DEVELOPMENT CHALLENGES TO SCALED CCS DEPLOYMENT

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Abstract

This paper covers two interrelated subjects. First, following on the preceding paper which focused on creation of adequate and stable revenues/incentives for carbon capture (Mackler), this paper discusses project development considerations associated with siting and permitting barriers that can impact project schedule and success.

Second, this paper supplements the earlier paper by providing a developer's eye view of the broad challenges facing carbon capture, especially in contrast to the demonstrated success of U.S. industry in deploying and driving down costs in other nationwide pollution control efforts such as deployment of SO_2 control to fight acid rain.

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1. Unique Permitting, Environmental Compliance, Market Access, and Infrastructure Issues that Can Derail Carbon Capture Projects

The first section of the paper describes a number regulatory, permitting, market access, and infrastructure issues that represent significant challenges for developers of carbon capture projects. These include:

1. Clean Air Act issues
2. NEPA implications associated with federal funding assistance
3. Voluntary carbon credit markets
4. Ineligibility of CCS based clean energy projects for state-level RPS compliance
5. Pipeline right of ways (ROWs)
6. Permitting sequestration sites

1.1 Environmental Regulatory Considerations: Clean Air Act (CAA) Permitting

In principle, carbon capture facilities can be fully integrated with the carbon emissions source or developed as a standalone facility with its own energy supply. In the case of the former, effluent streams and other environmental impacts associated with carbon capture would need to be addressed as a modification of the existing plant's environmental permits. In the latter case, the carbon capture facility could obtain its own environmental permits.

The present portfolio of CCS projects in the power sector focus on retrofits to operating electric generation facilities and for the most part the carbon capture plant will be constructed as a standalone facility with its own energy supply for both electric and process

steam. Associated environmental permits can involve a lengthy and rigorous application review and public comment.

Although post combustion carbon capture is an emissions control technology, project implementation can result in increases in select criteria pollutants produced by auxiliary steam and power generation necessary to support the operation of the carbon capture equipment. There has been extensive prior industry experience with amine scrubbing, particularly in the oil and natural gas industries, and so there is a long and successful history of these facilities operating with little adverse environmental impact.

Carbon capture projects provide significant environmental benefits through the reduction (>95%) in CO_2 emissions from fossil fuel facilities. At present the Clean Air Act (CAA) does not provide a mechanism under which emissions reductions for one species can be "traded-off" against an increase in some other emissions. Environmental reviews such as provided under the National Environmental Policy Act (NEPA) can and should consider such overall environmental benefits.

Although all types of energy projects require construction and operating permits, there is little precedent in obtaining such approvals for carbon capture. To date, only one scaled carbon capture facility has been permitted and placed into operation in the U.S. at NRG W.A. Parish Station in Texas for the Petra Nova project.

While this project was successful, there were unique aspects of the plant design that provides only limited precedent for follow-on projects in that the facility obtains its power and process energy from an on-site CHP plant and the capture plant processes only a portion of the boiler flue gas produced by the adjacent coal-fired boiler. Importantly, a CCS retrofit on an operating natural gas combined cycle plant has yet to fully permitted.

While most modern natural gas and coal fired power plants already operate state-of-the-art Air Quality Control Systems (ACQS) for criteria pollutants (e.g., SOx and NOx) there is potential for reducing such emissions, particularly from coal plants and from some chemical processing plants and refineries in conjunction with the installation and operation of carbon capture facilities. For example, a recent air permit application for a coal CCS project shows

that the retrofit will result in significant reductions in SO_2 emissions in addition to decarbonizing the generating facility.

Cost effective multi-pollutant carbon capture could provide a vehicle for significantly increasing the overall environment benefit associated with CO_2 emissions reductions and improve project economics through monetizing the value of emissions offsets in non-attainment areas.

1.2 NEPA Compliance

In principle, DOE funding in the form of a grant-in-aid of construction (DOE cost share) or federal financing through the DOE loan program constitutes major federal actions and thereby subjects the project to environmental review under NEPA. Such reviews, particularly if a full Environmental Impact Statement (EIS) is required, pose significant risk and challenge for any project, including CCS projects, and act as a barrier to private sector investment by extending the project development schedule, creating risk around outcome and potential impacts to project design. This is particularly the case if such reviews garner significant adverse intervention.

Recent guidance issued by the White House's Council on Environmental Quality (CEQ) reflected an understanding of the need for expedited federal reviews and offered some constructive proposals with respect to developing templates and reference frameworks for environmental oversight. However, CEQ emphasized the need for full and complete stakeholder engagement, particularly as these relate or otherwise impact Environmental Justice (EJ) communities.

Environmental oversight can be achieved through rigorous environmental reviews which are undertaken over a limited period and provide reasonable certainty of outcome.

There are two potential approaches which can address this goal:

- Programmatic EIS: Develop a programmatic EIS which would evaluate the overall environmental impacts of a carbon capture project based upon generic/representative cases. The programmatic EIS would be used with project specific data inputs to

develop a characterization of overall environmental impacts for each project. To be supportive of accelerated CCS adoption such programmatic EIS would need to be completed on a very timely basis. Further, the process should exclude consideration of CCS alternatives, such as renewable energy. With the passage of the Infrastructure Investment and Jobs Act, the Congress has clearly spoken on this issue

- Environmental Assessment: As necessary via statutory remedy or administratively, establish that NEPA conformance for carbon capture can be established with Environmental Assessment (EA) rather than an EIS. This determination could be made with the proviso that the projects conform to certain environmental metrics.

1.3 Lack of Protocols to Allow Access to Voluntary Carbon Market

Federal incentives from Section 45Q tax credits can be insufficient for certain projects depending on the type and location of the project.

As a result, additional benefit streams maybe necessary to close the revenue “gap.” Such streams could include carbon offsets, premiums for decarbonized power and other products and realizing some monetizable value from avoiding carbon compliance costs.

While there is no national, US carbon compliance market, there is a growing voluntary market for carbon credits which is used by entities seeking to reduce their carbon footprint through the purchase of credits, particularly verified/high quality credits. To date most of these credits have derived from nature-based projects such as afforestation. Use of credits is particularly helpful for companies wishing to achieve ESG goals. Environmental advocacy groups such as WRI have issued guidelines for CCS and recently a not-for-profit organization, VERRA, announced that working with the CCS+Initiative, a consortium of companies and NGOs, it will manage the development of a Verified Carbon Standard (VCS) for CCS to “ensure environmental integrity through proper carbon accounting and independent verification of the climate benefits.”

Completion of this work will no doubt establish a firm basis for qualifying CCS projects and thereby ensuring the integrity of voluntary CCS based carbon credits.

Federal support could also derive from an expansion of GSA and DOD federal procurements of electric energy from decarbonized fossil fuel power generation facilities using CCS. It will be important to extend the tenor of such federal contracts to at least 15 years and explicitly provide for federal procurements to reflect, at a minimum, the present approved social cost of carbon. Finally, providing a set-aside for firm decarbonized energy, as could be provided from CCS based natural gas generation facilities, would provide material support to CCS retrofit projects on modern natural gas combined cycle plants.

1.4 Disqualification from State RPS Markets

The US renewable energy industry obtained significant early support from state Renewable Energy Portfolio Standards (RPSs) which mandated the purchase of certain qualified clean energy resources by utilities and alternative retail suppliers. This regulatory obligation required that such entities produce or otherwise purchase/obtain sufficient Renewable Energy Credits (RECs) to cover their compliance obligations. As a result, RECs are a component of the clean energy value chain for renewables.

For the most part, such RPSs or Alternative Energy Portfolio Standards (AEPS) do not include CCS as a qualified resource. As a result, decarbonized power projects based upon CCS are not eligible to obtain RECs and therefore are not able to obtain monetizable value as clean energy resources. Most importantly, RPS compliance was a strong driver for compliance entities, such as utilities, to enter-into long term PPAs and other forms of off-take agreements that supported large-scale investment, which, in turn, permitted the renewable energy industry to drive down the technology cost curve.

Analogously, CCS deployment could be supported by expanding the qualification of clean energy resources under RPS/AEPS to include decarbonized fossil energy plants using CCS. Potentially, such efforts could obtain traction in states with significant utility or IPP owned fossil energy fueled electric generation and particularly in states which are suppliers of natural gas and coal to these facilities. In the past, several states have considered such

reforms, but have faced opposition from the renewable energy industry, which has sought to preserve its preferred RPS position, demanding that RPS targets be increased if CCS where to be made eligible for compliance purposes. As a result, it appears that such changes may be politically difficult to implement.

Aside from RPS/AEPS requirements, there are two carbon compliance markets in the US, one in California and a second which operates across a group of states in the northeast and Mid-Atlantic region, the Regional Greenhouse Gas Initiative (RGGI). In addition, California operates a separate transportation fuels carbon program which permits producers of lower carbon fuels used in California to earn Low Carbon Fuel Standard (LCFS) credits. The program also permits certain kinds of facilities, such as Direct Air Capture, to earn LCFS credits. As state participation in such regional programs expands, it will be important to ensure that carbon emitters will be able to use carbon emissions reductions from CCS compliance purposes.

In these cases, there are additional revenue opportunities for developers and investors in CCS associated with the monetizable value of carbon allowances. Since not all projects would be viable with the value provided from these programs, additional measures may be needed including providing grants and state tax credits for CCS projects.

1.5 CO_2 Pipeline infrastructure Rights-of-Way (ROWs)

Although not directly related to capture facilities themselves, pipeline access can imperil carbon capture project viability.

Typically, developers of CO_2 pipeline infrastructure are not considered to be “utilities” under state law and have no right of eminent domain. As a result, they are required to privately acquire necessary rights-of-way (ROW). As demonstrated in the case of the Summit and Navigator CO_2 pipelines, such ROW acquisition can be challenging and can materially extend the project development schedule as recalcitrant landowners attempt to delay ROW conveyance. Combined with NEPA compliance, ROW acquisition can become a “bridge too

far" for project developers and can materially undermine project feasibility as delays drive cost increases.

Congress has demonstrated an unwillingness to impose federal pre-emption upon states even for critically needed energy infrastructure. As a result, it remains likely that addressing this issue will require action by states, not direct federal intervention.

A potential approach would be for the federal government to provide financial incentives in the form of block grants to states which make necessary statutory or other rules changes under state law to characterize CO_2 pipeline infrastructure as utility property for exercising eminent domain or otherwise enact legislation that facilities ROW acquisition for such infrastructure.

1.6 Permitting of CO_2 Storage Sites

As with pipeline ROWs, permitting of storage sites is not directly related to the capture facilities themselves, and but rather is a critical component of the CCS value chain. This topic is dealt with in detail in Dr. Steven Carpenter's companion whitepaper.

In most cases the time frame for requisite permitting by EPA under the UIC is the critical path to CCS project financing and issuance of a Notice to Proceed (NTP) to commence significant onsite construction activity. EPA projections are 24 to 36 months, measured from application to a final and effective Class VI permit.

As a result, expediting the issuance of a Class VI permit is among the most effective vehicles available to accelerate CCS project commercialization. The Infrastructure Bill contained two initiatives toward this goal. First, it provided additional funding to EPA so that it can expand its internal capability to review, process and issue Class VI permits. Secondly, the Bill contained funding for states to organize and develop their own capability to take-on Class VI permitting activities under delegated authority from EPA. Several states are moving forward to assume this responsibility. However, it will probably take several years for states to acquire the resources and personnel, particularly in the case of states which have limited experience with oil and gas development.

The present EPA Class VI rules are based upon EPA authority under the Safe Drinking Water Act and primarily address well integrity, safety, and overall CO_2 injection activities, including post-closure requirements which have the potential to adversely impact ground water supplies.

A key question is what performance obligations will project lenders and investors require to ensure post closure storage integrity? This picture will become clearer as geologic storage projects reach financing closing and third-party investors complete due diligence to identify long-term risks. While the US O/G industry has demonstrated its ability to safely operate CO_2 geologic storage reservoirs and there is increasing evidence that long term post closure risks are very low, the financial and other guarantees investors may require have not been fully established.

Over a decade ago, in conjunction with preparation for large-scale CCS deployment under federal cap-and-trade, work on several initiatives to address this issue were begun. Legislation was proposed under which the federal government would accept post closure liability in whole or in part, analogously to the support offered to nuclear plant operators under Price Andersen. In addition, several states have considered legislative initiatives to accept post closure liability or even accept title to CO_2 at the boundary limits of state surface and injection of CO_2 in state-owned pore space. This approach was seriously considered by the Commonwealth of PA in 2009/10. Presently, several states, including North Dakota, have enacted statutes that would transfer post closure liabilities to the state, in whole or in part, thereby materially mitigating the long-term risk associated with some form of post closure event.

The industry would benefit from re-consideration of certain previously proposed provisions for incorporation into new federal legislation, including providing federal funding support to states which accept long term, post closure liability or otherwise to provide federal support for such long-term liability.

2. CCS Projects vs. Other Energy and Pollution Control Projects: Background

CCS projects generally face the same types of development challenges as other types of comparable energy projects. For example, the need to acquire requisite real estate/right-of-way, obtain a portfolio of permits and governmental approvals from federal and state agencies, structure necessary commercial agreements for engineering, procurement and construction (EPC) of the carbon capture facilities, pipelines and other supportive infrastructure as well as site host agreements, and processing arrangements to treat flue gas and process gas for CO_2 removal as well as construction and permanent financing.

These challenges need to be addressed systematically and as an integral part of overall project development. Over time, templates and approaches will be developed and implemented by developers to facilitate and accelerate CCS project development. Transactional momentum is the most effective tool for establishing lessons-learned, driving optimization/value engineering, and creating interest in technology optimization and innovation.

As in the case of other industry segments, transaction execution through development, construction and operation will drive down perceived and actual technology and commercial risk, compress margins, develop political support for enabling legislation affecting CCS as well as carbon pricing and establish a firm foundation for scaled deployment.

Since the late 1970s, the U.S. power and utilities industry has successfully undertaken several technical and commercial transformations which have dramatically altered the structure of the industry. To the extent that societal consensus has been achieved around the notion that decarbonized fossil fuels (using CCS) need to play a key long-term role in the U.S. energy economy, there is no reason to believe that developing and implementing CCS represents challenges and barriers that would prevent a similar outcome. However, significant progress toward decarbonization will be slowed should CCS be caught-up in a do-loop of debate regarding the elimination of fossil fuels.

Over the past 40 years, the US power industry has commercialized a portfolio of new technologies and has, over time, integrated these technologies into its investment and financing models. Examples include:

- The back-end Air Quality Control Systems (ACQS) for both coal and natural gas electric generation plants including flue gas desulfurization, selective catalytic reduction and activated carbon injection for Mercury emissions mitigation
- Circulating Fluidized Bed (CFB) boilers
- Super critical/ ultra-super critical boilers
- Advanced/high efficiency gas turbines culminating with the latest J and H class machines

In the 1990s and early 2000s, other technologies such as IGCC and pressurized fluidized bed (PFB) combustion were also beginning to move up the adoption path and would probably have followed the same deliberate long-term commercialization path had it not been for commercial/financing and market challenges, particularly the advent of shale gas, which undermined the value proposition for solid fuel utilization.

In the case of ACQS, the driver for scale commercial adoption began with the 1977 Clean Air Act Amendments and its mandates for sulfur dioxide emissions reductions which could only be achieved for higher sulfur content fuels with flue gas desulfurization. A similar "technology forcing" driver developed for back-end NOx controls since the levels of required emissions reductions transcended the ability of combustion controls to reduce nitrogen oxides emissions.

Initial SO_2 scrubbing installations had very high capital and O&M costs and required difficult and costly waste management systems. However, over a period of some 30 years, industry technology providers and contractors optimized flue gas desulfurization for both retrofit and new-builds and overall costs fell significantly over this period. In addition, innovative approaches to waste management were developed including oxidation of problematic sulfite sludges to gypsum, creating a by-product market for desulfurization products.
This transformation of the environmental profile of the US power industry was driven by regulatory mandates that forced technology innovation to achieve increasingly stringent

environmental standards. No doubt a similar outcome and downward sloping technology cost curve would be realized for decarbonization, if the US had some form of long-term carbon regime in the form of CAT or a carbon tax.

In the absence of a monetizable value on carbon, the US is reduced to using incentives, such as 45Q, to effectively establish carbon value, but limited to only those segments which the tax credit applies. Given this situation, for the foreseeable future, the US energy industry will be dependent upon a combination of incentives, including Section 45Q tax credits, and ESG considerations to support industry decarbonization investments.

However, while incentives of sufficient magnitude, duration and structure can conceivably support significant industry investment in CCS, they do not substitute for a thoughtful, comprehensive policy construct that provides a basis for forecasting long-term carbon value and permits long-dated amortization of CCS infrastructure; well beyond the 12-year term of 45Q credits.

As noted earlier, transactional momentum is the most important priority for the US CCS industry. It is the development of a robust portfolio of development projects which close financing, are constructed and placed into commercial operation that will drive commercial and technology innovation and cost reductions. Such transactional successes will also generate political support for such institutional and regulatory changes which will expedite and facilitate CCS deployment.

2.1 CCS Commercialization Conditions

The US energy industry responded robustly to the passage of the 1978 Energy Act with the goal of developing and constructing new alternative fuel facilities to replace what was thought to be dwindling reserves of conventional fossil fuels. This effort was led by the US energy industry which made significant investments in coal derived alternative fuels such as hydrogen and synthetic natural gas as well as the production of synthetic crude and drop-in fuels, including from oil shale.

For the most part, the industry planned to fund construction costs through financings raised at the corporate level using a combination of equity and corporate debt. Conspicuously, there was little work on the type of project level financings which is now typical for energy projects sponsored both by major energy strategics as well as financial investors. Although tax credits have long been used by the federal government to enable investment in select sectors, this earlier round of alternative energy investments was substantively supported by mandates and price supports rather than tax credits as employed to accelerate renewable energy adoption. It is important to note that in both cases federal financial support was one component of project revenue not the sole source of cash flow. Specifically, CCS projects, other than those involving the "utilization" of CO_2, (EOR, drop-in fuels, etc.), have no other source of income other than the monetized value of federal tax credits.

This characteristic represents a challenge for investors across the capital stack in CCS projects. As noted previously, investors are comfortable with renewable energy projects with multiple sources of revenue including federal tax credits, state RECs as well as cash flow from the sale of electric power. Faced with significant, continued investment opportunities in renewable energy and a "different" and potentially greater risk profile for CCS projects, it is not unreasonable to believe that there will be limited liquidity available for CCS investments, particularly early in the development of the CCS industry. As a result, it can be expected that the underlying cost of capital for CCS will be higher than for other comparable clean energy projects. This does not mean that CCS projects will not close financing and be executed, but that the economics will need to be correspondingly robust to satisfy investor metrics.

With this said, it is likely that the US energy and finance industries will, over time, evolve innovative financing constructs to address the issues associated with CCS projects. Similarly, the industry will develop templates for the foundational commercial agreements that support financings, (e.g., CO_2 flue gas "off-take" and operation and maintenance of CO_2 storage facilities, including the apportionment of long-term liability for sequestered CO_2), extended warranties for CO_2 capture equipment including long-term purchase agreements for amine and other CO_2 sorbents).

However, industry interest in devoting the resources necessary to develop these constructs will require "line-of-sight" to the prospect of a portfolio of scaled transactions. As a result,

building transactional momentum for CCS projects is critical to the creation of a development/financing ecosystem to drive down transactional costs, and reducing project risk. However, since the development and construction of new carbon capture projects requires four years or more, this process will take some time since there will not much in the way of large-scale CCS project operation on power generation much before the late 2020s. Successful construction and, importantly, operation of capture and storage, are necessary preconditions for driving out risk and optimizing both engineering design and financings. As a result, while the CCS revolution has begun in earnest the slope of the CCS maturation curve will be relatively low until the industry has completed and placed into operation multiple facilities.

2.1 Technology Maturity and CCS Commercialization Dynamics

For those who view climate change as requiring exigent action, there is high interest in accelerating reductions in anthropogenic carbon emissions and in rapid deployment of CCS at scale. However, since CCS involves investments across energy sector infrastructure, an extended timeframe will be necessary to drive down the technology cost curve and establish a strong commercial foundation for replicable transactions.

The most effective governmental action to support CCS deployment and consequent emissions reductions would be to provide a clear, long-term economic signal regarding carbon value sufficient to support CCS investments.

The nascent US CCS industry, fostered by the present incentive-based policy construct, is already facing head winds, as pandemic induced supply chain disruptions have adversely impacted project execution schedules and costs, including supply of critical engineered equipment and site consumables.

Addressing these issues will require systemic solutions including consideration of federal initiatives for onshoring of critical industries and supporting educational reform to produce qualified workers to satisfy the technology demands of modern automated heavy industry. The unfortunate reality is that after decades of deindustrialization, it is difficult to source US

made major fabricated/engineered equipment including large process vessels, certain piping, compressors, etc. As a result, the US is facing limitations on domestic supply and skilled labor necessary to fabricate equipment and engineer/construct complex process facilities.

Bringing CCS infrastructure into commercial service will require significant development, permitting, engineering and construction which can require over five years to complete. While it is possible to truncate or otherwise simplify the permitting approval process to shift project critical path or address right-of-way acquisition, etc., doing so is likely to implicate a range of long-held stakeholder engagement processes which undoubtedly will garner significant opposition. As a result, efforts to accelerate technology commercialization through new federal initiatives are not likely to be an effective tool for accelerating CCS industry development.

The most effective tool for driving down the technology cost curve for carbon capture is creating transactional momentum. Successful transactions which result in projects completing construction and entering commercial operation will increasingly address the technology and commercial risks that are associated with first-of-a-kind (FOAK) and follow-on early mover projects.

In addition, as noted previously, to the extent that investors can anticipate long-dated CCS industry growth, there will be willingness not only to make project level investments but to invest in innovative technologies, service companies and other enterprises that are collateral to carbon capture. This investment dynamic has been demonstrated in other aspects of the power/utilities industry and will operate to expand technology availability, enhance competitiveness, and reduce costs associated with carbon capture.

The Infrastructure Investment and Jobs Act (the “Infrastructure Bill”) contained significant appropriations to permit DOE to fund a range of CCS related activities including R&D, FEED studies, carbon infrastructure financing and commercial demonstration projects. Although DOE R&D funding has proven to be important in supporting new technology development, there has been less historic success driving technology commercialization through DOE

programs designed to implement technologies in an effort to overcome the cost and other barriers that make it difficult to implement FOAK projects.

The primary imperative is for Congress to enact some form of long-term construct which establishes a regime which monetizes the value of carbon and explicitly and unambiguously recognizes carbon emissions reductions associated with CCS as meeting climate goals.

The most powerful and effective near-term vehicle for monetizing carbon value and thereby creating the economic foundation for CCS project financing is to make selective revisions to Section 45Q to provide sufficient monetizable value from carbon emissions reductions to support private sector investment in CCS projects. These changes include increasing credit values for EOR to $60/tonne and 85$/tonne for geologic storage, respectively. Such Congressional action should include guidance and direction to the Internal Revenue Service to support timely completion of any necessary rulemaking to make the revisions actionable.

Decisions on CCS project investment are now side-lined awaiting line-of-sight to Congressional enactment such changes to Section 45Q with investors reluctant to proceed on projects which are financeable at present credit values, and thereby locking themselves out of improved economics, and proceeding on projects that require 45Q revisions and being left with stranded costs, should such revisions not be implemented.

CCS can be a key tool to decarbonizing the US energy economy and obtaining broad-based commitments to decarbonization which will support future federal policy action to create a sustainable construct for monetizing carbon value. As a result, as an initial step, timely Congressional action on Section 45Q is required.