PAYNE INSTITUTE COMMENTARY SERIES: **COMMENTARY**

DECARBONIZATION OF ETHANOL: PATHWAYS TO MONETIZATION SERIES
Part One: Stacking 45Q with Voluntary Carbon Markets

Importance of Policy Incentives in Economic Frameworks for CCS Projects

By Anna Littlefield, Siew Chiang, and Mike Matson

Last month, Red Trail Ethanol (RTE) announced their partnership with Puro.earth, a carbon crediting platform focused on engineered carbon removal that has an established *Geologically Stored Carbon Methodology* to certify actual carbon removal associated with long-term, subsurface storage of carbon dioxide. RTE is the United States' second carbon sequestration project utilizing an EPA Underground Injection Control (UIC) Class VI well, after Archer Daniels Midland's (ADM) project in Decatur, IL. As RTE injects a fraction of the annual volume of CO_2 compared to ADM (<20% in 2022 as reported on the EPA Subpart RR), monetization pathways are critical without the same economy of scale available to ADM. In this commentary series, we will explore the economic pathways for carbon capture and storage (CCS) projects, beginning with "credit stacking" voluntary carbon market credits and Section 45Q tax credits, with additional pieces on both the California-based Low Carbon Fuel Standard and Section 45Z tax credit.

CCS has been at the forefront of decarbonization commitments in public and private sectors, with the development of CCS projects rapidly accelerating in the U.S. following the signing of federal incentives of the Infrastructure Investment and Jobs Act (IIJA) and Inflation Reduction Act (IRA). However, despite the recent surge in CCS project announcements, a majority have yet to reach the final investment decision (FID) stage, as outlined in the recent Net Zero Roadmap report by the IEA. This underlines the necessity of understanding the economics of CCS projects to ensure that policy measures and investments are effectively aligned.

Understanding the economics of CCS projects for various industries will not only guide investment decisions, but also enable policymakers, investors, and project developers to better assess the financial feasibility, risks and benefits associated with these projects. A robust economic framework should facilitate the effective allocation of resources, the development of supportive policies, and mitigation of operational and financial risks, ultimately accelerating the deployment of CCS projects at a pace necessary to achieve climate targets.

Here we analyze an economic framework for a CCS project in a U.S. ethanol facility by accounting for existing government incentives and the potential uplift of voluntary carbon markets. This analysis aims to shed light on the financial viability for scaling up CCS projects across ethanol facilities in the U.S., considering the interplay between economic drivers and policy incentives.

Overview of Economic Framework for CCS Project in Ethanol Facility

With the deployment of CCS technologies, ethanol facilities can effectively curb their environmental impact by reducing the carbon footprint in their production, enhancing their sustainability credentials, and gaining a competitive advantage in the market with a lower-carbon ethanol product. Enhancement of the 45Q tax credit in the IRA has made monetization of CCS projects more viable for smaller CO_2 emitters, including ethanol producers, and stacking opportunities are increasingly more promising with the growth of voluntary carbon markets (VCM).

This economic analysis aims to provide an understanding of the implications of VCM for bioenergy with carbon capture and storage (BECCS) together with the 45Q tax credit and help navigate the dynamics of this market for CCS projects for ethanol facilities. The set of assumptions in **Table 1** and cost estimates in **Table 2** serve as the framework to drive the economic sensitivities to assess the net present value (NPV) and internal rate of return (IRR) under varying VCM prices for U.S. BECCS projects.

Table 1*. Assumptions for the economic analysis.*

Economic analysis assumptions	**Value**
Timeline for CCS project, years	12
Annual production capacity of ethanol, MMgal/year (source)	81
Biogenic CO_2 emissions, tons CO_2/year	227
CO_2 pipeline length, miles	5
45Q tax credit, $/ton CO_2	85
Range of projected VCM prices for BECCS, $/ton CO_2 (source)	50-150
Tax rate, %	25
Discount rate, %	10
Weighted average cost of capital (WACC), %	10
Total CAPEX, $MM	57
OPEX incurred per CO_2, $/ton CO_2	25

Notes: 1) Median value for EIA's data for 187 ethanol facilities, 2) conversion ratio for biogenic emissions of 2.8 kilotons of CO_2 per million gallons of ethanol produced, 3) assumed onsite saline aquifer storage for distance for CO_2 pipeline length.

Table 2. *Assumptions for cost estimates for CAPEX and OPEX.*

Value chain	**Description**	**Value**
Capture (source)	Total CAPEX, $MM	24
	OPEX, $/ton CO_2	16
Transport (source)	Total CAPEX, $MM	4
	OPEX, $/ton CO_2	0.1
Storage (source)	Total CAPEX, $MM	29
	OPEX, $/ton CO_2	9

This approach of dual opportunity stacking not only maximizes profitability but also aligns with broader carbon abatement goals, emphasizing the strategic importance of both the 45Q tax credit and voluntary carbon market participation for ethanol facilities in navigating the dynamic CCS project development landscape. Although the limited standardization with the numerous registries and exchanges within the voluntary carbon market has posed challenges for companies to navigate around these platforms, several initiatives and regulatory bodies have emerged to establish clear standards for the carbon credits, with policies being formulated to make corporate commitments to require standards and documentation of their emissions.

Evaluating Projected Revenues of CCS Project in Ethanol Facility

This analysis simulates the stacking of credits under 45Q and the VCM potential for BECCS. A tax credit value of $85/ton CO_2 and variable VCM prices for BECCS from $50-150/ton CO_2 were used for the 12 year-period of the CCS project injection phase. As seen in the economic sensitivity in **Figure 1**, increases in profitability of the project in terms of NPV and IRR are driven by the increases in VCM prices. 45Q revenue remains constant and accounts for a smaller portion of the total profitability. Currently, most all VCM transactions are business-to-business direct sales with terms under NDA; however, as the marketplace of credits grows, additional sales mechanisms, such as spot pricing on an open marketplace platform, are expected to develop.

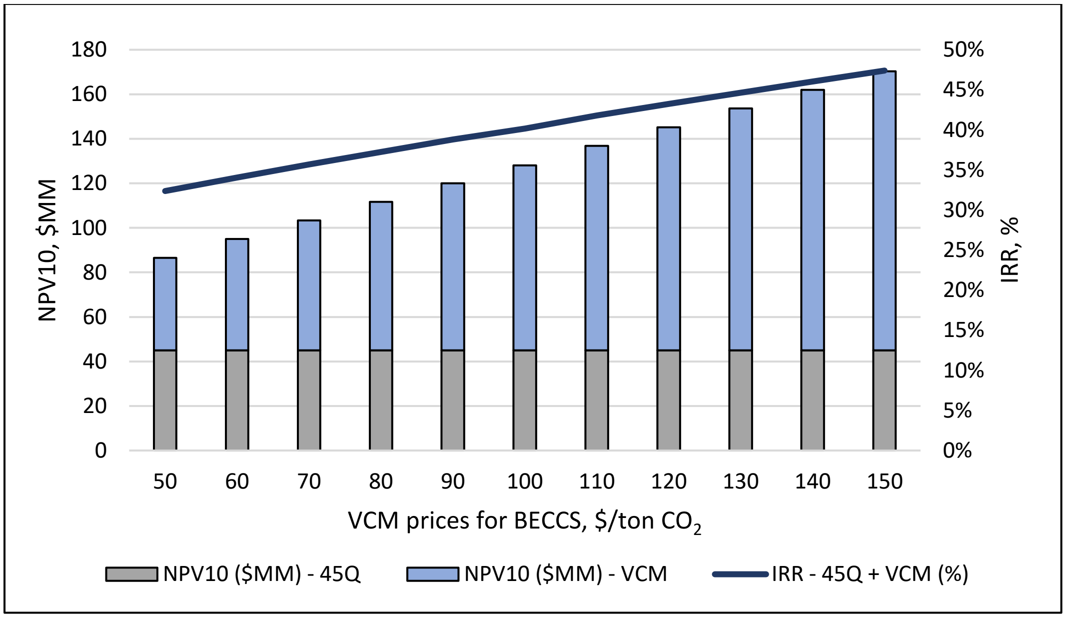

Figure 1. *Sensitivity analysis for NPV10 for VCM prices for BECCS ranging from $50-150/ton* CO_2.

Although economics of most CCS projects announced post-IRA have been driven by 45Q, this option to stack the two revenue streams should not be overlooked. A dual opportunity stacking maximizes profitability and in so doing aligns with broader carbon abatement goals, making decarbonization more feasible for ethanol facilities (and other small-scale emitters) in a burgeoning industry with narrow profit margins. This model reflects a spectrum of outcomes and demonstrates the potential benefits on the high-end of VCM credit values. Although all models inherently involve speculation, the predominantly favorable results from this analysis indicate substantial potential to be realized. This raises the question: why are more companies not aggressively pursuing opportunities within the voluntary carbon market?

The State of the Voluntary Carbon Market

Operating in the free market framework, VCMs are not bound by the same governmental oversight as 45Q tax credits. The flexibility and dynamic nature of this decentralized system that depends on voluntary engagement is not without complexity. A debate on the efficacy of carbon credits has been ongoing since they were first introduced as part of the 1997 Kyoto Protocol and will likely persist through the ongoing COP28 in Dubai.

VCMs allow any entity to offset carbon emissions by purchasing the carbon credits, generated through projects or efforts that capture greenhouse gas emissions. Motivation for investing in VCMs has increased in recent years, as public sentiment and investor preference are increasingly dependent on organizations' environmental stewardship and social consciousness. In theory, each carbon credit represents a tangible reduction in CO_2 in the atmosphere, either through carbon removal or emissions avoidance. In reality, the landscape of these credits and markets suffers from a lack of centrality and some past misdeeds eroding confidence in credit credibility.

For average observers and astute investors alike, the network of VCMs can seem frustratingly convoluted. Credits can represent renewable energy generation, afforestation, reforestation, methane capture, energy efficiency conversions, geologic storage of CO_2, improved livestock management practices, carbon farming, recycling and waste reduction, biofuels, public transportation infrastructure, conservation projects, direct air capture, and sustainable water management projects. Within these genres of carbon credits, a host of providers, and multiple carbon credit registries operate. In the U.S., the primary registries are Verra, The Gold Standard, The American Carbon Registry, Climate Action Reserve, and Puro.earth, though many other smaller or more niche registries also offer credits.

Beyond these complexities of VCMs, criticism has centered around issues of double counting, lack of standardization, and the ability to ensure additionality (i.e., that projects are truly resulting in emissions reductions beyond what would have occurred under a business-as-usual scenario). An article published in TIME in March of 2023, highlighted the research led by Barbara Haya, Director of the Berkeley Carbon Trading Project. An audit of 300 carbon offset projects found "pervasive" issues with carbon accounting. While this study focused on Improved Forest Management (IFM), it speaks to ubiquitous issues that exist in emissions reduction efforts and their translation to discrete carbon credit values. A successful market for credits must be built on robust methodologies for measurement, verification, standardization, and transparency.

To help navigate and validate a complex landscape of credit providers and credit types, oversight agencies have emerged, such as the Voluntary Carbon Market Integrity Initiative (VCMI) and the Integrity Council for the Voluntary Carbon Market (ICVCM). In June of 2023, these two agencies announced a partnership, aimed at streamlining the validation of carbon credits and "operationalizing the markets". While these agencies seek to improve transparency and validity, they still exist within the VCM ecosystem and therefore are not above reproach. Haya highlights the inherent challenge of motivation in the carbon market landscape saying "All participants in the market as it is structured today benefit from more credits."

Conclusion Remarks and Path Forward

The partnership between Red Trail Ethanol and Puro.earth (and other similar ventures) may indicate that the carbon mitigation industry is recognizing the economic benefits of stacking the 45Q tax credit and credits obtained through VCM. The modeled scenario sheds light on the potential revenue and profitability for ethanol producers, though the same benefit could be realized for other emitters as well. The sensitivity analysis highlights the benefit of combining the stable 45Q credits with the dynamic value of the VCM, which holds much of the potential for improving profit margins in this industry, and ultimately increases the odds of these critical projects being built. Although navigating the VCM ecosystem presents challenges, improved oversight and internal checks and balances within the market are creating a more reliable framework for prospective buyers. Regulators must navigate the inherent challenges of motivation that underpin this network, while operators must weigh the value proposition of free-market carbon credits against the risks, for with flexibility may come instability. Aligning these two revenue streams from the stable and predictable 45Q credits with the more dynamic, less regulated voluntary carbon market, operators can leverage the strengths of each: a reliable foundation coupled with the potential for flexibility and innovation.

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Anna Littlefield is the Program Manager for Carbon Capture Utilization and Sequestration for the Payne Institute at the Colorado School of Mines. As a current PhD student in the Mines geology department, her research focuses on the geochemical impacts of injecting CO2 into the subsurface as well as the overlap of geotechnical considerations with policymaking. Anna joins the Payne Institute with 8 years' experience in the oil and gas industry, where she worked development, appraisal, exploration, new ventures, and carbon sequestration projects. Her academic background is in hydrogeology with an M.S. in geology from Texas A&M University, and a B.S. in geology from Appalachian State University. Anna is passionate about addressing both the societal and technical challenges of the energy transition and applying her experience to advance this effort.

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Since joining BCG, Mike has advised clients on large cross-sector climate and energy-related transformations. His clients have included many major corporations and energy companies, with whom he works to develop CCUS assets. In addition, he has extensive experience working with clients on upstream oil and gas, reservoir engineering, drilling engineering, energy storage, and geothermal solutions.

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