case study, we chose to feature projects that had the highest median percentile for the demographic index in the US. All project study areas for the case studies are defined by a three-mile radius surrounding the project location, which allowed us to capture all census tracts within three miles of the project.

Nature-based removals

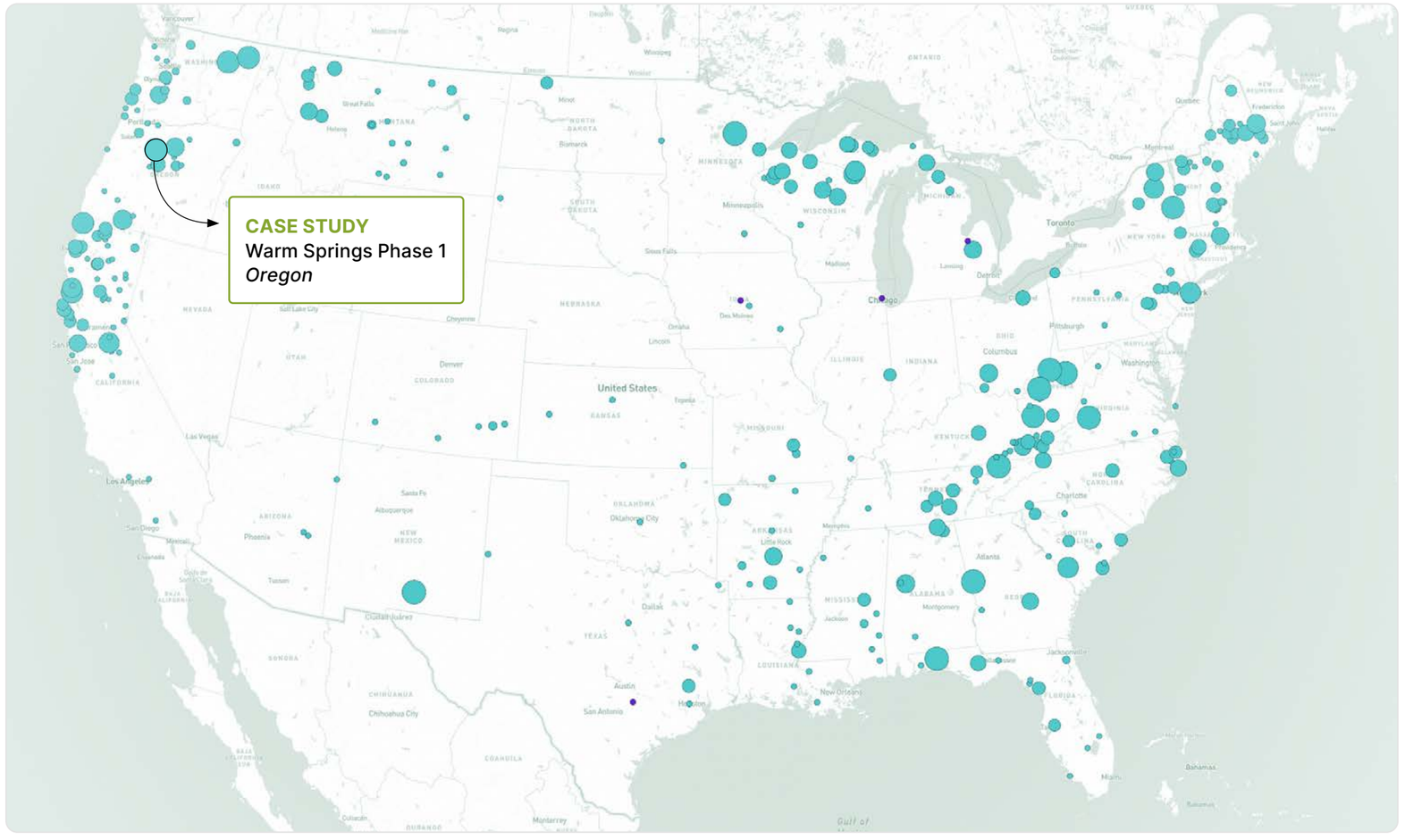


Figure 11. Map of all nature-based projects from major voluntary carbon market registries located in the United States. The size of the circles represents the volume of credits issued (larger circles = more credits issued). The purple circles represent non-removals and the teal circles represent removals. Our case study project for nature-based removals (Warm Springs Phase 1) is located in Oregon. Source: Carbon Direct.

Most nature-based projects are clustered regionally. The majority of nature-based projects are CDR with a small minority (~5%) classified as non-removals (**figure 11**). Nature-based removal projects are densely concentrated in certain regions—Northern California, the Pacific Northwest, the Southeast, the East Coast, and around the Great Lakes.

Nature-based CDR projects are not disproportionately located in EJ communities (**figure 12**). There is a somewhat normal distribution of the data, with a "regular shape" along the violin chart. The median at the 49th percentile tracks closely with the national median for all census tracts with the demographic index—showing that there is no correlation between nature-based CDR project locations and race or income.

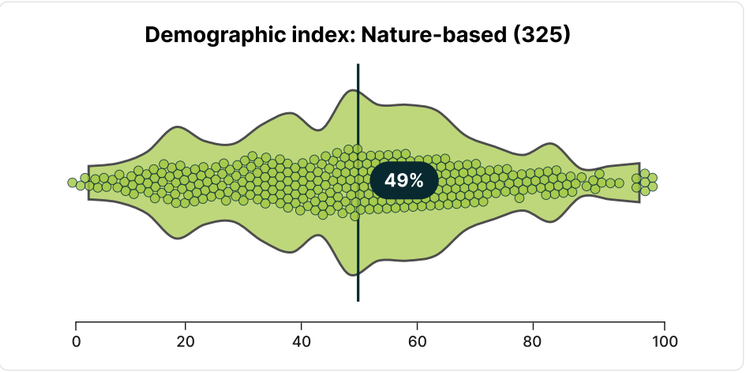


Figure 12. Violin chart of the demographic index for all nature-based carbon dioxide removal projects in the US, based on a three-mile study area. Source: Carbon Direct.

Case study: Warm Springs Phase 1

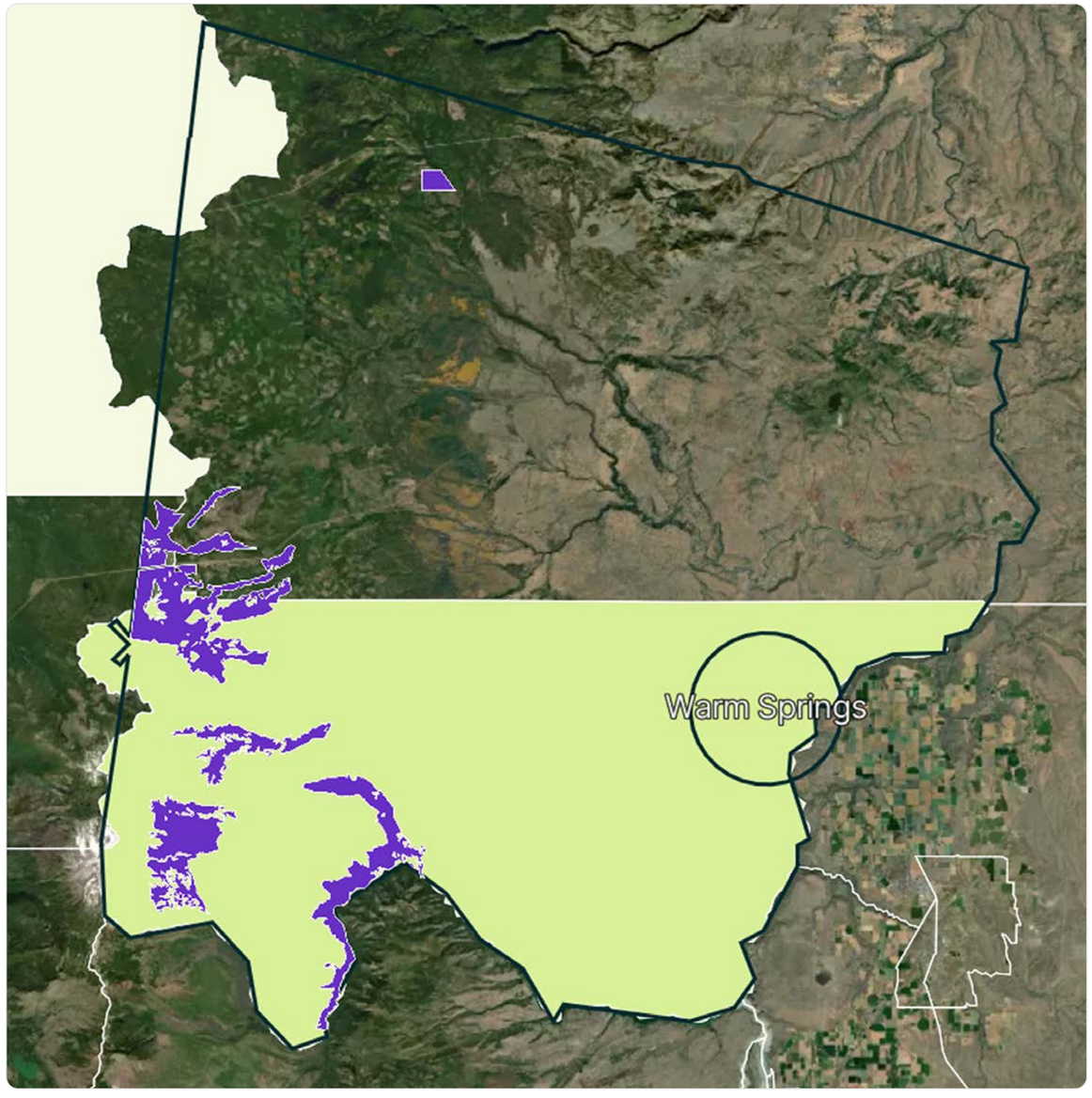


Figure 13. Three-mile study area map of the Warm Springs Phase 1 project, showing the demographic index. The 0-50th percentile census tracts are shaded transparent, and will not show up visually within the color gradient. Source: Carbon Direct.

We investigated the environmental burden impacts of a nature-based removal project, based on the project with the highest demographic index median percentile. This project is located in the Pacific Northwest region and called “Warm Springs Phase 1.”

This case study for nature-based CDR is defined by a three-mile study area map of the Warm Springs Phase 1 project. A visualization of the demographic index, which includes the variables “people of color” and “low-income,” is shown in **figure 13**. The Warm Springs Phase 1 project is located on the Warm Springs Indian Reservation, as shown by the reservation boundary on the map. Based on the project’s location, the demographic index shows a percentile value of 80-90%, suggesting that this census tract is home to historically marginalized and vulnerable communities.

Case study: Warm Springs Phase 1

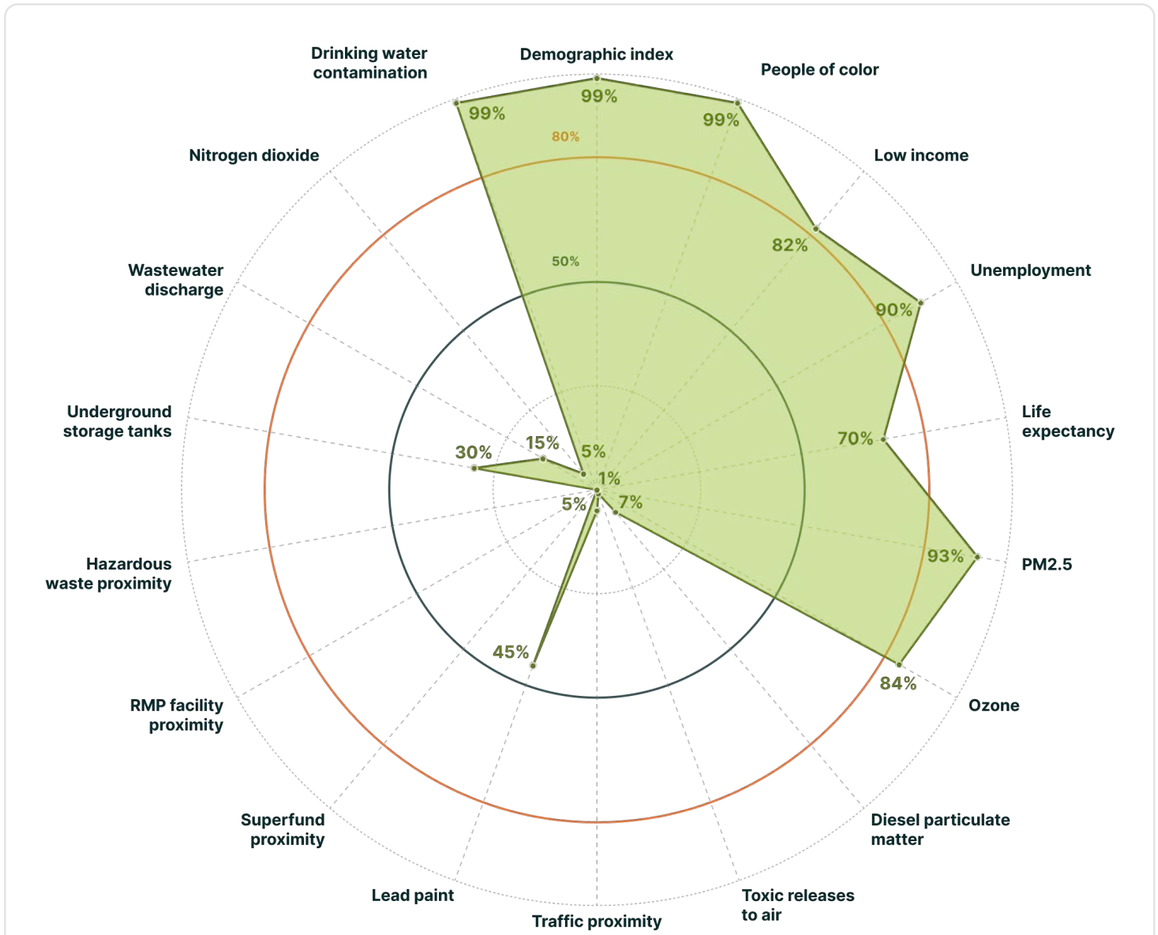


Figure 14. Radar chart for three-mile study area around Warm Springs Phase 1, a nature-based carbon dioxide removal project, by demographic and environmental burden indicators (e.g., superfund proximity, hazardous waste proximity). Four out of five key demographic indicators, and three environmental burden indicators, cross the threshold of concern, suggesting that this is a community that experiences environmental justice challenges. Source: Carbon Direct.

The communities living in proximity to this project fall across the 80th percentile threshold for all significant demographic indicators, as well as for three environmental burden indicators—drinking water contamination, exposure to PM2.5, and exposure to ozone pollution (**figure 14**). Given the project's location, which is on Tribal lands, these results highlight how Indigenous communities across the US often face disproportionate burden and experience environmental injustice. This does not mean the CDR project is contributing to or mitigating these pre-existing conditions. Rather, the analysis demonstrates the socioeconomic context of the project's location.

LEGEND

- Nature-based CDR projects
- 50th percentile (below national average)
- 80th percentile (above threshold of concern)

Hybrid removals

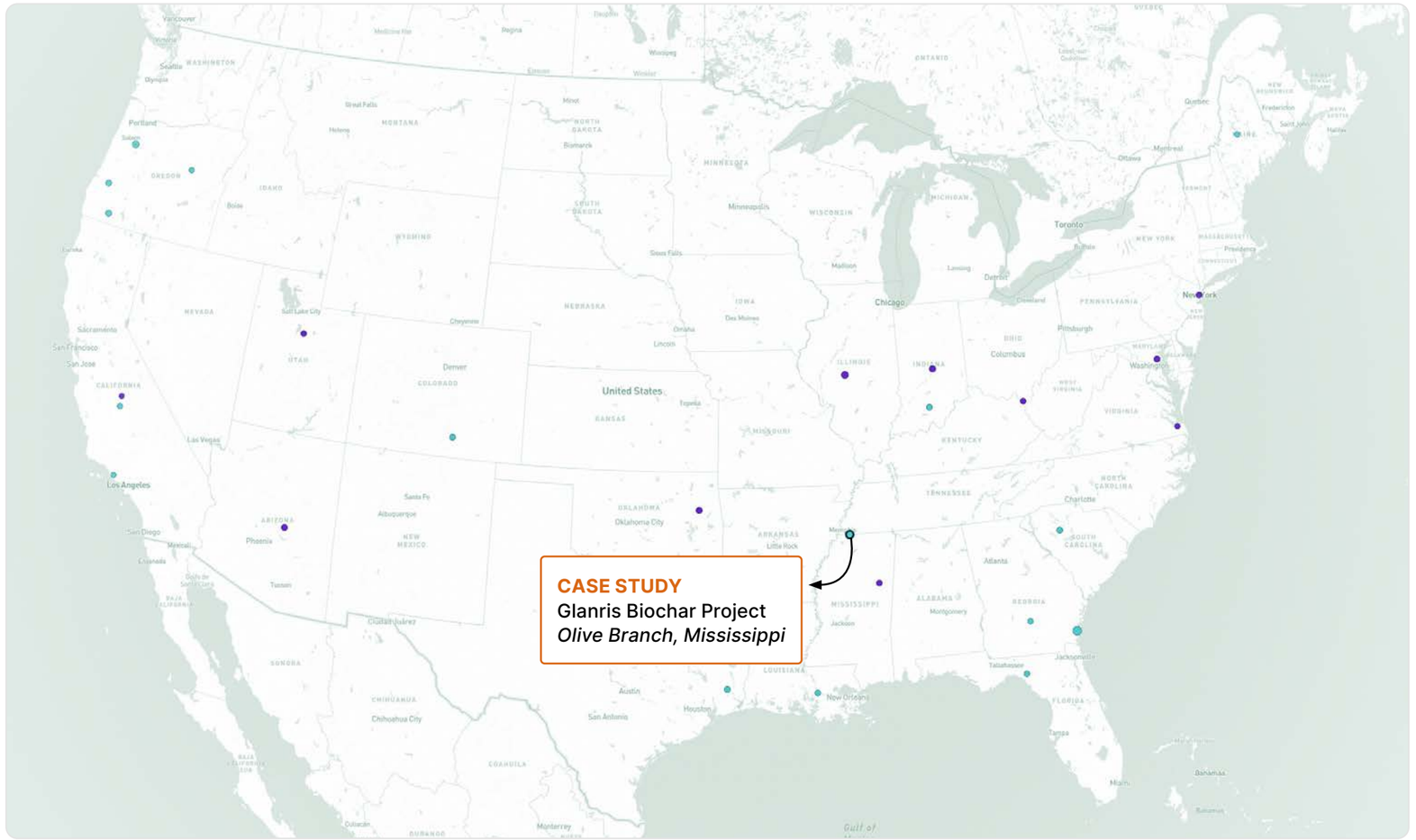


Figure 15. Map of all hybrid projects from major voluntary carbon market registries located in the United States. The size of the circles represents the volume of credits issued (larger circles = more credits issued). The purple circles represent non-removals and the teal circles represent removals. Source: Carbon Direct.

Hybrid projects are spread more sparsely and not densely clustered by region. Unlike nature-based CDR, there are no regional patterns or clusters for hybrid CDR projects in the US. There are about the same number of hybrid CDR projects as there are hybrid non-removal projects (**figure 15**).

Hybrid projects are not disproportionately located in frontline communities. The median percentile of the demographic index for all hybrid projects in the VCM is the 49th percentile. There are much fewer hybrid CDR projects to analyze, which reflects the irregular shape of this violin chart. Given the sample size, these results are not statistically significant. Still, this violin chart shows that there is no correlation between hybrid project locations and race or income (**figure 16**).

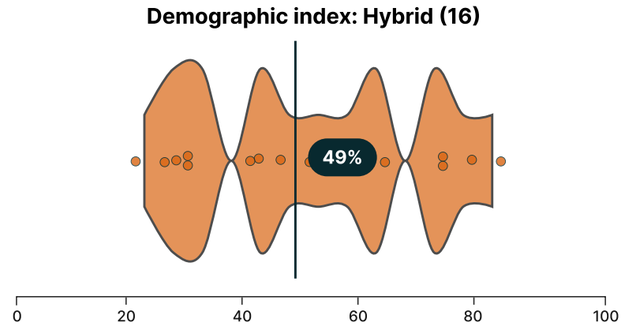


Figure 16. Violin chart of the demographic index for all hybrid carbon dioxide removal projects, based on a three-mile study area. Source: Carbon Direct.

HYBRID REMOVALS

Case study: Glanris Biochar Project

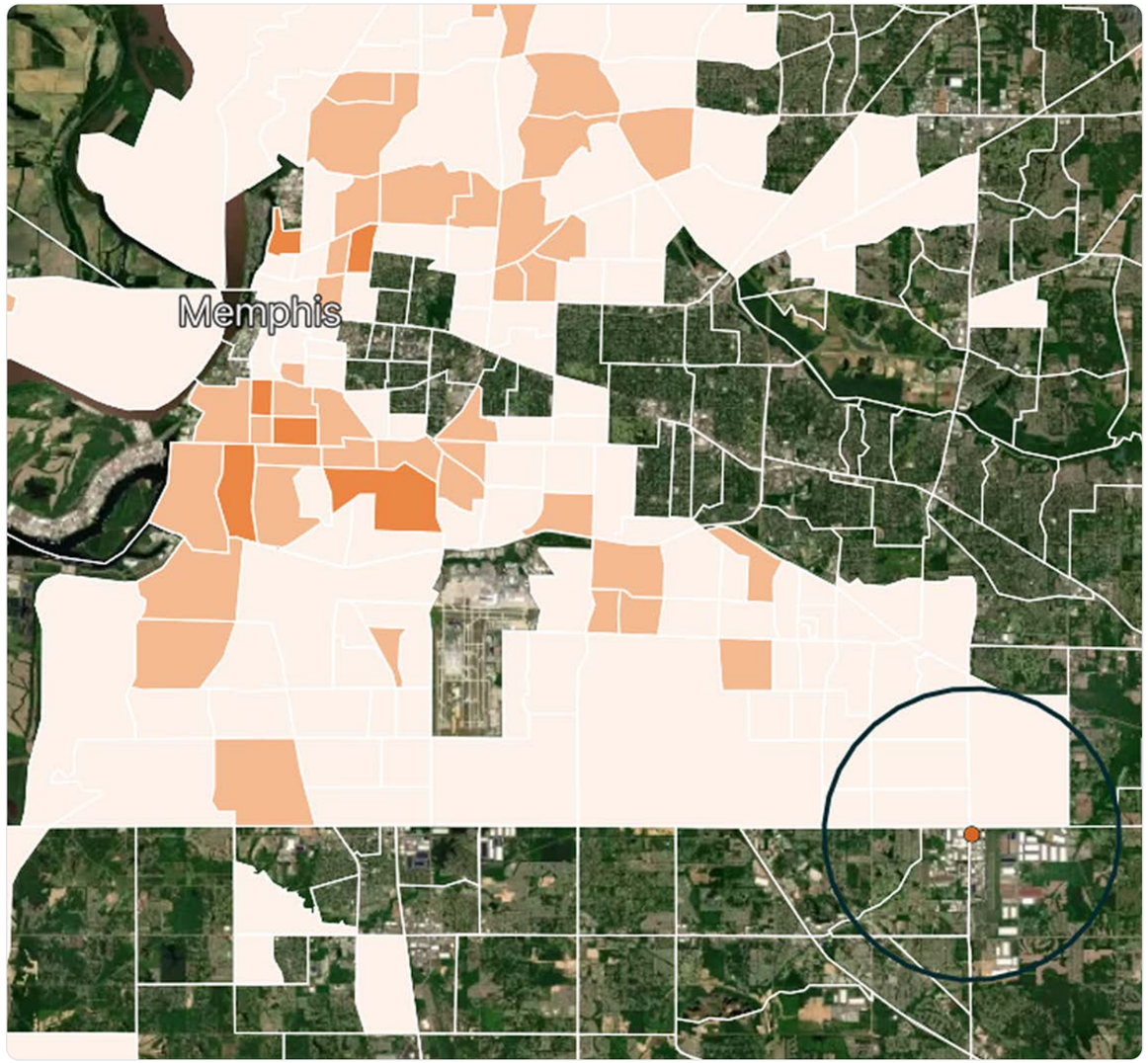


Figure 17. Three-mile study area map of the Glanris Biochar Project, showing the demographic index. The urban area of Memphis to the northwest of the project contains a higher concentration of low income and communities of color than the rest of the US. The 0-50th percentile census tracts are shaded transparent, and will not show up visually within the color gradient. Source: Carbon Direct.

We selected the hybrid CDR project with the highest median percentile for demographic index in the US, which is located on the border of Mississippi and Tennessee just south of Memphis. The Glanris Biochar Project is located in Olive Branch, Mississippi.

This case study for hybrid CDR is defined by a three-mile study area map of the Glanris Biochar project and the map shows a visualization of demographic index, which include the variables “people of color” and “low-income.” The demographic index for the project location is in the 79th percentile (**figure 17**). The surrounding metro area contains census tracts with high percentiles of disadvantaged communities. Expanding the aperture of analysis to consider the larger urban context is important for CDR siting and development.

LEGEND

Survey area

Demographic index:

- 0-50%
- 50-80%
- 80-90%
- 90-95%
- 100%

HYBRID REMOVALS

Case study: Glanris Biochar Project



Figure 18. Radar chart for three-mile study area around Glanris Biochar Project, a hybrid carbon dioxide removal project, by demographic and environmental burden indicators (e.g. superfund proximity, hazardous waste proximity). Source: Carbon Direct.

This case study shows the environmental burden and pre-existing environmental justice challenges for a hybrid project with the highest concentration of communities of color living in proximity to the project. The radar chart for the Glanris biochar project shows that the study area represents a place where there are a majority of people of color, as the people of color indicator is in the 90th percentile (**figure 18**). The demographic index is at the 79th percentile, which reflects the high concentration of communities of color but not a high presence of low-income communities. The study area also closely approaches or crosses the 80th percentile for five of the environmental burden indicators. This does not mean the project contributes to these inequities. This CDR project is in a community context with EJ dimensions. A future CDR project in such a community should consider these dimensions when approaching project design, implementation, and engagement.

LEGEND

- Hybrid CDR projects
- 50th percentile (below national average)
- 80th percentile (above threshold of concern)

Engineered removals

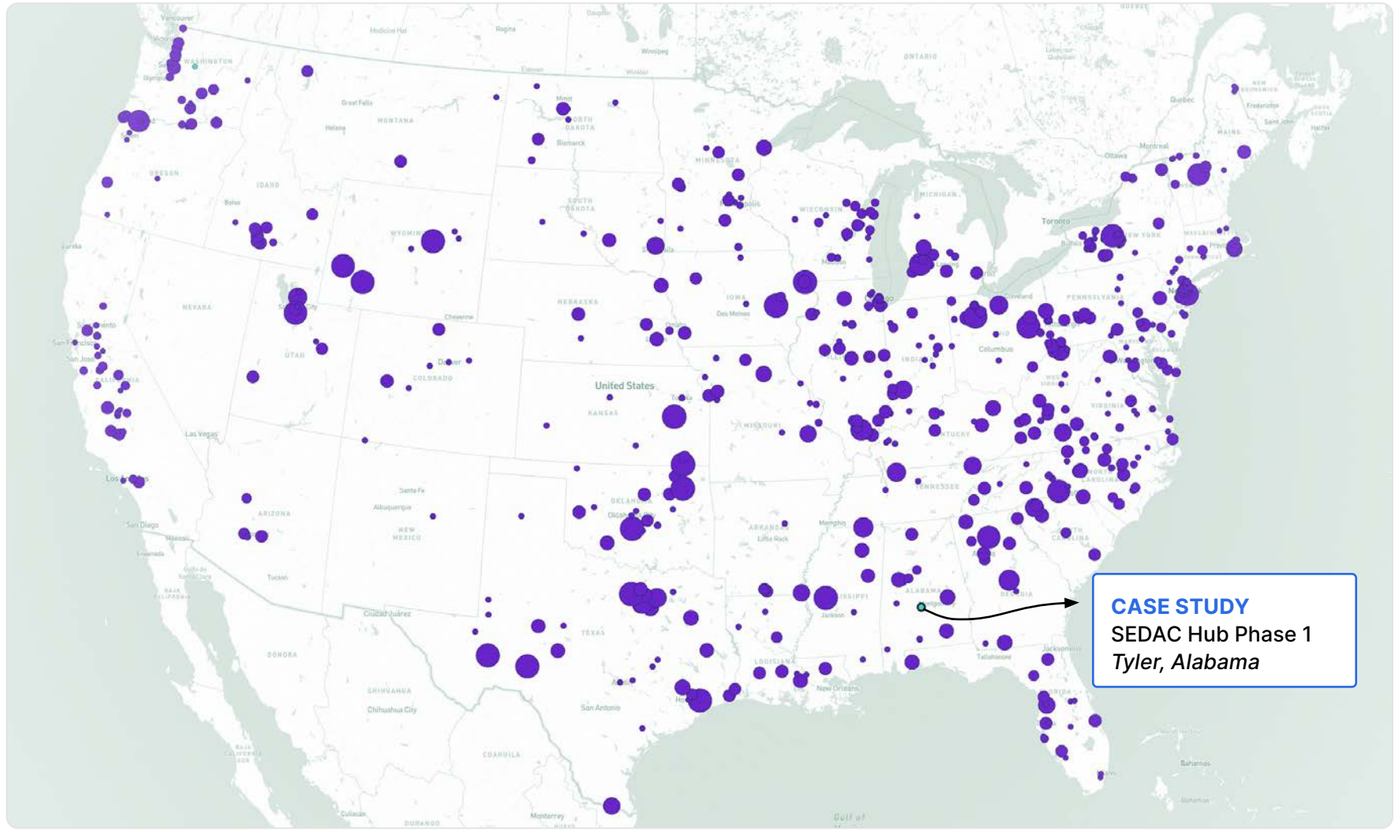


Figure 19. Map of all engineered voluntary carbon market projects in the US. The size of the circles represents the volume of credits issued (larger circles = more credits issued). The purple circles represent non-removals and the teal circles represent removals. Source: Carbon Direct.

Most engineered projects are non-removals. Only two are CDR—both are DACS projects, which is a quickly emerging but nascent technology. These two projects are located in Washington and Alabama. Looking across the VCM at all engineered projects in the US, there are clusters concentrated regionally (**figure 19**).

We chose to analyze all engineered carbon credit projects across the VCM, due to the very limited dataset for engineered CDR (only two projects). Engineered projects are not disproportionately located in EJ communities. The violin chart shows the median percentile of people of color and low-income variables, indicated here as demographic index for all engineered projects in the VCM and falling in the 47th percentile (**figure 20**). There is no correlation between engineered project locations and race and income.

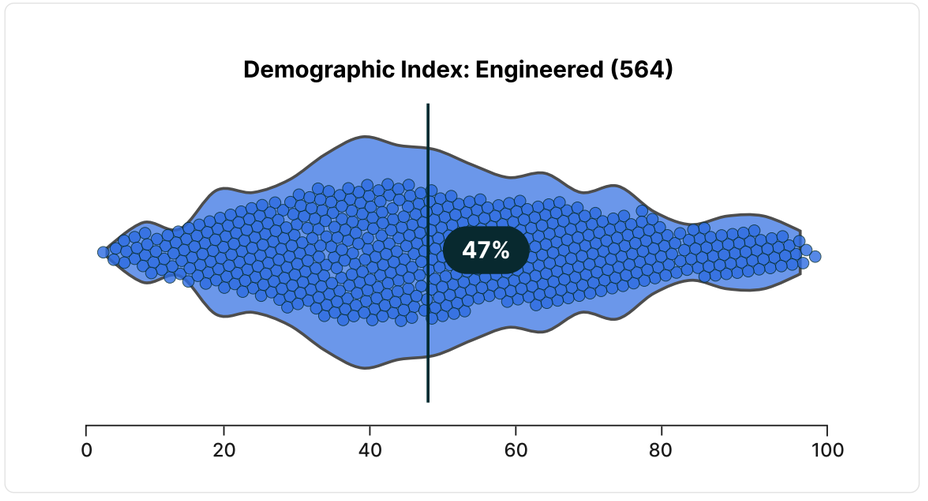


Figure 20. Violin chart of the demographic index for all engineered projects in the voluntary carbon market in the United States, based on a three-mile study area. Source: Carbon Direct.

ENGINEERED REMOVALS

Case study: SEADAC Hub Phase 1

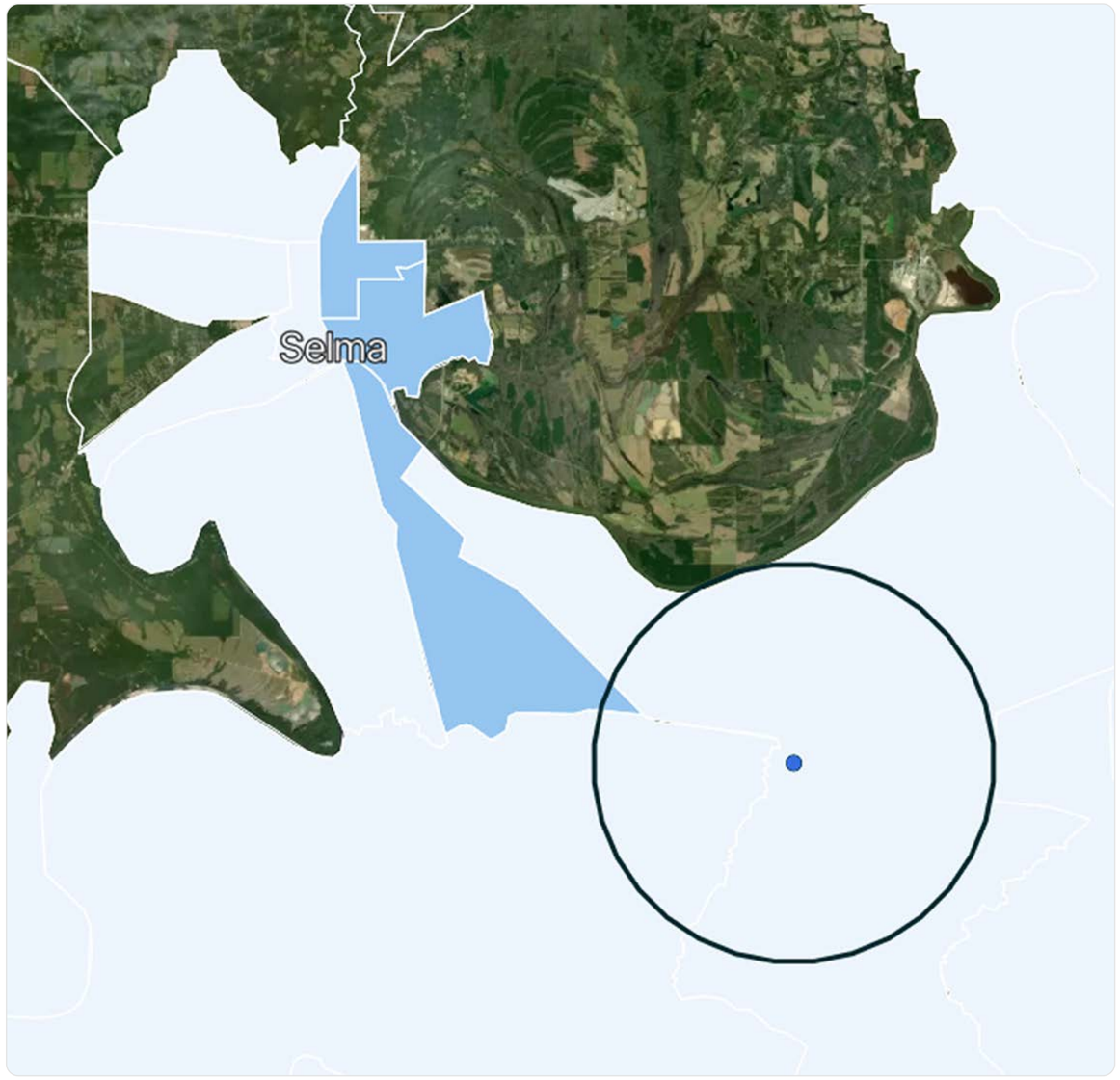


Figure 21. Three-mile study area map of the SEADAC Hub Phase 1 project, showing demographic index. The 0-50th percentile census tracts are shaded transparent, and will not show up visually within the color gradient. Source: Carbon Direct.

We selected the DACS project with the highest median percentile for demographic index, located in Tyler, Alabama: SEDAC Hub Phase 1. This case study for engineered CDR is defined by a three-mile study area of the SEDAC Hub Phase 1 project in northern Mobile County, Alabama.

The demographic index for the census tract containing the project is in the 50-80th percentile, 50-80th percentile, suggesting that the communities in close proximity to the project are not frontline communities. (**figure 21**). For this project, Selma is the closest city that has census tracts crossing the 80th percentile threshold. Carbon Direct does not consider the communities in immediate proximity to the project as being home to a majority of disadvantaged communities or vulnerable populations. However, the nearby city of Selma shows a different story, which is important for CDR developers to consider.

ENGINEERED REMOVALS

Case study: SEADAC Hub Phase 1

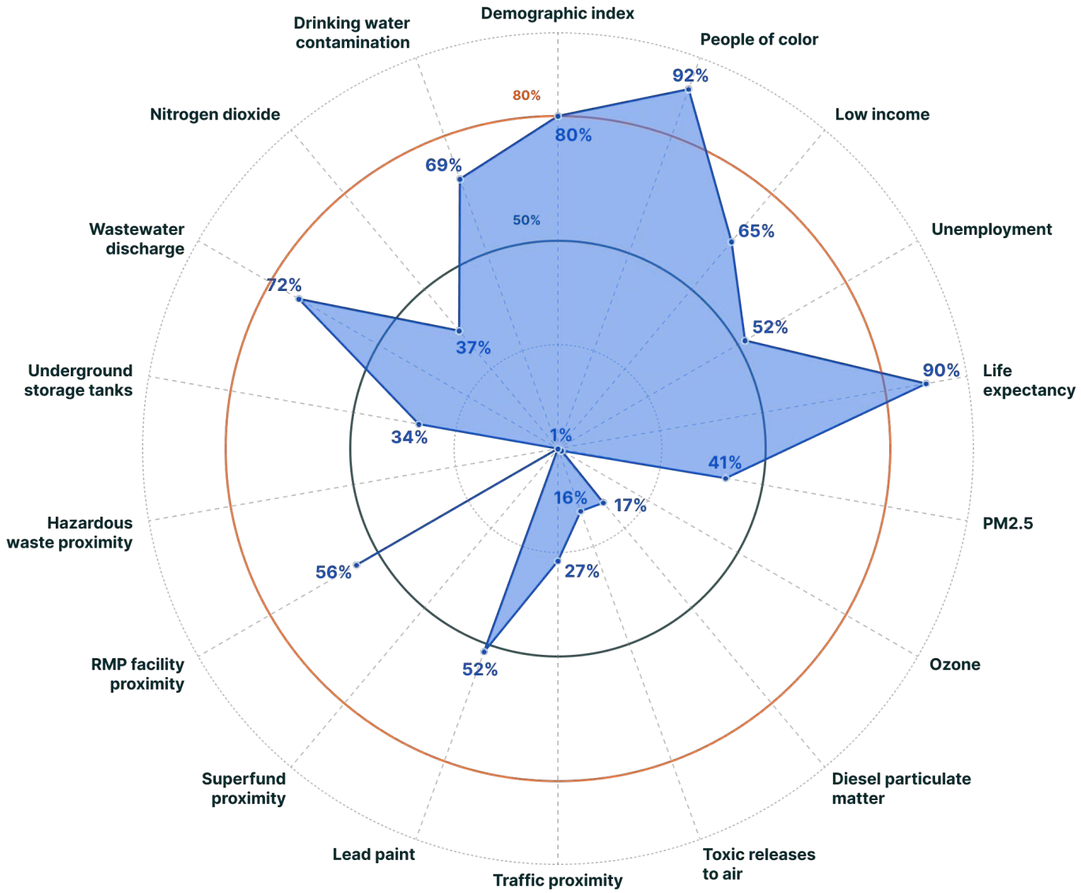


Figure 22. Radar chart for three-mile study area around SEADAC Hub Phase 1 project, an engineered carbon dioxide removal project, by demographic and environmental burden indicators (e.g., superfund proximity, hazardous waste proximity). Source: Carbon Direct.

No environmental burden indicators cross the threshold for concern for this project. The radar chart shows that the study area represents a place where there are a majority of people of color (indicator is in the 92nd percentile). The demographic index, people of color, and life expectancy indicators all cross the 80th percentile, suggesting there are vulnerable communities in proximity to the project (**figure 22**). This is one of two DACS projects that are currently in the VCM registries. DACS projects are an emerging CDR approach. This CDR project is in a community context with EJ dimensions. A future engineered CDR project in such a community should consider these dimensions when approaching project design, implementation, and engagement.

LEGEND

- Engineered CDR projects
- 50th percentile (below national average)
- 80th percentile (above threshold of concern)

Conclusion

In this first-of-its-kind study, Carbon Direct analyzed the demographic profiles and environmental burden indicators for communities living in proximity to CDR projects. This analysis yielded three key findings: (1) there are no major correlations between CDR project locations and frontline communities, (2) some CDR projects *do* exist near frontline communities within higher environmental burden, and (3) CDR projects are still nascent within the broader context of the VCM. While these results do not indicate concerning patterns, they are still noteworthy and underscore the importance of evaluating projects on a case-by-case basis for EJ dimensions.

Major takeaways

1

Causality and “why”

This research does not allow us to confidently explain the “why” or identify any causal reasons for the absence of a pattern. However, the lack of a pattern provides insight into how policymakers and EJ advocates can respond.

CDR is a nascent field, and projects are clustered within the nature-based pathway. These could be two contributing factors.

2

CDR community engagement

As CDR scales, there is strong potential for these projects to advance restorative justice and benefit frontline communities.

Project developers must engage these communities to build trust and develop consent. Strong, equitable community engagement plans will be key to scaling CDR in the future to receive social license.

3

Restorative justice

The research demonstrates that: (1) projects are not disproportionately located in frontline communities, which means (2) these communities do not incur disproportionate harm.

However, CDR projects have the potential to bring benefits to frontline communities. EJ advocates and CDR project proponents should design and implement robust community benefits plans.

4

Future unknowns

CDR projects represent only a fraction of the current VCM. If we are to meet climate commitments, CDR must scale rapidly. This report will be a useful foundation for understanding future trends.

Policymakers, EJ advocates, researchers, and CDR proponents must consider EJ dimensions as a central piece of project siting, alongside technical and environmental considerations.



Source: Goodboy Picture Company on iStock.

Additional insights

Additionally this research provided the following insights:

- **Nature-based CDR:** The majority of US-based CDR projects in the VCM are nature-based.
- **Hybrid CDR:** The majority of hybrid projects for CDR are biochar, and there are approximately the same number of removal and non-removal hybrid projects in the VCM.
- **Engineered CDR:** The majority of US-based engineered projects in the VCM are not CDR. There are only two DACS projects in the US registered in the VCM, neither of which had a noteworthy correlation between environmental burden indicators nor demographic index.
- **General trends:** While Carbon Direct could not determine trends based on the median of projects, trends may exist for the tail ends of the data.
- **Importance of place:** The lack of general trends does not preclude local and place-based impacts and concerns.
- **Using these findings:** This landscape analysis serves as a resource for policy advocates, project developers, and frontline communities in the US. This study is not meant as a tool for decision-making for CDR planning, given that it is an analysis of community demographic profiles in proximity to existing CDR projects.

Future research can build on this study to capture emerging CDR trends. The results of our analysis suggest several questions for future research and investigation:

- What are the economic benefit indicators in the same study area? Do VCM or CDR projects correlate with these indicators?
- Given EJ concerns around CCS: How does the location of avoidance or reduction projects (like CCS) relate to where frontline communities live?
- How do project developers consider EJ principles in CDR projects? Are there patterns in how CDR developers create and design community engagement and benefits plans?
- How are investments in CDR prioritizing certain removal pathways? Do these priorities have EJ implications?
- How will the growth of CDR in the carbon market influence current observations?
- How can we apply this method and approach to CDR in a global context?

This study lays a foundation for understanding the current landscape of CDR projects in the US. As CDR continues to scale as a climate solution, it will be essential for CDR advocates to conduct social impact and EJ analyses of future project sites.

While this study demonstrates there is currently no disproportionate impact of CDR projects on frontline EJ communities, this does not mean this pattern will carry into the future. Through meaningful community engagement, strong community benefits plans, and adherence to EJ principles, CDR projects can advance equitable climate solutions.

Originally published as Carbon Direct, which is now Relae. Learn more at relae.co

Appendices

Appendix A: Data and methods

VCM registries

VCM registries list and detail carbon credit projects that have issued and/or retired carbon credits:

- **Issued:** Certificates granted for verified emissions reductions or removals, allowing them to be sold or used for offsetting.
- **Retired:** Credits that have been used to offset emissions and can no longer be traded or reused.

VCM registries are often called the “legacy carbon market” and do not capture **planned or future** projects, which will largely feature **carbon removal**. Currently, the bulk of CDR is captured in offtake agreements, where companies commit to purchase credits in the future, when they are ready to be issued. Because of market uncertainty, Carbon Direct did not include these projects in our analysis. Future analyses should integrate projects beyond those listed on the VCM.

Carbon Direct used data from the following registries:

- American Carbon Registry (ACR)
- Verra
- Climate Action Reserve (CAR)
- International Energy Agency’s Carbon Capture, Utilisation and Storage (IEACCUS)
- Puro.earth
- Gold Standard
- CDR.fyi

EJ Screen

EJScreen is a mapping tool that the EPA hosts and manages. The current administration has taken this tool down. Carbon Direct downloaded all EJScreen data before the current administration removed the tool for public use. EJScreen integrates US census data (demographic and population) at the census tract level with environmental burden indicators and a suite of other climate vulnerability and environmental data.

- EJ Screen is used widely in EJ research methodologies and public agencies focused on Environmental Impact Statements, EJ assessments, and for identifying communities that should be prioritized for EJ concerns.
- EJScreen data represents percentiles (thresholds) for comparing census tracts within the state or nationally.
- EJScreen data is only available in the US. No datasets exist at the global level that are as comprehensive as EJScreen.

Carbon Direct used the following demographic variables and environmental burden indicators from EJScreen:

- **Demographic variables:** people of color, low-income, demographic index, unemployment, life expectancy
- **Environmental burden indicators:** diesel particulate matter, drinking water contamination, nitrogen dioxide (NO_2), wastewater discharge, underground storage tanks, hazardous waste proximity, risk management program (RMP) facility proximity, superfund proximity, lead paint, traffic proximity, toxic releases to air, diesel particulate matter, ozone, particulate matter 2.5

Data

Carbon Direct analyzed 342 CDR projects out of a total of 937 unique VCM projects in the US against standard EJ indicators (i.e., demographics and environmental burden):

- We conducted summary statistical analyses and correlation analysis on population-weighted data.
- We used median for census tracts that fall into a project area and compared project type medians against national medians.
- We layered 1-mile, 3-mile, and 10-mile radii for project study areas.
- We used 80th percentile and above as a threshold to identify indicators of concern.
- We compared population-weighted median percentiles against national medians.

Non-removals projects that are sold on the VCM are categorized as “other” in this analysis. These types of projects include:

- Alternative carbon capture, utilization, and storage (CCUS) and carbon utilization
- Refrigerant systems optimization and leak mitigation
- Transportation efficiency and modal shifts
- Waste treatment and mitigation of ozone-depleting substances
- Waste heat capture and energy recovery
- Industrial process optimization and fuel switching
- Renewable energy
- Other projects, not otherwise classified

Limitations in the data accounted for in our analysis included:

- **Data granularity:** Census data isn’t specific enough to know where people live exactly (e.g., do minority communities live closer to the project or further within the census tract). Also, EJScreen blocks are still fairly large and may fail to capture nuanced relationships.
- **Small sample sizes:** Many CDR technologies are nascent and have limited real-world deployment. Making strong claims of trends based on such limited data should be avoided.
- **Geospatial technicalities:** The calculations do not account for how nearby data points may be correlated (spatial autocorrelation).
- **Incomplete data:** This assessment only used project data that is available on registries. CDR projects that are proposed, are under construction, or that otherwise lack public data (e.g., projects purchased through offtake agreements) are not accounted for in this assessment.

Methods

We aggregated data from multiple registry sources and then filtered for US-only projects. We deduplicated the data, generated buffer zones at 1, 3, and 10 miles, and then joined project data with EJScreen census block group data. We then computed population-weighted median EJ metrics for each project at each buffer distance. For this analysis, we exclude projects that do not fall in one of our relevant CDR technology pathways (nature-based, hybrid, or engineered). We calculated relevant summary statistics for each technology pathway and socioeconomic indicator, treating values above the 80th percentile as crossing the threshold of concern. We then looked at specific projects for case studies.

Appendix B: Glossary

Carbon dioxide removal (CDR): A climate mitigation strategy that focuses on removing carbon dioxide from the atmosphere. Carbon removal projects focus on a variety of removal pathways or methodologies. Carbon Direct organizes these into three distinct categories: nature-based, hybrid, and engineered.

CDR removal pathway: The method or process by which a project removes CO_2 from the atmosphere.

Nature-based CDR: Approaches to CDR that focus on natural climate solutions and ecosystem processes like reforestation.

Hybrid CDR: Approaches to CDR that combine both natural and engineered climate solutions, like BECCS.

Engineered CDR: Approaches to CDR that focus on engineered and technological solutions like DACS.

Voluntary carbon market (VCM): The voluntary carbon market is a system where businesses, organizations, and individuals can buy and sell carbon credits to offset their greenhouse gas emissions. These credits fund projects that reduce or remove carbon dioxide from the atmosphere, such as reforestation or renewable energy initiatives.

Issued carbon credits: Certificates that represent a verified reduction or removal of greenhouse gases from the atmosphere. These credits are created and approved by regulatory bodies or carbon offset programs when a project, such as reforestation or renewable energy, successfully reduces emissions.

Retired carbon credits: Carbon credits that have been used to offset emissions and can no longer be traded or sold. Once a company or individual purchases and retires a credit, it is permanently taken out of circulation, ensuring that the claimed emission reduction is accounted for and cannot be reused.

Environmental justice (EJ): A social movement, a policy framework, and a body of scholarship and advocacy, environmental justice emerged in the US from the civil rights movement in the 1970s and 1980s. Environmental justice focuses on structural inequalities at the intersections of social marginalization and environmental pollution, demonstrating clear evidence of the disproportionate burden from environmental harms on low-income communities, communities of color, and Indigenous populations in the US. In the decades since, EJ has emerged as a key political framework, both domestically and globally, to encourage climate solutions that identify, consider, and address structural inequality.

Frontline communities: Populations that experience the earliest and most severe impacts of climate change and environmental hazards due to their geographic location, socioeconomic status, or historical marginalization. These communities, often composed of low-income groups, Indigenous peoples, and communities of color, face disproportionate risks from pollution, extreme weather, and resource depletion. Climate and environmental justice efforts prioritize their leadership and needs to ensure equitable solutions.

Demographic index: A composite index of the people of color and low-income households indicators from US EPA's EJScreen. Race and socioeconomic status were the two defining areas of concern for early EJ advocates. This index captures the combination of race and class represented as (people of color + low-income/2).

Radar chart: Also known as a spider chart or web chart, this form of data visualization allows viewers to compare multiple variables at once. It displays data as a polygon with each axis representing a different category, making it easy to see strengths, weaknesses, and patterns across multiple dimensions.

Violin chart: A type of graph that shows the distribution of data across different categories. It combines a box plot with a density plot, helping to visualize both the spread of the data and where values are most concentrated, making it useful for comparing multiple groups.

Acknowledgements

The following people and organizations contributed to this research and report:

Core team

Grant Gutierrez, PhD (lead) Head of Community Impacts

Sarah Braverman, Project Manager and Global Policy Analyst

Leslie Aguayo, Environmental Justice Associate

Jasper Croome, Senior Software Engineer, Data Visualization

Jared Stapp, PhD, Data Engineer

Liam Kilroy, Research Associate, Statistical Analyses

Adrianna Sutton, Senior Science Writer and Editor

Chi Thorsen, Director, Creative and Brand

McKnight Foundation

Sarah Christiansen, Director, Strategic Climate Initiatives

Ben Passer, Program Director, Midwest Climate and Energy

Carbon Direct

Ben Bogart, Director, Data Enablement

Colin McCormick, PhD, Principal Scientist

Zara Ahmed, DrPH Chief Operating Officer

Matthew Potts, PhD, Chief Science Officer

About Carbon Direct

Carbon Direct Inc. helps organizations go from climate goal to climate action. We combine technology with deep expertise in climate science, policy, and carbon markets to deliver carbon emission footprints, actionable reduction strategies, and high-quality carbon dioxide removal. With Carbon Direct, clients can set and equitably deliver on their climate commitments, streamline compliance, and manage risk through transparency and scientific credibility. Our expertise is trusted by global climate leaders including Microsoft, American Express, and Alaska Airlines, as well as by the World Economic Forum, which selected Carbon Direct as an Implementation Partner for the First Movers Coalition. To learn more, visit www.carbon-direct.com.

Disclaimer

Carbon Direct does not provide tax, legal, accounting, or investment advice. This material has been prepared for informational purposes only, and distribution hereof does not constitute legal, tax, accounting, investment, or other professional advice. No warranty or representation, express or implied, is made by Carbon Direct, nor does Carbon Direct accept any liability with respect to the information and data set forth herein. The views expressed in this document are opinion only, and recipients should consult their professional advisors prior to acting on the information set forth herein.

Cover image: A Chosen Soul on Unsplash.