ENERGY FUTURES INITIATIVE

Turning CCS projects in heavy industry & power into blue chip financial investments

EXECUTIVE SUMMARY

FEBRUARY 2023

ENERGY FUTURES INITIATIVE

The Energy Futures Initiative advances technically grounded solutions to climate change through evidence-based analysis, thought leadership, and coalition-building. Under the leadership of Ernest J. Moniz, the 13th U.S. Secretary of Energy, EFI conducts rigorous research to accelerate the transition to a low-carbon economy through innovation in technology, policy, and business models. EFI maintains editorial independence from its public and private sponsors. EFI's reports are available for download at www.energyfuturesinitiative.org.

CONTRIBUTORS

Project Executive
Ernest J. Moniz

Project Leads
Jeffrey D. Brown
Stephen D. Comello

Contributing Authors
Minji Jeong
Michael Downey
Madeline I. Cohen

Additional Contributors
Joseph S. Hezir
Melanie A. Kenderdine
Madeline G. Schomburg
David Ellis
Alicia Moulton
Jaycee Scanlon
Sonia Velazquez

White Paper Authors
Jeffrey D. Brown, Stanford University
Steven Carpenter, Carpenter Global, LLC
Stephen D. Comello, Stanford University
Susan Hovorka, University of Texas, Austin
Sasha Mackler, Bipartisan Policy Center
Michael H. Schwartz, Elysian Carbon Management

Layout and Design
Ryan Smith

Copyediting and Review
Carolyn Clark

EFI acknowledges the helpful feedback and guidance provided on earlier versions of this report by experts across the CCS, finance, energy, heavy industry, legal and policy landscape.

EFI honors the contributions made by the late Steven Carpenter to this work, and to the broader CCS industry and community.

This report was supported by a grant from **JP Morgan Chase & Co.**

EXECUTIVE SUMMARY

The United States has reinforcing goals of 50-52% CO_2 emissions reduction from 2005 levels by 2030, and net zero emissions by 2050. To reach these goals will require an immense mobilization of resources, private capital, and innovation to support accelerated scale-up of current technologies (e.g., solar and wind energy, vehicle electrification, etc.), and emerging solutions. Carbon capture and sequestration (CCS) — the capture of point source CO_2 emissions and permanently storing them in geologic formations — is a critical component within a portfolio of decarbonization solutions. CCS can materially reduce the overall cost of achieving U.S. decarbonization goals, while mitigating several hundred million metric tons of emissions per year. It can be deployed across various kinds of power and industrial applications, helping multiple sectors support the overall decarbonization mission. CCS can enable negative emissions via bioenergy and direct air capture with carbon capture and storage, and help jumpstart the low-carbon hydrogen economy. CCS can deploy a talented workforce to a growth industry (carbon management) and leverage existing infrastructure and expertise in creating new economic opportunities on the order of tens of billions of dollars in incremental investment. However, it will take concerted policy action — building on existing momentum — to make these promises a reality.

Without "sticks," the policy of "carrots" for accelerating the development and deployment of CCS as a decarbonization technology must be generous and stable enough to attract the necessary private capital.

Several variants of carbon capture are well-established and already in commercial use across such industries as natural gas processing, urea production, and petrochemical production from coal gasification. In the U.S., there are thousands of miles of oilfield-serving pipelines that inject CO_2 underground for enhanced oil production purposes. All the basic elements of the CCS value chain - capture, transport, deep underground injection, and ongoing monitoring — have been deployed in various commercial applications in the U.S. for decades. As a key approach to greatly reducing CO_2 emissions from fossil fuel combustion and industrial processes, the elements of this value chain now need to be configured and deployed as a cohesive decarbonization solution.

Despite existing capabilities, CCS progress to date as a decarbonization solution in the U.S. has been disappointing. A fundamental reason for this is simple: CO_2 emissions are not restricted or priced at the national level. If such requirements existed with a sufficiently stiff cost — as, for example, is the case for pollution discharges into water or sulfur emissions into the air — then there would be a clear commercial impetus to avoid such penalties by reducing emissions via deployment of CCS. Clearly, a significant CO_2 emissions price would dramatically enhance the case for CCS, but such a price is not anticipated in the U.S. anytime soon.

Without "sticks," the policy of "carrots" for accelerating the development and deployment of CCS as a decarbonization technology must be generous and stable enough to attract the necessary private capital. However, until very recently and albeit in only specific cases, the federal support mechanisms of corporate income tax credits — offered on a per metric ton of CO_2 sequestered

basis — have not been large enough to cover the capital and operating costs of CCS, especially when given the challenges associated with first-of-a-kind deployments. Importantly, to kick-start at-scale investment in CCS as a decarbonization solution there are two fundamental challenges that need to be addressed: application heterogeneity and value chain complexity.

Application heterogeneity refers to the deployment of CO_2 capture technologies in new industrial settings. Current carbon capture technologies have been engineered and optimized for specific flue gas characteristics such as temperature, pressure, CO_2 concentration and the presence of other chemicals and impurities. While there is considerable expertise and experience in these settings, the same cannot be said for the variety of retrofit scenarios across industrial and power sector applications — settings for which carbon capture is key to materially reduce emissions. It will take effort to tune carbon capture to each new heterogeneous application and, crucially, progress in one setting may not translate seamlessly to another. Each new application of carbon capture is a first-of-a-kind; to drive down costs and build up commercial confidence in each commercial setting, the innovation of multiple applications needs to occur in parallel.

Importantly, to kick-start at-scale investment in CCS as a decarbonization solution there are two fundamental challenges that need to be addressed: application heterogeneity and value chain complexity.

Value chain complexity refers to the four links that connect a CO_2 capturing industrial facility to permanent geologic storage: capture, transport, deep underground injection, and ongoing monitoring. Each of these four value chain links are industries unto themselves, much like the oil sector is divided into exploration, production, midstream, refining and distribution subsectors. As such, CCS is a complex decarbonization solution that requires integration across markets, technologies, and geographies to be functional. Moreover, each of the four CCS links are currently regulated relatively independently from each other, with little coordination across federal, state, and local agencies. Taken together, the nascency of CCS economic, infrastructure, and regulatory regimes effectively saddles potential developers with a multitude of risks for each of the four links in the value chain. The complexity and compounding financial risk attendant to managing these four links simultaneously makes CCS a distinctly challenging decarbonization solution.

On a risk-adjusted basis, even in the presence of greater financial support mechanisms, CCS remains challenged relative to most other kinds of development when it comes to attracting investment capital. Given such conditions, now is a critical time to develop a coordinated, comprehensive, long-term set of incentives as well as improved market, permitting, and regulatory policies. All these are needed to attract billions of dollars of private sector financial capital and widen the application of CCS to key industries. Without private capital to leverage public investment, CCS will not scale up and a key solution will remain lacking, and by such postponement, driving up the overall cost of decarbonization.

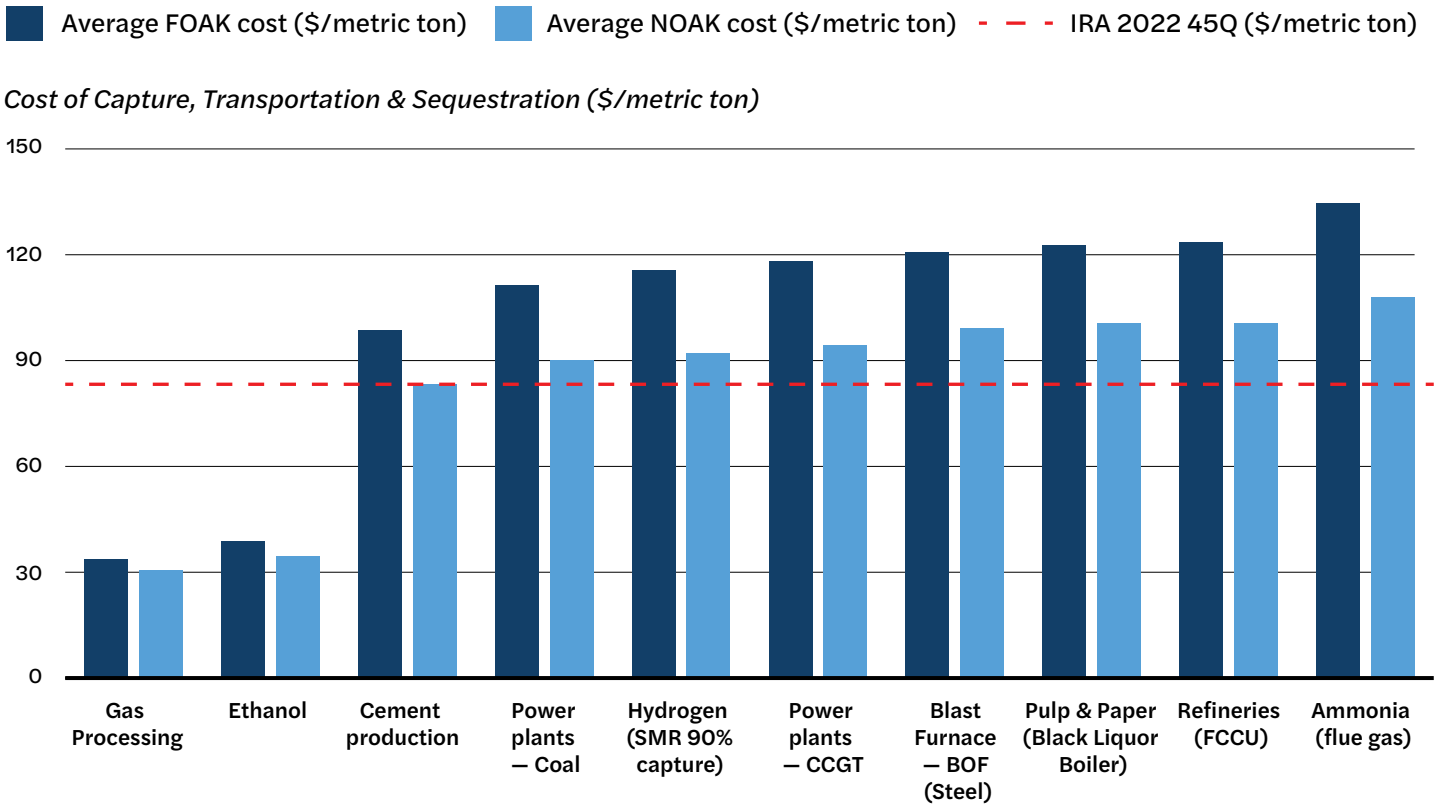
Yet, there is hope. Significant progress has been made over the past five years to jumpstart the CCS industry through a series of complementary regulatory and legislative actions. The investment case for CCS deployment in several industries, such as ethanol production and gas processing, has been markedly improved. In addition, the passage of the Bipartisan Infrastructure Law (BIL) in late 2021 provides $12.1 billion of funding to carbon management to 2026, the majority of which is allocated to grants designed to support demonstration of multiple CCS projects. The Inflation Reduction Act (IRA) signed into law in mid-August 2022 provides an enhanced Section 45Q federal corporate income tax credit value of $85/metric ton for CCS tied to geologic sequestration. Crucially, IRA made this tax credit available to a new set of non-corporate CCS facility owners, allowed tax credit transferability, and in some circumstances allowed owners to receive cash as opposed to a non-cash tax credit. In combination, these two landmark bills (the BIL and IRA) are considered gamechangers for CCS. Some analysts project that the annual quantity of CO_2 captured and sequestered in the U.S. could reach 450 million metric tons by 2035, spurring many billions of dollars of investment.

This study identifies six broad themes regarding the investment challenges for CCS that are consistently raised by project owners, developers, and investors, and offers policy recommendations to address said challenges to attract private capital.

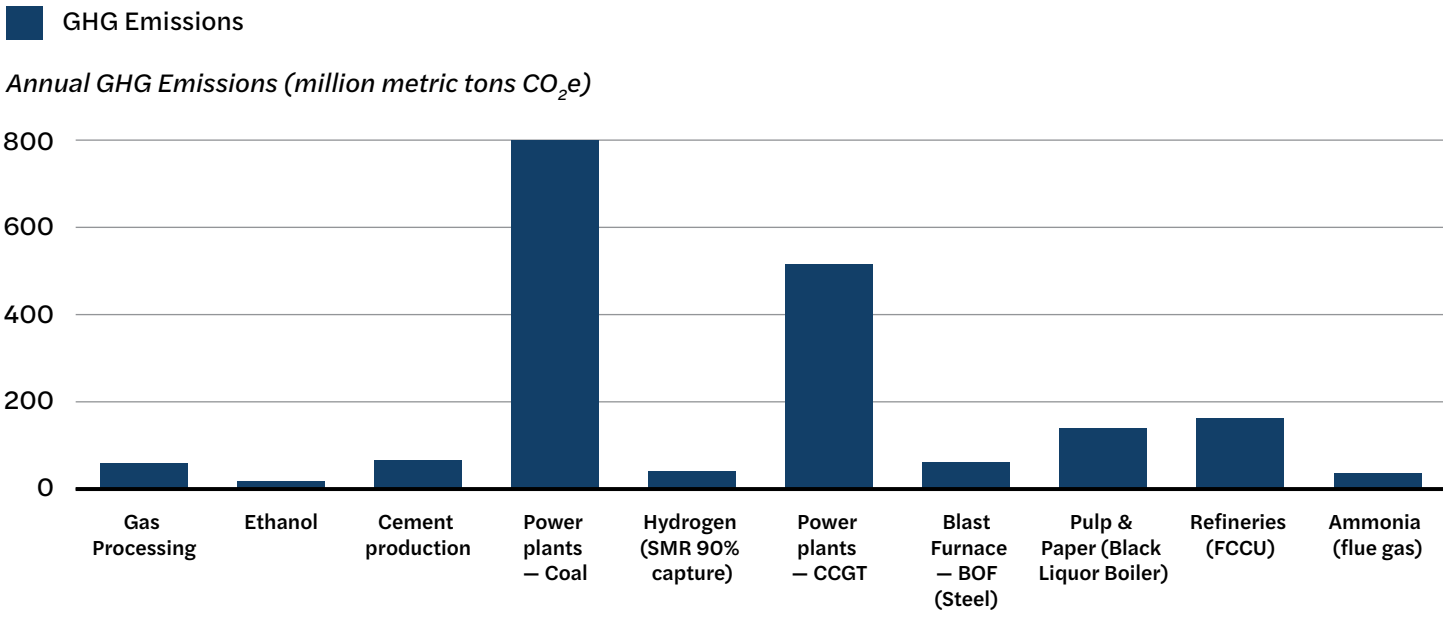
While the bold steps offered by the BIL and IRA to support CCS are significant, further policy action is needed to materially deploy CCS to help decarbonize the U.S. stock of electricity and industrial facilities. In many cases, these policy changes are not costly, but their absence may dissuade significant capital flows to first-of-a-kind applications (FOAK). Without FOAK deployment in a variety of CCS applications to start the learning process, necessary cost reductions will simply not appear. Specifically, CCS deployed for steel, pulp mill wood-byproduct boilers, natural gas and coal-based generation and hydrogen production using steam methane reformers are all currently out-of-the-money (i.e., more expensive than the value of the credit) for FOAK and in some cases mature Nth-of-a-kind (NOAK) installations. Crucially, these out-of-the money CCS applications make up the bulk of CO_2 emissions from the U.S. electricity and industrial sectors (ES-1a and ES-1b, next page).

This study identifies six broad themes regarding the investment challenges for CCS that are consistently raised by project owners, developers, and investors, and offers policy recommendations to address said challenges to attract private capital. These themes are related to a mix of supply and demand side issues (Theme 1 and 2); informational and industrial coordination barriers (Theme 3 and 4); and environmental and economic justice concerns (Theme 5 and 6).

ES–1A | By industry comparison of calculated First-of-a-kind (FOAK) & Nth-of-a-kind (NOAK) $/metric ton cost of CCS to the Inflation Reduction Act tax credit incentive



ES-1B | By industry comparison of annual (2021) GHG emissions in million metric tons CO_2e (EPA FLIGHT data)



Theme 1: Light at the end of the deployment tunnel — supply & demand incentives

Application heterogeneity coupled with value chain complexity requires CCS developers and investors to develop several interdependent, new industries *de novo*. These commercial entities — including technology providers, constructors, emitting facility owners, investors, and lenders — must see a clear, long-term, durable trajectory of policy support mechanisms driving CCS applications from early commercialization ventures to routine deployment. If the prospects of such a successful trajectory are weak, these entities will not see a commercial rationale for deploying the financial and human resources needed to develop CCS. In response, the necessary policy support mechanisms take the form of both supply (cost) and demand (revenue) incentives.

First mover CCS projects in most power and industrial applications will require supplemental support beyond the $85/metric ton tax credit through a mix of grants and loans to reduce costs enough to garner the interest of private capital. This action would facilitate the deployment of FOAK facilities, initiating a cycle that catalyzes learning effects, leading to CCS cost and operational efficiencies in subsequent installations. Since most near-term CCS projects will involve retrofits of existing power and industrial facilities, each with its own idiosyncrasies and need for significant customization, it is only through the accumulation of experience via multiple deployments across multiple industries that long-run cost reductions found in NOAK installations can be realized.

Complementing cost reducing policies are those that spur demand for CCS, such as clean energy standards within electricity generation. Clean, firm baseload power in the form of CCS coupled to existing (and new) fossil fuel generation is needed to help cost-effectively decarbonize the electric sector. This is especially important with increased electrification of industry, buildings, and transportation. Including CCS within state-level procurement standards, combined with updates to electricity market dispatch rules, offers a durable demand signal needed to help form a new carbon management industry.

Supply & demand incentive policy recommendations

- The Department of Energy should in part target BIL commercialization grant funds to the first three-to-five installations in key industries to supplement the current $85/metric ton tax credit, essentially providing low-cost equity to first movers. Additional grant funding totaling $3.2 billion would be needed to accomplish the necessary mixed funding across the six highest-emitting industrial sectors.

- Congress should allow the Department of Energy to issue loans through the Loan Program Office (LPO) to projects receiving grants as part of FOAK commercialization deployments.

- LPO should administratively update its rules to allow loans to 4th and 5th of a kind CCS installations Current regulations ban an LPO loan for CCS if the subject project technology has been used in 3 or more commercial facilities in the U.S. that have at least 5 years of operating history.

- States should modify state clean electricity procurement standards to allow fossil fuel generation with CCS to become an eligible compliance solution.

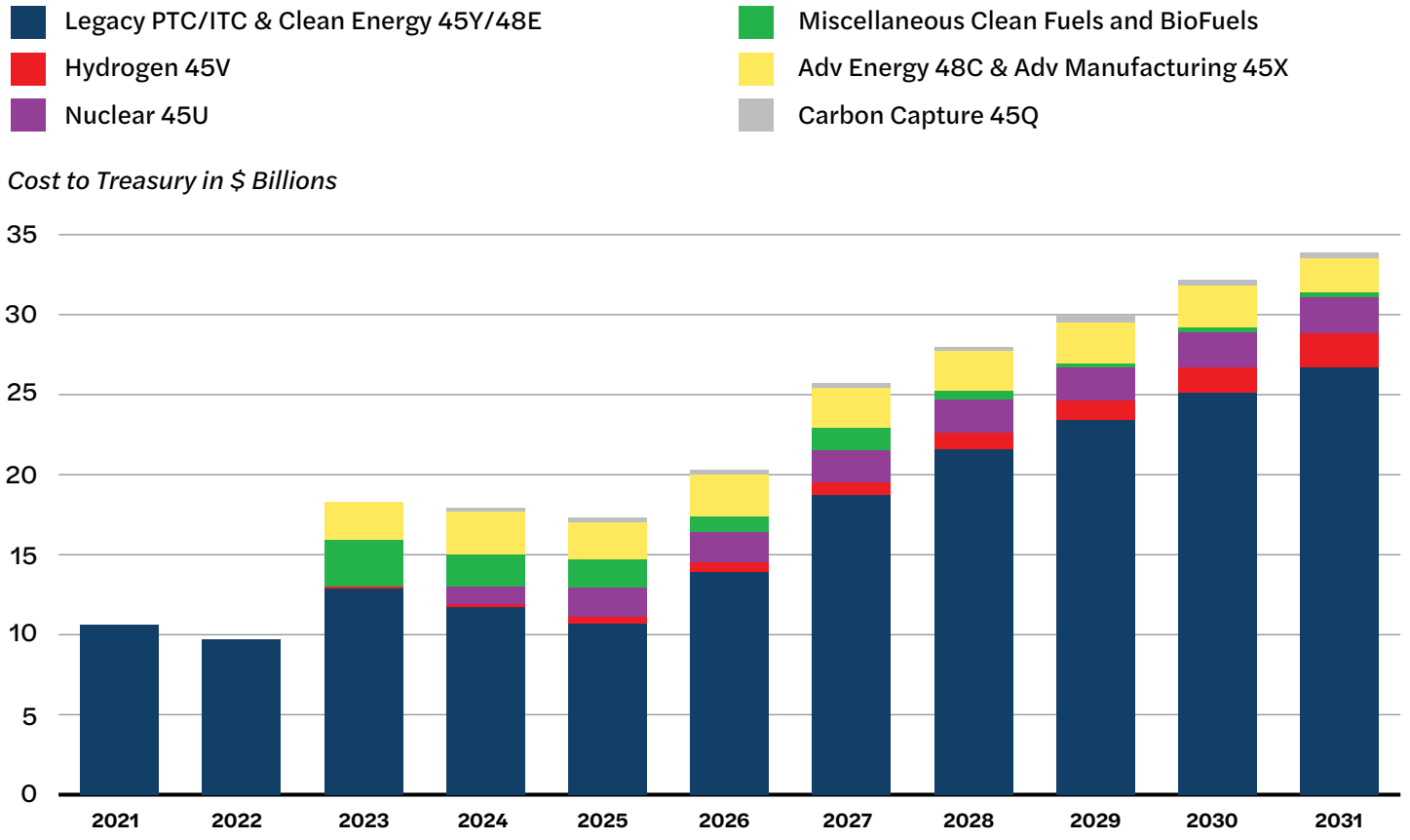
- State regulators and deregulated electricity market authorities should update market rules to allow either take-if-available energy contracts under Power Purchase Agreements or clean capacity payments (e.g., zero emission credits), for CCS-enabled fossil plants to ensure levels of dispatch for clean baseload power sufficient to ensure project financial feasibility.

Theme 2: Tax credits need to become more efficient and accessible

The passage of the IRA will lead to an expansion of the clean energy corporate income tax credit market from ~$10 billion per year (2021 and 2022, measured in terms of cost to the Treasury in forgone tax revenue) to ~$34 billion per year in 2031 (Figure ES-2). Moreover, the IRA also made considerable improvements to the usability of 45Q, specifically the direct pay and transferability provisions.

This CCS focused tax credit is eligible for "direct pay" provisions for the first five years of the incentive for (tax-paying) private parties, followed by seven years of enhanced transferability for corporate taxpayers. Tax-exempt entities such as governmental, cooperative, and tribal owners of CCS projects can now use direct pay provisions for all 12 years of claiming the credits. Key proposed benefits of direct pay include: its simplicity (refund of cash issued as part of a corporate tax return) and value certainty (100 cents on the dollar provided all reporting requirements are satisfactory and true). A crucial intended benefit of transferability is the ability to allow developers who earn tax credits to transfer them to another party in exchange for cash, should they deem doing so as beneficial. Taken together, these provisions promise an increased value of 45Q to developers while expanding the market of would-be consumers of tax credits.

ES-2 | Aggregation of U.S. Congress Joint Committee on Taxation scoring of pre-IRA and IRA energy related corporate tax credits (net of direct pay)



Attracting new participants to make use of ("monetize") transferred tax credits, thereby creating new sources of financial capital for CCS projects, should be a first-order priority of policymakers. The current pool of tax credit consumers has limited capacity to monetize additional credits, given a combination of relatively low corporate tax rates and longstanding federal limitations on a corporation's pre-credit federal tax liabilities that can be offset using corporate tax credits. In theory, there is more than enough remaining taxable corporate income across all sectors of the U.S. economy to fully utilize the new tax credit supply generated by IRA. However, most of these firms are not familiar with federal clean energy tax credits. As a result, it is imperative that well implemented direct pay and transferability rules create the conditions to attract the needed participants to monetize the opportunities presented in the IRA. Further, consideration should be given to allowing tax-exempt pension funds and charitable foundations to benefit from the same IRA direct pay provisions as tax-exempt entities. Tax-exempt pension fund and foundation fiduciaries have the financial sophistication to use direct-pay tax credits; otherwise, with no direct taxes owed to the federal government, they cannot easily use traditional non-refundable/non-cash tax credits.

Tax credit incentive policy recommendations

- The IRS should ensure that the new regulations required to implement the 45Q direct pay and transferability provisions of IRA are designed in a manner that will be conducive to bringing a broader range of new buyers into the market.

- Congress should consider expanding the pool of eligible entities able to make use of all clean energy tax credits.

Theme 3: Critical data and knowledge exist on capture and geologic storage; increasing its availability and accessibility would accelerate commercialization

Detailed data and knowledge about carbon capture technology and geologic storage characterization, cultivated over decades through federally funded research programs, represent a valuable informational resource that could be used to accelerate CCS development. Potential changes in how technical data concerning carbon capture technology and geologic sequestration sites are characterized, aggregated, and made accessible could unlock that value for potential developers.

Yet not all this information is readily accessible in a form that would-be CCS developers could use to inform critical investment and design decisions. The general result is a reduction in the pace of potential new solution development, as well as an increase in development costs across the value chain because project designers, sponsors, and regulators do not fully benefit from knowledge spillovers. There needs to be a balance struck between rewarding the federal grantee who has put resources at risk and supporting would-be follow-on developers who could benefit from learning from first movers. Further, there needs to be a focus on taking new and existing data originally collected for research purposes and developing tools useful for commercial development.

Information sharing from federally funded projects policy recommendations

- The Department of Energy should require that all key engineering performance data be disclosed by the funding recipient to the Department as a condition of awarding competitively procured cost-sharing agreements for carbon capture projects. Without infringing upon private corporate intellectual property or patents, DOE should subsequently negotiate timely and comprehensive public disclosure of such information with the funding recipient.

- The Department of Energy should allocate additional funding to aggregating existing data, collecting new data, and building tools to support geologic sequestration commercial development. EDX — the energy database managed by NETL — is a comprehensive repository of curated public and private data and analytical tools for geologic resources. Additional funds beyond the BIL are needed for EDX to aggregate data across state and federal agencies and build tools needed to help reduce the development risk of geologic storage sites.

- The Office of Information and Regulatory Affairs (part of the Office of Management and Budget) should take the initiative to harmonize federal air pollution databases to facilitate identification and screening of facilities amenable to CCS retrofits. Harmonization of the Greenhouse Gas Reporting Program (EPA), National Emissions Inventory (EPA) and Emissions & Generation Resource Integrated Database (DOE) would materially reduce the efforts of would-be carbon capture developers to screen for ideal host facilities.

Theme 4: Streamline federal and state regulatory requirements across the CCS value chain of capture, transportation, sequestration, and long-term monitoring

CCS value chain complexity — aligning capture, transportation, sequestration, ongoing site care, and long-term liability transfer elements — creates coordination costs and development risks that are disadvantageous to most developers, relative to other clean energy projects. Even highly experienced investors and specialty pools of funds that are otherwise quite willing to pursue "risky" projects shy away from CCS in large part because of value chain complexity.

The lack of permitted geologic storage sites, compounded by the prospect of building large-scale pipelines, creates "holdup" problems across multiple physical and regulatory landscapes for CCS that are distinct from other industries. These include: a lack of a clear permitting regime for interstate CO_2 pipelines (federal policy); uncertainty surrounding the ownership of pore space where injected CO_2 will ultimately reside (state regulation); challenges related to obtaining unitization of land/pore space (largely state regulation if not on federal land); length of time and related uncertainty regarding underground injection permitting (federal or state regulation); and the estimation and available funding approaches used for financial assurance necessary to support post-operation and post-closure injection site care (federal and state regulation).

Policy recommendations to reduce CCS value chain complexity

- State Governors should each create one empowered coordinating body to manage all state-level CCS regulatory interfaces including: facility siting, eminent domain, pore space unitization, long-term liability requirements, etc.
- State coordinating bodies and legislatures each need to develop clear, workable regulations and statutes concerning pore space unitization, post-closure liability, and pipeline eminent domain.
- Congress should take up the issue of the appropriate federal role in permitting, eminent domain, and economic regulation for interstate pipelines and geologic sequestration sites.
- Congress should consider authorizing innovative public private partnerships (including federal ownership stakes) in FOAK CCS pipeline and sequestration infrastructure to the extent so doing facilitates the construction of larger and less costly subsequent developments.

Theme 5: Siting analysis for a carbon capture project needs to address fenceline community health issues

Current permitting approaches, and the attendant public disclosure processes, for carbon capture projects have been built on legacy assessment systems and precedents that apparently lack the flexibility and transparency needed for simultaneously scaling up CCS nationally, protecting human health, and maintaining air quality standards. Especially in the case of retrofits that append carbon capture capabilities to existing facilities, the current framework can lead to limited disclosure of environmental benefits and/or detriments, undermining the social license to operate such capture projects.

Under current regulations, a carbon capture developer is typically motivated to analyze and permit a carbon capture installation in isolation from the CO_2-emitting host facility, because the developer wishes to avoid "reopening" currently applicable air emissions permits at the host facility. In many cases CCS installations provide non-CO_2 environmental benefits to the host facility such as mitigating some criteria pollutants (including common smog and acid-rain precursors) by pre-treatment of flue gases. Yet when the carbon capture is permitted as a standalone project, these non-CO_2 benefits are not adequately considered or disclosed in the permitting process.

There is inherent tension in the current system. On the one hand, expanding the entire air permitting process for new carbon capture retrofit projects to consider the host plant would trigger additional regulatory requirements under EPA air permitting rules that could pose delays, raise other non-CCS issues, and potentially jeopardize the project entirely. On the other hand, not considering the entire system could lead to an incomplete assessment of environmental impacts disclosed to the public.

Policy recommendations for carbon capture project emissions disclosure/research

- State environmental quality authorities should require carbon capture project proponents to perform and comprehensively disclose an analysis of the combined impact on emissions of CO_2, criteria air pollutants (CAP), and hazardous air pollutants (HAP) of the host facility and the new capture plant. This would be a community disclosure requirement, not a change in the actual Clean Air Act-based permitting regime that EPA generally has delegated to individual state air quality authorities.

- The Department of Energy should fund and undertake research examining the net changes of CAP and HAP that result from carbon capture installation, particularly in industries characterized by host facilities that produce both high quantities of CO_2 and conventional pollutants.

Theme 6: Harness community benefits given the energy transition

Building CCS infrastructure can preserve existing jobs and the economic base within a community (e.g., continuing the operation of an existing cement plant), while also providing new opportunities (e.g., building and operating a carbon capture installation adjacent to a host cement plant). These benefits may manifest all along the value chain, where the need for new infrastructure (e.g., pipelines and geologic sequestration sites) may create new economic benefits.

How the labor force will grow and what specific benefits will accrue to the groups proximate to CCS development can be shaped by constructive negotiations between communities, their leaders, and CCS developers. Community engagement by developers offers the chance to design outcomes to accommodate preferences expressed by those who have a stake in the project. This approach where communities have agency and efficacy in the process, also benefits developers by gaining a social license to operate. The appropriation of benefits afforded to both parties — the developer and the community – can be formalized within a community benefits agreement (CBA), which, in turn, acts as an enduring basis for continual engagement across all phases of the project.

Policy recommendations for sharing community benefits

- The Department of Energy, working with states and local governments, should provide direct funding for the capacity building of communities to lead the negotiation of CBA with CCS developers.

CONCLUSION

Turning CCS projects into blue chip investments: A suite of mutually reinforcing recommendations

The recommendations associated with the themes ought to be viewed as mutually reinforcing in enhancing the investment quality of CCS as a decarbonization solution. It is the totality of the recommendations that can materially lower the barriers to private flows of capital to CCS projects. Taken together, these recommended policy actions would address the investment challenges faced by project owners, developers and investors, meaningfully supporting the at-scale deployment of CCS as an industry within a portfolio of solutions needed to reach U.S. decarbonization goals.