Addressing Cash Flow Challenges for Commercial Carbon Capture Projects

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Earlier in his career, Mackler played a key role in BPC's first project as the Research Director at the National Commission on Energy Policy (NCEP), which produced a comprehensive set of policy recommendations many of which were incorporated into the 2005 Energy Policy Act. He subsequently launched BPC's energy innovation portfolio, including the formation of the American Energy Innovation Council. Mackler has managed a number of energy policy projects on topics such as tax incentives, federal RD&D, finance, workforce transition, carbon capture and storage, low carbon fuels, cap and trade, climate impacts and adaptation, and geoengineering research. Prior to his work with NCEP, he was an analyst in the Clean Air Markets Division at the Environmental Protection Agency.

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Abstract

Despite a considerable consensus about the need for CCUS technologies to achieve climate goals, formidable hurdles stand in the way of commercializing these technologies and deploying them at the scale and in the timeframe needed to meaningfully contribute to climate-change mitigation. This paper makes several key points about the nature of the commercial revenue challenges that confront CCUS technologies and about potential policy responses to these challenges.

- CCUS is best understood as a pollution control technology. As such, its entire value proposition rests on the ability to mitigate CO_2 emissions. This is in contrast to other widely discussed zero-carbon technologies (such as wind and solar or nuclear) that offer an emissions-free option for generating a product (such as electricity) that has market value independent of its carbon characteristics.

- Implementing CCUS entails both upfront capital costs and long-term operating costs. As a result, the main commercial challenge for CCUS project developers is to secure a stream of revenues—based on expected CO_2 mitigation benefits—that is sufficient to cover ongoing operating costs while also generating a reasonable (and reasonably assured) return on the required capital investment.

- Ideally, energy and climate policies would be implemented across the economy in a manner that created financial incentives to reduce CO_2 emissions to appropriate levels. In such a world, tailored and technology-specific policy interventions would be largely unnecessary. However, these economy-wide policies are not yet in place in the United States.

- Alternatively, interventions on the "demand side" of the energy markets could also create new revenue streams for decarbonized energy and products. Market

regulations in different sectors have been utilized successfully in the past (e.g., state renewable portfolio standards in the electric sector). As discussed in Section 8 below, clean electricity standards, low-carbon procurement standards for industrial products, and voluntary carbon markets are promising emerging concepts that could be designed and implemented in ways that create clear market opportunities for technologies like CCUS to successfully deploy. By and large, these mechanisms do not yet exist at meaningful scale.

- Therefore, federal policy incentives are critical because they are the only viable mechanism today that can produce incremental project cash flows for CCUS. Further, it is unlikely that constructors, developers, manufacturers, and corporate owners of CCUS projects will engage in costly and risky commercialization efforts today unless they believe a long-lasting and adequate incentive mechanism exists for the CCUS industry.

- Until there is an overarching policy or regulatory framework that delivers and sustains sufficient market value for captured CO_2, other policy instruments will be needed to address cashflow requirements for CCUS projects. The main tool available at present is the Section 45Q federal tax credit. However, as currently configured, 45Q is insufficient—both in magnitude and in accessibility—to overcome commercial hurdles for most CCUS projects. This paper outlines how to improve its effectiveness.

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1. Introduction

This white paper is part of a series on carbon capture, utilization, and storage (CCUS) organized by the Energy Futures Initiative (EFI), an independent energy and climate policy research organization in Washington, DC founded by former Secretary of Energy Ernest Moniz. The goal of the series is to highlight the key commercialization challenges confronting CCUS technologies in the United States and globally.[a] Each paper addresses a particular set of barriers to the rapid demonstration and broad deployment of these technologies, including (1) technology risk, (2) geologic storage risk, (3) cashflow adequacy, (4) non-financial risk, and (5) financing risk. Therefore, no paper in isolation is comprehensive in its assessment; however, taken as a package the series intends to provide a state-of-the-art overview of the key obstacles confronting CCUS and how they can be overcome. This paper focuses on the third barrier: cashflow adequacy. Specifically, this paper examines cashflow challenges for commercial-scale CCUS projects, discusses key differences between CCUS and other clean energy technologies with regard to cashflow risk, and explores near- and longer-term options for addressing this barrier to CCUS deployment.

[a] The broader term "carbon management" encompasses the full suite of approaches for either (1) capturing CO2, directly from emission sources (CCUS) or (2) removing CO2 from the atmosphere or oceans (also known as carbon dioxide removal or CDR).

2. Background and Context

Carbon capture, utilization, and storage (CCUS) is well understood to be a critical category of technologies for the rapid, cost-effective, and deep decarbonization of the energy system. These technologies can be applied in a variety of combinations and industrial configurations to meaningfully reduce the amount of CO_2 that reaches the atmosphere or, in the case of carbon dioxide removal (CDR) technologies, to remove CO_2 already in the atmosphere (see also footnote 1).[1] Multiple modeling analyses have shown that CCUS deployment can serve to reduce the overall cost and time required to transition to a net-zero economy.[2] But the actual demonstration and deployment of commercial scale CCUS projects has lagged trends in other emerging technologies considered important for the clean energy transition, such as wind and solar and, increasingly, battery storage. The resulting gap between theory and practice has tainted stakeholder perceptions with respect to CCUS potential in real-world applications. This paper focuses on the financing challenges, and specifically the project cashflow requirements, that have played a major role in slowing CCUS deployment to date and discusses policy options for more effectively addressing these requirements.

As a starting point, it is helpful to highlight a key difference between CCUS and other clean energy technologies, both to understand why CCUS technologies have not followed the same commercialization and deployment trajectory and to design policy interventions that are better tailored to the specific financing needs of CCUS projects. Fundamentally, CCUS is best understood as an add-on pollution control technology, like a catalytic converter in an automobile or a scrubber in a power plant smokestack.

As such, CCUS technologies are potentially quite valuable, particularly given the reality that, despite growing momentum to diversify and decarbonize energy systems in the U.S. and globally, carbon-based fossil fuels such as oil, natural gas, and coal still account for more 80 percent of the world's current energy inputs.[3] CCUS could allow for some continued use of fossil fuels to provide firm or dispatchable energy for power and industrial applications, thereby complementing more intermittent sources of low-carbon energy such as wind and solar or non-energy sources of dispatchability such as battery storage by offering both energy and capacity simultaneously. Carbon capture could also have value as a way to eliminate emissions from hard-to-decarbonize industrial processes (such as cement production) or to remediate historic emissions (in the case of CDR technologies).

The ability to decouple fossil energy utilization from CO_2 emissions and subsequent climate impact is, however, a different value proposition compared to wind and solar or nuclear energy, which replace emitting energy technologies that consume fossil fuels with non-emitting ones that have no fossil fuel requirements. This distinction is critical for understanding how different technologies fit into an overarching energy transition and reinforces the need for tailored policy interventions to enable each to become commercially successful.

3. An Overview of CCUS Development Efforts to Date

Beginning in the 2000s, early efforts to develop carbon capture technology focused on coal-fired power plants. At that time, many expected Congress to eventually expand the sulfur dioxide and nitrogen oxides trading regulations created by the Acid Rain Program to include a CO_2 trading program for the power sector. Air quality regulations implemented by the U.S. Environmental Protection Agency (EPA) had spurred the commercialization of improved flue gas desulfurization technologies (scrubbers) across a broad cross section of the nation's coal-fired generating stations and could have played a similar role in driving post-combustion carbon capture for power plants. Utilities at the time strongly resisted the expansion of air quality regulations to include CO_2 emissions but did begin to experiment with carbon capture retrofit technologies and explore the potential to develop dedicated geologic storage wells adjacent to their power plants.[4,5]

During this period, the federal government sought to follow the general model that had been used to support other clean energy technologies, pairing Department of Energy (DOE) funding for research, development, and demonstration projects with federal tax credits to mitigate investment risk and promote deployment. This model has been widely credited with helping wind and solar energy technologies achieve rapid gains in deployment in recent years. In the case of CCUS, DOE's Office of Fossil Energy launched the Clean Coal Power Initiative (CCPI) with funding from the American Recovery and Reinvestment Act of 2009—to date, the most ambitious effort to scale CCUS technologies. A year earlier, in 2008, Congress had also introduced a federal tax credit for CCUS. Known as the Section 45Q credit (after the relevant section of the federal tax code) and modeled on the wind energy production tax credit, the CCUS tax credit was designed to benefit all carbon capture projects rather than just supporting the first few.

Other policy and market conditions that had been critical to the success of earlier clean energy technologies, however, did not exist for CCUS. Wind and solar, for example, had benefited from state-based electric sector initiatives offering financeable long-term arrangements to purchase power from certain projects at premium rates through state renewable portfolio standard (RPS) programs or to guarantee power sales and cost recovery through agreements between public utility commissions and their regulated electricity providers. Regulatory certainty was likewise important in the deployment of an earlier generation of clean energy and pollution control technologies: improvements in scrubber technology, for example, were driven by the direct regulation of acid rain pollutants while the successful development of a domestic commercial nuclear industry relied on regulated utilities' ability to count on recovering their costs from ratepayers, as well as additional federal guarantees to limit technology risk. In industries outside the electric sector (such as cement and steel production and petroleum refining), the development and adoption of clean technologies has likewise been driven by a combination of R&D funding, commercial considerations, and mandates or regulations.

In the case of CCUS, early federal efforts to support technology deployment met with mixed success at best. The failure of many CCPI projects to achieve commercial operation came to symbolize the end of the first era of CCUS development and left many observers with the impression that CCUS is fundamentally flawed as a technology pathway, particularly as other power sector trends—expanded reliance on natural gas and the increasing cost-competitiveness of renewable technologies—seemed likely to continue driving down coal-plant CO_2 emissions without the need for CCUS. The Section 45Q tax credit, meanwhile, suffered from shortcomings that limited its effectiveness as a deployment incentive (these shortcomings are discussed in greater detail in later sections).

More recently, a growing sense of urgency about the need for faster decarbonization, not just in the power sector but economy wide, has prompted new thinking about and renewed interest in CCUS. This has led to a shift in emphasis from single-source to single-sink capture projects and more creative efforts to develop viable business models for CCUS, including models that feature novel technology development, shared infrastructure to link multiple sources to multiple sinks (often called "hubs"), and capture opportunities beyond coal-fired power plants.

A slate of new commercial deployment initiatives prompted by the Energy Act of 2020 and the Infrastructure Investment and Jobs Act of 2021 reflects this pivot to a new phase of

CCUS development. The 2021 infrastructure bill, for example, created a new DOE Office of Clean Energy Demonstrations with substantial funding for new CCUS projects across a range of applications, as well as for hydrogen and direct air capture "hubs."[6] Congress also increased the Section 45Q tax credit and made other changes to the 45Q program in 2018. Nonetheless, CCUS projects continue to face significant commercial hurdles.

4. Understanding the Revenue Challenge for CCUS Projects

Important work is currently underway to reduce technology risks and improve technology performance in the carbon capture space, but neither the capital costs of installing a CO_2 capture system nor the ongoing costs of operating that system will ever fall to zero. This is because, barring fundamental technology breakthroughs, CCUS systems require additional equipment and ongoing energy and materials inputs to operate—all of which negatively affect the economics and often the efficiency of the host plant. This means that, in any application, reducing CCCUS technology risks through a variety of public–private demonstration efforts is a necessary but not sufficient condition to support broad-based deployment. A viable business model is also required, in the sense that individual owners and operators of CCUS systems must find a way to effectively balance cash flows and structure commercial arrangements such that the revenues from these systems predictably exceed costs and provide investment-grade financial returns over the useful life of the capture equipment.

Figure 1 schematically illustrates the key elements of a viable business case for CCUS projects where captured CO_2 is either used for enhanced oil recovery (EOR), thereby generating some associated revenues, or transported directly to a saline reservoir for geological storage. In current energy markets and with existing policy incentives, the cost versus revenue balance does not yet support CCUS implementation in most applications. This is a primary reason for the slow market adoption of CCUS technology so far.

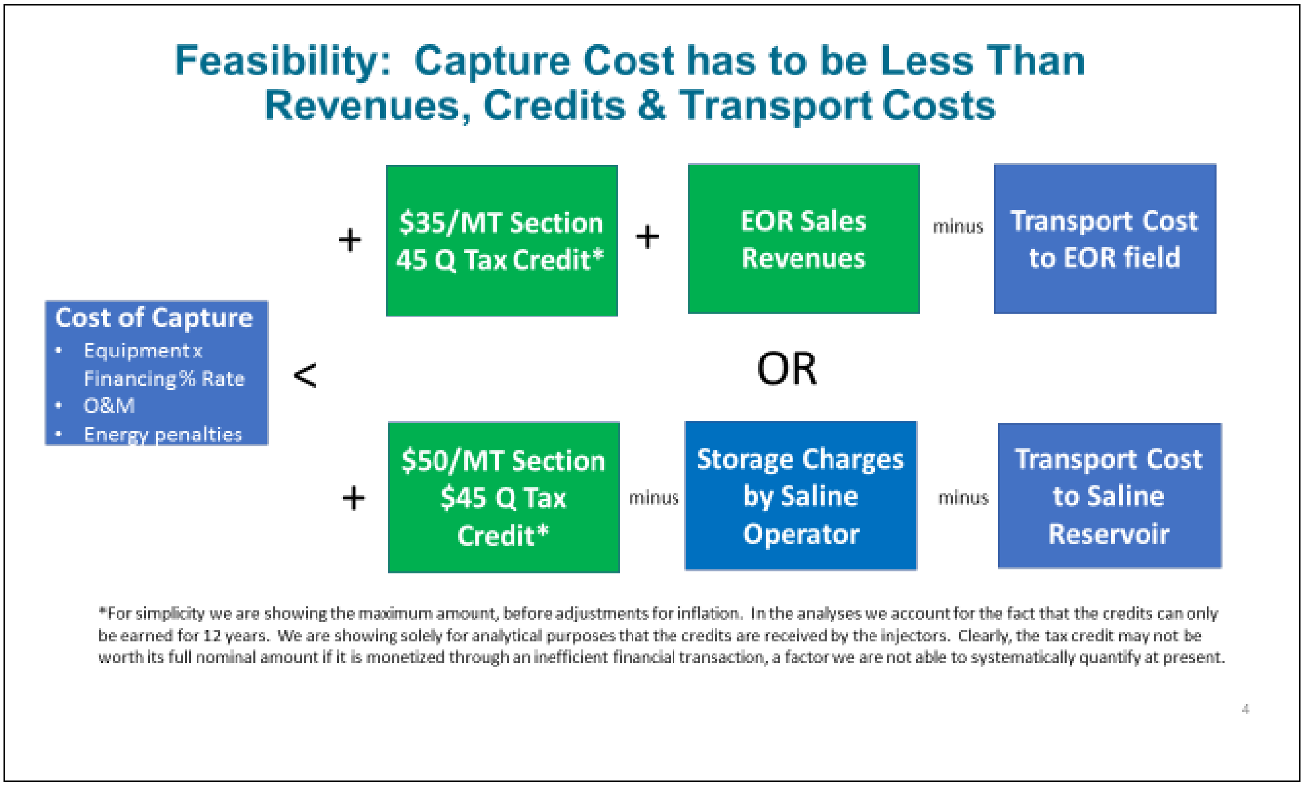

Figure 1. A Business Model for CCUS Projects.[7]

On the cost side of Figure 1, it is reasonable to expect that CCUS project costs can be managed effectively and become sufficiently predictable to gain investor confidence, particularly as CCUS technology benefits from the “learning by doing” that typically occurs in the early stages of commercialization. Capital equipment, engineering, and other inputs to a CCUS project are similar to those found in other large industrial projects today. Once technology cost and performance are well understood, firms experienced in project development, engineering, construction, and operation can be expected to provide the type of pricing and guarantees typical of conventional energy and industrial projects.

The bigger challenge at present is on the revenue side of the ledger, where, in the current regulatory and market environment, revenues from CO_2 capture are both too low and too unpredictable to give project developers confidence that they can recover their costs. Table 1 shows that current CCUS projects face a negative net revenue situation in most applications, even when the value of the Section 45Q tax credit is taken into account. (The exception, indicated by the top row of the table, is at facilities that emit a pure stream of CO_2. This obviates the need to process the exhaust gas stream and substantially reduces capture costs and equipment requirements. However, only a relatively small number of facilities offer these very low-cost capture opportunities.) Exacerbating the revenue challenge, project developers who have to access the tax equity market to monetize the federal tax credit can expect to receive substantially less than the face value of the credit. (Shortcomings of the Section 45Q program are discussed in detail in the next section.) Meanwhile, other potential revenue sources for CCUS projects, such as voluntary carbon markets, are generally too small or too uncertain at present to make up the shortfall.

A further point, not captured in Table 1, is the importance of revenue stability (or, if not stability, predictability). Without long-term offtake contracts in the primary products of power or commodities, CCUS projects may be exposed to significant market risk and uncertain or volatile revenues. Even in the best-case scenarios that currently exist for CCUS investment—for example, at a location that is geographically proximate to oil fields where the captured CO_2 can be sold for enhanced oil recovery (EOR), thereby generating an additional revenue stream—revenue uncertainty and associated financial risk may be a significant issue.[b] In the case of EOR, sales contracts for CO_2 are typically tied to the price of oil, a commodity with high price volatility. Since banks and bond rating agencies use "worst case" numbers to establish credit, these revenue risks add up to poor financing terms for CCUS projects, creating a secondary problem in addition to the revenue shortfalls themselves.

During workshops held by EFI to discuss CCUS and CDR, many parties cited the need for strong "demand side" policies that would support the scale up of carbon capture projects. Effectively, such efforts would create a market opportunity or drive premium prices for a decarbonized product either through a soft mechanism such as voluntary carbon markets and government procurement or through mandates and regulations, such as a clean energy standard. Clearly such mechanisms would be helpful. If they were actually available today and creating reliable, contractually-enforceable, long-term cash flows for projects, they would reduce the size of needed federal incentives (i.e., the 45Q tax credit could be set at a lower value and scale-up could still progress).

[b] Of course, revenues from EOR sales would have to be weighed against taking a lower federal tax credit ($35/ton compared to $50/ton for "pure" storage) and against any other revenue opportunities that might be foreclosed by utilizing the CO_2 for EOR before it is stored (for example, use for EOR might make the captured CO_2 ineligible for credits in voluntary carbon markets or as a compliance option under a mandatory CO_2 reduction program). For further discussion of these issues, see Sections 6 and 7.

However, as we discuss in Section 8 below, these demand-side policies are mostly aspirational today. While the desirability of such demand-side policies is indisputable, the political and economic obstacles to their implementation remain daunting. Hence, the critical importance of strengthening the section 45Q tax credit in the near-term is raised as a key priority in Section 7.

Table 1: Costs of CCUS for Various Applications (illustrative for nth-of-a-kind projects)[8]

Source (concentration)	Application	Capture ($/MT)	Compression ($/MT)	Transport ($/MT)	Storage ($/MT)	Total Cost ($/MT)	45Q Revenue ($/MT)	Net Revenue ($/MT)
Pure CO_2	Ethanol, natural gas processing, some fertilizer	**$0**	**$18**	**$4**	**$7**	**$29**	**$50**	**$21**
High CO_2	Cement, methane reforming	**$35**	**$10**	**$4**	**$7**	**$56**	**$50**	**-$6**
Medium CO_2	Coal power, FCCU (high capacity)	**$40**	**$10**	**$4**	**$7**	**$61**	**$50**	**-$11**
Low CO_2	Natural gas power (high capacity)	**$55**	**$10**	**$4**	**$7**	**$76**	**$50**	**-$26**

**Note: These costs are illustrative estimates based on certain generalized assumptions for project parameters; specific projects could experience lower or higher total costs depending on geographic location and other site or market specific factors. The utilization via EOR business case is harder to generalize given tradeoffs on tax credit value, specific market value for CO2, and other revenue opportunities, however it is clear that even with the additional revenue potential for EOR the project economics remain marginal for all cases but the high concentration sources at current credit levels.*

As already noted, other low-carbon technologies such as wind and solar benefited from a combination of policies (such as renewable portfolio standards) and market arrangements (such as long-term power purchase agreements) that provided sufficient revenue—and sufficient revenue certainty—to overcome cashflow risks. By contrast, there are currently no state-level power sector programs providing secure long-term offtake contracts for CCUS, nor are there any widely available mechanisms for charging premium prices for industrial products that have a lower carbon footprint because they incorporate CCUS. That leaves the 45Q tax credit as the financial lynchpin for most CCUS applications in the United States. Why that program, as currently configured, remains insufficient to motivate CCUS deployment at scale is the focus of the next section.

5. The Section 45Q Tax Credit

When it was first introduced in 2008, the Section 45Q tax credit was conceived as a modest financial incentive to help bring down the cost of CCUS projects that would be principally driven through other policies. The value of the credit was initially set at $20 per ton for CO_2 that is captured and permanently stored in a geologic reservoir with no other commercial use and $10 per ton for captured CO_2 where permanent storage occurs "incidentally" as a result of using the CO_2 in other commercial applications such as for enhanced oil recovery (EOR). Like the production tax credit (PTC) for wind, the 45Q credit offered a stream of credits for up to 12 years after a project commenced construction. Unlike the wind PTC, the credit was subject to an overall volumetric cap of 75 million tons CO_2. At the time, it was clear that the size of the credit—at $20 per ton—was not sufficient to cover the cost of adding CCUS at most power plants or other industrial facilities. However, the expectation was that other policy and market drivers would emerge, as they had for wind and solar, to provide further incentives for deployment.

By the time Congress revisited the Section 45Q tax credit a decade later, in 2018, it was clear that this expectation had not been met and that the existing tax credit was insufficient as the main or only driver for encouraging CCUS deployment at scale. In addition to the fact that no national program had been adopted to limit CO_2 emissions, CCUS projects faced further challenges, among them the fact that the Internal Revenue Service did not finalize its guidance on meeting CO_2 storage requirements for purposes of claiming the tax credit until January 2021.[9] A further source of uncertainty for prospective project developers was the concern that credit claims by facilities with pure streams of CO_2 and low capture cost (such as natural gas processing or ethanol plants) might put future credit availability at risk, given the 75-million-ton cap.

Recognizing that financial and policy conditions were suboptimal for CCUS deployment, Congress revised the 45Q credit with several important enhancements in 2018. Credit values were raised to $50 per ton for capture with pure storage and $35 per ton for capture that included utilization and storage. The overall volumetric cap was eliminated entirely and the commence-construction date for eligible projects was extended to January 2024. Nonetheless, the fact that few large CCUS projects have advanced in the U.S. in the last few years points to ongoing challenges in developing a viable business case for this technology.

Even at the higher credit values introduced in 2018, for example, the Section 45Q tax credit suffers from shortcomings that have limited its effectiveness as a deployment incentive. Some of these shortcomings are common to tax equity markets in general, others are more specific to CCUS (see text box), but the bottom line is that the credit has remained too small and too uncertain in its useability to assure positive cashflow for most CCUS projects over their operating lifetime. This is particularly true in the major categories of power generation or industrial commodity production, which include the largest point-source CO_2 emitters. (As shown in Table 1, the credit may be adequate to support CCUS in a small set of industrial applications—including at facilities for ethanol production, natural gas processing, and some fertilizer production—but these opportunities are limited.)

The value proposition is far from clear even for CCUS projects that propose to sell captured CO_2 to oil companies for use in EOR operations. Though such sales could, in theory, help close revenue shortfalls, these types of projects also qualify for a smaller tax credit ($35 per ton CO_2 over 12 years, compared to $50 per ton for pure storage)—thus, revenues from EOR sales must, at a minimum, exceed the $15-per-ton difference in credit value as well as any other potential revenue sources (for example, from selling voluntary carbon credits) that might be foreclosed if the CO_2 is used for EOR.

Box 1: Shortcomings on the Section 45Q Tax Credit

Industry professionals have warned that the Section 45Q tax credit will be difficult to monetize in the same manner and on the same scale as the renewable energy tax credits that have helped propel broad-based deployment of wind and solar technologies. In part this is because the number of investors capable of using a pure tax credit like the Section 45Q credit is inherently limited. Industry experts point to three main problems:

Cost to access the credit—The precise costs of accessing tax equity to help finance a project will depend on market conditions, but it is well understood that tax equity providers—typically large banks and insurance firms with predictable tax liabilities—will extract value from the tax credit in exchange for their participation. This effectively diminishes the value of the tax credit to project developers. In fact, a National Commission on Energy Policy study with Bloomberg New Energy Finance comparing the effectiveness of tax credits to cash subsidies found that cash payments were roughly twice as effective at leveraging public dollars to achieve a desired outcome—in other words, a direct payment to a developer would produce roughly double the project investment as the same amount of subsidy provided in the form of a tax credit.[10,11]

Thin markets for tax equity—The cost of accessing tax equity depends on the amount of tax equity providers in the marketplace (fewer providers means a less competitive market and higher costs to access tax equity). In 2020, tax equity for renewable energy constituted a $17–$18 billion market.[12] This is a narrow slice of the finance world and a small fraction of the capital investment estimated to be needed to decarbonize current energy systems. Rapidly expanding 45Q and other clean energy tax credits could cause demand for tax equity to increase faster than supply, since there are a limited number of counterparty entities with the capability to participate in these deals. This could constrain financing options for CCUS, increase the leverage of tax equity providers, and further reduce the value of the credit from a project financing standpoint.

Counterparty preferences—As tax credits become available for a wider array of clean energy technologies and competition for a limited pool of tax equity providers increases, projects characterized by low risk, clear and short development horizons, and smaller capital needs are likely to be advantaged. Well-established wind and solar technologies fall in this category. CCUS projects, on the other hand, remain non-standard and have substantially longer development horizons, generally higher capital needs, and greater technical risk. This makes them less appealing to typical tax equity investors (who are tax professionals and not energy experts).

In 2021, a bipartisan group of lawmakers in Congress began working on further enhancements to the Section 45Q tax credit in an effort to improve its effectiveness.

Separate clean energy tax packages with many common elements have since been put forward in the House and Senate. Proposed provisions include (1) an increase in the Section 45Q credit to $85 per ton for capture and pure storage and $60 per ton for capture, utilization, and storage; (2) a further extension of the commence-construction date to January 2032; and (3) the option for project developers to receive direct payments in lieu of the tax credit.[c] The House and Senate bills differ in some details—for example, with respect to project size thresholds and acceptance of EOR as a qualified activity. These differences will need to be reconciled in conference if both bills pass in their respective chambers. The "direct pay" provisions in both bills represent a particularly important and potentially powerful change to the existing tax credit because they would enable CCUS developers (and other projects that qualify for clean energy tax credits) to elect cash payment in lieu of a tax credit. This greatly simplifies project financing and increases the effective value of the federal incentive (for reasons discussed in the text box). Because it resolves the problems of limited size, low risk tolerance, and high transaction costs in tax equity markets, a direct payment option—in combination with higher credit values and extended development times—is a key piece of the 45Q reform agenda.

Changes to strengthen the Section 45Q tax credit were expected to be included in the Build Back Better legislation put forward by Democrats as part of the budget reconciliation process in 2021. The path forward for these reforms is unclear now that Build Back Better has stalled in Congress, but the bipartisan support that has existed for this program for more than a decade suggests that there will be opportunities to enact reforms in the near future, potentially even as part of a bipartisan, "regular order" tax bill. Specific options for strengthening the Section 45Q tax credit are discussed in the next section.

[c] Note that the draft bills also propose to create a new credit category, and a higher credit value, for technologies that capture CO_2 from the ambient air (as opposed to capturing CO_2 from the exhaust gases of large combustion sources or industrial processes). These proposals targeting so-called direct air capture (DAC) technologies are discussed further in the next section.

Table 2. The 45Q Tax Credit Over Time

	2008 Original	2018 Current	2022 Possible
Value ($/MT)	20 / 10	50 / 35	85 / 60
Availability	Volume Capped	Until 2025	Until 2032
Credit Stream	12 years	12 years	12 years
Mechanism	Tax Credit	Tax Credit	Tax Credit

6. Options for Strengthening the Section 45Q Tax Credit

The history of the Section 45Q tax credit has been one of incremental improvements to a program that was never designed to support a CCUS project's entire revenue needs. It is time to review the credit from a fresh perspective and tailor it to better address the current situation given other technology and policy realities. Until market or regulatory conditions change, at least three major modifications are needed to make the Section 45Q tax credit more effective: (1) an increase in the value of the credit, (2) a significant extension of the window for project eligibility (to at least 2032 and probably longer), and (3) provisions to make the tax credit easier to monetize, including a direct payment option. Each of these reforms is discussed below.

Increase the value of the credit: Setting an appropriate value for a federal tax credit given the numerous configurations and applications of CCUS technology is a challenge, although one that is not unique to CCUS. As the stakeholder and policy community has coalesced around $85 per ton (storage) and $60 per ton (utilization and storage) for point sources, this should be considered the minimum increase necessary. However, policymakers could also consider the merits of beginning with a higher credit initially (for example, around $100 per ton) and ramping it down over time (for example, to a level of $85 per ton by year 12). As the credit is currently configured, its value increases over time from current levels to the new levels over a period of years.

Policy makers should also consider the need to address both capital and operating costs for CCUS projects. This suggests that a credit design with two distinct values and timeframes would be most effective. Specifically, a high credit value—sufficient to cover both capital and operating expenditures—could apply over an initial project financing period (typically on the order of 12 years), but then the credit could transition to a lower value after the initial period to help cover operating costs over the life of the project.[d,13]

Finally, policy makers should create a new credit category for technologies that remove CO_2 already in the atmosphere—this type of carbon management is often called "direct air capture" (DAC).[e] Recent discussions in Congress have included proposals to increase the 45Q credit for DAC projects to $180 per ton (for pure storage) and $130 per ton (for utilization and storage). These values reflect the higher cost of DAC systems compared to point-source capture systems—even so, they may be inadequate to incentivize DAC deployment given the dearth of experience with DAC technology (very few DAC facilities are currently in operation). Hence, policy makers should consider appropriate credit values and the need for complementary policies or tax credits tailored specifically to DAC and other forms of CDR.

Provide for a longer "commence construction" window: Engineering and constructing large CCUS projects is complex and time consuming, especially with comprehensive permitting requirements on the surface and subsurface. Three-to-five-year schedules from project conception to operation should be expected. Considering this, the window of time made available to bring projects forward and qualify for the credit should be long enough to allow new projects to successfully advance. An extension to 2032 would help alleviate pressure and provide enough flexibility for developers to bring forward an initial wave of next-generation CCUS projects. At that point, policymakers could consider whether other meaningful climate policies have been enacted, making a 45Q extension unnecessary or, if not, whether and how to extend the credit.

Make the tax credit easier to monetize: As discussed in Section 6, support in the form of cash or long-term contracts is far more effective for scaling new technologies than

[d] This approach would be different from the approach taken with the 12-year wind production tax credit, but it would appropriately reflect inherent differences between CCUS and other clean energy technologies. In the case of wind, for example, the main deployment hurdle is overcoming initial project capital costs. Once a wind facility is built, there are no fuel requirements, operating costs are low (relative to capital costs), and revenues from electricity generation can be expected to be sufficient to cover operating costs. CCUS projects, by contrast, have higher ongoing operating costs and will be uneconomic to operate unless they can continue to realize revenues from the CO_2 emissions they capture. In fact, a modern CCUS project in Texas, the Petra Nova project, recently ceased operations due primarily to its poor EOR sales revenues and not because of poor technology performance, so this is more than just a theoretical risk.

[e] Because CO_2 is present in far lower concentrations in the ambient air than in the exhaust gas streams of major emissions sources, there are significant technology and design differences between DAC systems and CCUS systems. Current DAC designs, for example, typically require fans to move large quantities of air over a solid or liquid sorbent.

incentives based on tax equity or tax liability. The simplest option here is to make the Section 45Q tax credit redeemable for cash. During the 2008–2009 financial crisis, Congress established a temporary grant program pursuant to Section 1603 of American Recovery and Reinvestment Act to offer cash grants in lieu of tax credits for renewable energy technologies such as wind and solar. A review of the program by the National Renewable Energy Laboratory concluded that the 1603 program was straightforward to implement and produced numerous benefits: It increased speed and flexibility, lowered transaction and financing costs, stretched the supply of traditional tax equity, and was accessible to smaller developers (including new entrants) and innovative technologies that were less capable of tapping tax equity markets. By improving the economics of renewable energy projects—including by allowing the use of more debt and lowering the cost of capital to developers and projects—the 1603 program successfully supported the extensive build-out of renewable projects during the period it was available.[14] Adding a cash payment option is a well-tested and critically important way to improve the effectiveness of the Section 45Q tax credit, by providing better value for the public investment and increasing the prospects of successful project completion.

Table 3. Proposals for Strengthening the 45Q Credit

	2008 Original	**2018 Current**	**2022 Possible**	**Idealized Credit**
Value ($/MT)	20 / 10	50 / 35	85 / 60	85 / 60 (min) – capex & opex Smaller credit - opex
Availability	Volume Capped	Until 2025	Until 2032	Until 2032 (min)
Credit Stream	12 years	12 years	12 years	12 years for phase 1, Project Lifetime for phase 2
Mechanism	Tax Credit	Tax Credit	Tax Credit	Direct Pay

NOTES:

1. *A new DAC credit value is under consideration in the 2022 update that would provide a higher credit value of $180/ton (for storage) and $130/ton (for utilization and storage) for qualifying DAC projects.*
2. *The specific credit value in the idealized case should be at least this level but could arguably be higher in the early years and scale down progressively over time as capital costs are repaid, shared infrastructure is developed, and technologies improve. For reasons discussed in the text, absent other overarching climate policies, the credit should never be expected to fall to zero. Policymakers should consider a new, lower-level tax credit that follows the 12-year stream and is designed to cover operating costs over the life of a project.*
3. *Other modifications to the 45Q credit are under consideration, including requirements on size thresholds and qualifying utilization pathways. These changes are not discussed in this paper, not because they are deemed unimportant but because the focus here is on changes that reduce cash flow risks to commercial projects.*

7. Other Revenue Opportunities for CCUS Projects

This section identifies other potential revenue opportunities for captured CO_2 that could help compensate for the limitations of the Section 45Q tax credit and support a viable business model for future CCUS projects. There are reasons for optimism that one or more of these opportunities can play an increasing role over the next decade, but the prospects that any large and predictable revenue source will emerge in the near term remain highly uncertain. Two opportunities that rely on mandatory regulations or requirements are considered along with a third option that relies on voluntary carbon markets.

Carbon standards for electricity markets: Few states that have adopted renewable portfolio or clean energy standards have included fossil-fired power plants with CCUS as an eligible compliance option. Even if that were to change, CCUS would become economically competitive against other qualifying low-carbon technologies only at a level of policy stringency that requires deep penetration of clean technologies. This is simply because the cost of CCUS projects, which would offer both energy and capacity, are higher than costs for either energy-only technologies (such as wind and solar) or capacity-only technologies (such as battery storage).[f] However, under an ambitious clean energy standard it is likely that CCUS projects would, over time, find opportunities to secure power purchase agreements at a premium price, as has happened for renewable technologies in the context of renewable portfolio standards. For this reason, clean energy standards are considered a strong policy for driving cost-effective advanced technologies into power markets.

Markets for low-carbon industrial products: Markets for industrial commodities such as cement, steel, fuels, paper, etc. are highly competitive and characterized by low margins and easy substitutability. As a result, producers lack pricing power and generally cannot command a premium price for decarbonized versions of their offerings. This could change—

[f] This problem, it is worth pointing out, is not unique to CCUS: Other low-carbon technologies that offer both energy and capacity—such as nuclear power, geothermal, and hydropower—will struggle to compete against lower-cost options even in carbon-constrained markets.

for example, through state or federal “buy clean” procurement policies or through initiatives such as the First Movers Coalition, which was announced at the UN Glasgow Climate Conference, Breakthrough Energy’s Catalyst program, or the new Frontier Fund launched by a set of companies focused on advance market commitments for carbon removal.[15, 16, 17]

For now, however, meaningful and scalable programs for promoting the decarbonization of industrial processes remain in their infancy. A limited number of tailored regulatory programs do exist that provide opportunities to earn revenues from carbon reductions: for example, the California Low Carbon Fuel Standard (LCFS) provides a crediting system for transportation fuels based on carbon intensity that recognizes certain CCUS and DAC products. Other states, including Washington, Oregon, and other jurisdictions, are following California in adopting LCFS programs—if these programs recognize CCUS, they could meaningfully improve the balance sheet for CCUS projects, provided they offer sufficient certainty in terms of timelines, stringency, and CO_2 pricing (these characteristics remain a challenge in California’s LCFS program).

Voluntary markets for carbon credits: Such markets are still relatively immature, but they have the potential to play a significant role, provided that a framework exists for standardizing and monetizing the CO_2 benefits from CCUS and other climate-friendly investments. At present, standards for quantifying the emission benefits of various approaches do not yet exist in a form that provides mainstream customers with the clarity and confidence they need to put significant capital to work. Since there are a range of carbon offset types available in the existing marketplace, including low-cost natural solutions of varying quality, attracting the level of capital needed to support meaningful CCUS deployment will require higher standards for offset quality, carbon accounting, and durability. A robust, transparent, and self-governing marketplace for voluntary carbon reductions does not yet exist although there are encouraging signs of progress and some notable boutique transactions have occurred.[18] Customer preferences and willingness to pay underpin voluntary markets. Accounting challenges aside, it seems likely that CCUS projects tied to EOR will struggle to attract buyers for carbon credits given the optics of using captured CO_2 to increase oil production, which will be perceived as conflicting with climate goals.

8. Conclusion

The lack of a clear long-term climate policy makes it difficult to establish a viable business case for the sustained build-out of CCUS, CDR, and other advanced energy technologies once DOE grant support has been utilized to buy down technology risks. Thus, the current situation creates a conundrum from an energy policy standpoint that can be summarized as follows: what may be a rational investment from a system-level perspective (if the aim is to achieve full decarbonization) could remain economically challenged on a project basis for the foreseeable future without new policy interventions. If regulations are not implemented that force reductions in CO_2, emissions, or (alternatively) market-based policies such as a carbon tax or cap-and-trade program are not implemented at a level that drives substantial CO_2 reductions, or if consumers are unwilling to pay extra for products with reduced upstream carbon emissions, tailored policies will need to be designed that adequately close project revenue gaps. These policies need to provide support that is not only sufficient in magnitude to close these gaps at the project level (for both capital and operating costs), but also predictable and readily monetizable—otherwise the goal of scaling CCUS and CDR will remain unmet.

In the near term, the existing 45Q tax credit could be revised in several straightforward ways to address the core challenges to its effectiveness. Modifications should be considered that increase the credit value for point sources and DAC, extend the credit through at least 2032 (and probably longer), provide for a long-term stream of credits sufficient to cover the operating costs of CCUS and CDR projects, and allow for a “direct payment” option in lieu of the tax credit.

Longer term, comprehensive climate policies are needed that include CCUS and CDR and that recognize the potential value these technologies provide in decoupling fossil energy use from carbon emissions, delivering both clean electricity capacity and energy, providing a pathway to high-temperature process heat and low-carbon transportation fuels, and permanently removing CO_2 directly from the atmosphere or oceans. The 45Q credit can be designed to support each of these applications but other high-potential, technology-agnostic interventions should be prioritized over time such as carbon pricing programs, expanded clean energy portfolio standards, climate-targeted procurement initiatives, and stronger carbon accounting systems. The implementation of these policies in ways that provide predictable revenue flows to low-carbon projects over their operational lifetimes will make it possible to scale back tailored incentives like the 45Q credit while also driving CCUS and CDR deployment, in its many forms, at the level needed to achieve climate and energy goals.

Notes

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