Market Expectations On Future Revenue Streams For Carbon Dioxide Removal

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Overview

To avoid the worst consequences of climate change, a rapid decarbonization of global energy systems is indispensable, especially through a rapid deployment of renewable energy technologies and the electrification of transport and heating. As emphasized by the Intergovernmental Panel on Climate Change (Masson-Delmotte et al. 2022), maintaining global temperatures well below the 2°C threshold in the long term is not sufficient with emissions reductions alone—Carbon Dioxide Removal (CDR) is also needed to neutralize residual emissions and to address the "overshoot" arising from excessive cumulative CO_2 in the atmosphere.

To achieve a global removal capacity of 5–15 Gt per year in the second half of the century, the rapid build-up of a CDR industry is necessary, given the nascent nature and still high cost of many CDR technologies and solutions (Sievert et al. 2024). Fueled by the voluntary carbon market, various government support schemes, and venture capital investments, a diverse landscape of CDR solutions is developing, spanning from bioenergy with carbon capture and storage (BECCS) and direct air carbon capture and storage (DACCS) to nature-based and hybrid technology–nature solutions such as biochar, enhanced rock weathering, and direct ocean capture (Fuss et al., 2018; Smith et al., 2024). While the revenue potential for CO_2 removals is limited as of 2024, the companies developing these CDR solutions (partly from the energy sector, partly new entrants) are betting on a number of different markets and revenue models for carbon removal credits in the near- to mid-term future. Further, solutions such as BECCS combine carbon removals with usable energy generation, adding a second revenue stream (Fajardy & Mac Dowell, 2017).

To grow the CDR industry in line with Paris-compatible pathways, the revenue uncertainty is a major challenge: government subsidies like tax credits from the United States Inflation Reduction Act might be time-limited, and "prestige" buyers on the voluntary carbon market might turn away from pricey removals. While compliance markets such as the European emissions trading system (EU ETS) could become large markets, it is unclear to what extent and when they might accept removals as equivalent to allowances (Sultani et al., 2024). Climate policymakers are increasingly aware of this challenge, as underlined by recent discussions in the EU, UK, and the US (European Commission, 2023).

Given the diverse landscape of CDR solutions and the global footprint of the emerging industry, it is still unclear which markets or non-market revenues are most crucial for different players, and in which time horizons investors expect different removal markets to materialize and grow. To fill this gap, this conference contribution empirically studies the market and revenue expectations among key CDR players globally, drawing on a quantitative survey and qualitative interviews with the senior management of key CDR industry actors. The results inform policymakers on the most important intervention points to decrease revenue uncertainty, as well as researchers modeling future energy systems that include carbon dioxide removal to reach climate targets.

Methods

This study combines quantitative survey data with qualitative interviews in a mixed methods research design. First, the CEOs, founders, or other senior managers of global CDR companies were contacted via e-mail. We identified relevant companies based on achievements or ratings in key industry competitions, such as the XPRIZE competition (considering the top 100 companies only), the AIRMINERS kiloton fund, the Frontier advanced market commitment, and public funding schemes such as from the U.S. Department of Energy. We only consider companies with (planned) removals at the kiloton scale by the end of 2025, a carbon storage permanence of at least hundreds to thousands of years, and active business operations in 2024. From approximately 110 companies on our long list, 51 replied and contributed by January 2025.

Following approval of the process by ETH Zurich's ethics committee, online interviews were conducted, combining a quantitative survey (ranking the importance of nine different markets/revenues, over the time 2024–2050) and qualitative questions concerning the underlying considerations for the ranking. The quantitative data is analyzed

descriptively, and the interview transcripts are coded using the software MAXQDA. We then combine insights from the quantitative and qualitative parts to derive policy implications, as well as implications for energy system modelers.

Results

While the analysis has not been fully finalized by January 2025, preliminary results highlight important patterns. First, voluntary carbon markets—especially advanced market commitments—have been highly important in 2024 and are considered key to drive CDR development through 2026. However, there is great uncertainty concerning the scalability of these markets, and most actors expect compliance markets—such as the EU ETS—to become the most important revenue source by 2030. Importantly, reliance on compliance markets is widespread across technologies, going well beyond BECCS and DACCS, which are the focus of attention for EU policymakers to date. Also, many CDR companies in the United States (a key geography for the industry) expect to commercialize their removals in compliance markets in the EU, UK, and Japan, which would require respective market openings that are not currently foreseen (except for Japan). With respect to "revenue stacking" involving energy generation and other revenue sources, this appears limited to a few BECCS companies, whereas most other industry players essentially plan for a "pure play" CDR business

Conclusions

In summary, our study indicates that recent growth in CDR relied heavily on voluntary carbon markets, yet policy-driven compliance markets are widely seen as the ultimate driver for large-scale revenue. The findings underscore the importance of clear regulatory frameworks and international coordination to enable the integration of CDR solutions into established emissions trading systems. Further investigation should focus on how different policy instruments can mitigate revenue uncertainty and accelerate CDR deployment to align with global climate goals, in a coordinated matter with the global low-carbon energy transition more broadly.

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