PENNSYLVANIA'S PATH FORWARD FOR CARBON CAPTURE, USE, & STORAGE

Summary of an expert convening organized by:

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Disclaimer: This is a summary of presentations from and discussions among a diverse set of speakers with a variety of opinions on the subject matter presented. The speakers were not asked to review this document. The positions summarized here do not necessarily reflect the positions or thinking of the workshop sponsors.

Executive Summary

On April 20, 2022, Pennsylvania Environmental Council (PEC), Clean Air Task Force (CATF), and Great Plains Institute (GPI) hosted a day-long convening in Pittsburgh, PA, to present information about carbon capture, use, and storage (CCUS) and to discuss the path forward for CCUS in Pennsylvania. The day was structured to progress from the broad (the global energy transition) to the narrow (e.g., implementation details in Pennsylvania). This paper captures some of the key topics of discussion.

- **Climate Change, the Global Energy Transition, & CCUS:** Humanity is far off course to limit global warming to 1.5-2°C, and emissions are still climbing. Zero-carbon electricity can play a role in decarbonizing various sectors of the economy, but there are many sectors where some kind of liquid or gaseous fuel is probably needed. Decarbonizing the entire global energy supply requires options. Renewables will be a significant part of the solution, but they have their limits, including the seasonality and large surface footprints of wind and solar. CCUS provides an option to decarbonize existing fossil fuel assets, while carbon removal provides an option to remove emissions that are already in the atmosphere.

- **CCUS Overview: Technology, Finance, & Policies:** CCUS is not one technology, but rather a diverse suite of technologies to capture, transport, utilize, and store carbon dioxide (CO_2). ("Carbon management", which also includes removal of carbon from the atmosphere, is an even more diverse suite.) Costs for CCUS depend on application, purity of the CO_2 stream, distance from CO_2 storage locations, availability of transport, economies of scale, and more. Policies and incentives are needed to reduce CCUS costs, ease access to financing, and accelerate deployment. In recent years, there has been tremendous progress and bipartisan interest in Congress in advancing CCUS deployment, including expansions of the 45Q tax credit and substantial funding in the bipartisan infrastructure law. The Council on Environmental Quality has also developed guidance for federal agencies about responsible implementation of CCUS. With respect to CO_2 pipelines, the federal regulatory model (apart from safety) still remains largely undefined.

- **CCUS Potential in Pennsylvania:** Pennsylvania is among the highest-emitting states, which means deploying CCUS could make a big difference. Pennsylvania also has an advantageous and diverse subsurface geology, though it will be important to figure out how to coordinate subsurface usage as CO_2 sequestration is added into the activity mix. There are hundreds of years' worth of CO_2 emissions that could be stored underground in the region (as well as offshore), but there is a need for more local characterization of storage opportunities. Given the geologic storage potential, high concentrations of industrial emitters and 45Q-eligible facilities, substantial amount of CO_2 that is relatively easy to capture, existing natural gas infrastructure, and other factors, the western part of Pennsylvania (plus nearby Ohio and West Virginia) could be a good location for a CCUS / clean hydrogen hub. The region could also see near-term benefits in terms of job

creation and retention from CCUS retrofits of facilities and the buildout of CO_2 transport infrastructure. Collaborative efforts are already underway, including a CCUS Inter-Agency Work Group within the Commonwealth and a multi-state effort on regional CO_2 transport infrastructure.

- **Policy Needs to Operationalize Carbon Management in Pennsylvania:** To make CCUS deployment a reality in Pennsylvania, there is a need for strong federal policies, as well as funding. A supportive state policy and regulatory framework is also crucial. Key issues to address include: deciding whether Pennsylvania should seek primacy over Class VI wells (for CO_2 sequestration); clarifying who owns pore space; determining the requirements and incentives for pooling pore space; resolving the question of long-term liability for sequestered CO_2; determining whether and how to advance comprehensive regulation of CO_2 pipelines; building human capital within agencies for CCUS development; and supporting public education and engagement about CCUS deployment.

CCUS can be a global decarbonization option that Pennsylvania can help to pioneer, but if it is to be an option at all, action is needed now.

Climate Change, the Global Energy Transition, & CCUS

The concentration of carbon dioxide (CO_2) emissions in the atmosphere now is far out of range of where it has been for the past several hundred thousand years, and it continues to rise. The fundamental balance of CO_2 on the planet is out of whack, largely due to fossil fuel burning and the subsequent emissions into the atmosphere. There is some absorption by oceans and forests, but there is a net contribution to CO_2 stocks in the atmosphere. Even with all the climate pledges around the world, humanity is not on a path to limit global warming to 1.5-2°C. Humanity is way off course, and emissions are still climbing (except for a brief dip during the start of the COVID pandemic, which was followed by the largest one-year increase in history).

Bringing the emissions curve down is fairly simple in concept. Currently, there are a handful of major energy end-uses (i.e., buildings, transport, and industry), two major energy carriers they operate on (electricity and fuels, in the form of liquid petroleum and natural gas), and various forms of primary energy production (e.g., renewables, nuclear, fossil energy), with fossil energy providing 80% of primary energy. To make progress on emissions, that picture has to change. In terms of energy carriers, the biggest change is probably figuring out how to do zero-carbon fuels. Electricity is only 20% of planetary energy consumption, and the rest is consumed as liquid or gaseous fuels. The electricity supply must be decarbonized, and that decarbonized electricity can play a role in decarbonizing other sectors, but there are many sectors where some kind of liquid or gaseous fuel is probably needed. In terms of primary energy, renewables and nuclear will continue to provide energy production, but if fossil fuels are going to do the same, some kind of carbon sequestration and/or removal will be necessary.

A popular view among some policymakers and media outlets is that climate change can be solved just with wind, solar, and batteries (and perhaps some hydro), but more options are needed. Wind and solar today are about 1.5% of global energy supply; assuming that very small wedge can grow to fill the entire need, while that need also perhaps doubles given growing global energy demand, is a challenging proposition. Renewables will be a significant part of the solution and should be sited as much as possible, but they have their risks. Two key risks include:

- *The seasonality of wind and solar*. Wind and solar exhibit substantial variation on weekly and monthly timescales, with multi-week gaps in supply availability. That is a hard problem to solve with current battery technology (which is usually 4-8 hours), and even long-duration storage options (10-100 hours) may not be able to fill those gaps (and if they could, it would be very expensive).
- *Surface footprint*. This is a very crowded planet, and “empty” space is not necessarily empty. Spatial constraints are real. Hugely scaling up wind and solar for electricity and zero-carbon hydrogen production would involve an enormous surface footprint, whether on land or in the oceans. As the better sites for wind and solar around the world are exhausted, more land use conflicts around siting are to be expected, and the deployment curve will likely flatten out more (i.e., an S curve).

Decarbonizing the entire global energy supply requires options. In addition to renewables and storage, zero-carbon options include natural gas with CCUS, hydrogen turbines, and perhaps small modular nuclear. In its latest report, the Intergovernmental Panel on Climate Change (IPCC) highlights the need for CCUS. Emissions must be reduced quickly, and assets that cannot be retired quickly need to undergo retrofits. The amount of CCUS in these reports keeps growing; across the various pathways in the latest IPCC report to keep global warming to 1.5°C with limited or no overshoot, the average amount of CCUS between now and 2100 was 665

gigatonnes (Gt), including a huge scale-up by 2030 in the industrial sector. More broadly, international 1.5°C modeling scenarios show that not only does the world have to hit net-zero by mid-century, but it also has to go net-negative after that utilizing negative emissions technologies, including bioenergy with carbon capture and storage (BECCS), direct air capture (DAC), and other biological sources of carbon sequestration. If action on emission reductions is delayed, substantially more negative emissions will be required.

According to analyses, most of the emissions reductions needed by 2050 are expected to come from technologies that are not yet mature (which means continued innovation is crucial), and the vast majority of emissions remaining before reaching the Paris goal are already locked into existing assets. The options on the table for addressing climate change thus need to include carbon management — which includes both CCUS and atmospheric carbon removal. CCUS provides an option to decarbonize existing assets, while carbon removal provides an option to remove emissions that are already in the atmosphere. Carbon management is *not* the sole solution, but if it is to be an option at all, action is needed now (if not yesterday).

CCUS Overview: Technology, Finance, & Policies

Technology & Application

CCUS is not one technology, but rather a diverse suite, including various technologies to capture, transport, utilize, and store CO_2. (Carbon management, which also includes carbon removal, is an even more diverse suite.) Many of the technologies for carbon capture and storage already exist and have existed for decades.

CCUS has diverse potential applications. It represents perhaps the only way to fully decarbonize cement production and is one of the key ways to decarbonize steel and other sectors. CCUS may not be feasible for every industrial source, and options such as fuel switching and electrification should also be considered, but even there CCUS can play a role. For instance, CCUS could open up the blue hydrogen market, which can facilitate fuel switching in industrial facilities. CCUS technologies can help future-proof U.S. industries and can be applied globally.

In operational CCUS projects so far, the actual percentage of CO_2 capture has been quite variable. Facilities being planned today are looking at 90+% capture, and there are no technical barriers to that. The application and the design specs at any given facility will influence capture levels.

Some existing infrastructure could be converted for CCUS purposes. Well bores have value, probably as monitoring wells (and probably not as injectors). Pipelines themselves may not have much value, given changes in pressure and materials that may be needed to carry CO_2, but the rights of way have significant value.

Costs & Finance

There is a need to reduce CCUS costs, accelerate deployment, ease access to financing, overcome ecosystem challenges (e.g., transport), and improve the value chain.

Just as there is not one CCUS technology, there is not one CCUS cost estimate. Costs depend on application, distance from CO_2 storage locations, transport availability, economies of scale, and more. Where there is a relatively pure stream of CO_2, costs for carbon capture are lower, but where the CO_2 content is lower, it can be harder and more costly. As a rule of thumb, costs per ton of CO_2 abated are reduced about 30% from first-of-a-kind to second-of-a-kind projects.

Supportive policies help reduce costs through learning-by-doing (i.e., by getting more projects operating). Policies and incentives are also needed in part because carbon management technologies are generally hard infrastructure projects that do not produce sellable electricity or energy that can help offset costs. They are climate / emissions reduction technologies.

Further investment is also needed from the financial industry to make CCUS technologies and projects viable on a very large scale. There are some industrial areas where the existing incentives are sufficient, but there are others where carbon management is more difficult and requires additional investment. Investments in the energy transition are currently lopsided, though. Most low-carbon investment in 2021 went into electrified transport and renewables, with only a sliver going to CCUS. Climate solutions need investment now; addressing climate change will not be free.

Congressional Policy

The United States has done more than any other government to commercialize CCUS technologies. Since the beginning of the 117th Congress, there has been tremendous progress and bipartisan interest in the issue, with support spanning the entire political spectrum and all regions of the country.

The 45Q tax credit is the foundational policy for carbon management deployment in the United States, and its reform and expansion in 2018 was pivotal. The stalled reconciliation bill would have included additional 45Q enhancements, including a 6-year extension of the credit, direct pay (which would avoid the need to go through tax equity markets), higher credit levels for industry and power projects, higher credit levels for DAC projects, and lower annual CO_2 capture eligibility thresholds (which would help innovation by making sure projects go forward).

In addition, the bipartisan infrastructure law had historic levels of investment (over $12 billion) in carbon management technologies, including large-scale pilots and demonstration programs. The billions of dollars involve lots of agencies and departments, including in the Department of Energy (DOE), the Environmental Protection Agency (EPA), the Department of Interior (DOI), and the Council on Environmental Quality (CEQ). With respect to transport and storage, the bipartisan infrastructure law included the SCALE Act in its entirety, which provides low-interest grants and loans to project developers and funding for site characterization, permitting authorities, and state primacy efforts. The infrastructure law directed additional funding to EPA's Class Vi program (which involves wells to inject CO_2 into deep rock formations) to increase staff capacity and training and to provide grants for states, and it allowed DOI to grant offshore CCS leases, access, and rights of way and to promulgate regulations. At DOE, the law established an innovation program with flexible federal loans. The legislation also included CCS in the Permitting Council's FAST 41 program.

The recent policy push is unlocking a lot of commercial carbon management activity. More than 80 projects are in planning (mostly in the industrial sector), with most announced in 2021. Various value chain elements in the United States are starting to unlock, including storage, transport, and hubs / clusters, and work on DAC is growing. The policies could deliver a 13-fold increase in carbon management capacity in the United States by the mid-2030s, which could support tens of thousands of jobs.

CEQ Guidance

CCUS will only deliver the desired social and environmental benefits if it is well governed. The Biden Administration is working to make CCUS a widely available, cost effective, and rapidly scalable solution and to accelerate responsible development and deployment across sectors. The Administration issued a report in June 2021 stating its position on CCUS, and CEQ developed guidance for federal agencies (released in February 2022) about responsible implementation of CCUS. Under direction from Congress, CEQ is also establishing at least two regional task forces on CCUS that will exist for at least five years and will provide guidance to CEQ on matters such as gaps in the guidance and how to improve it.

CEQ's guidance covered four main areas:

- First, it looked at facilitating federal decision-making on CCUS projects and CO_2 pipelines — balancing the need to move CCUS in a timely manner with having the appropriate guardrails. The government already has an existing regulatory framework

to safeguard the environment, health, and safety for industrial activities. The guidance encouraged agencies to consider where Programmatic Environmental Impact Statements could be helpful in facilitating CCUS and to include reasonably foreseeable effects, including cumulative pollution. The guidance also encouraged the Permitting Council to help move infrastructure forward, and it encouraged agencies to increase the transparency of CCUS in greenhouse gas reporting, monitor sequestration, and update regulations for CO_2 pipelines.

- Second, it focused on the ways the scale of CCUS raises concerns about health and the environment, as well as questions about who benefits from deployment. It emphasized that engaging communities and tribes, protecting communities from pollution, and incorporating environmental justice considerations are paramount. The guidance recommended that agencies undertake measures to have a transparent process of public engagement, evaluate impacts on host communities early in the process, provide information in advance on impacts and benefits, consult tribal nations in ways that strengthen relationships, and avoid imposing additional burdens on overburdened communities. The guidance also recommended that agencies with substantial CCUS activities do interdisciplinary research.
- Third, the guidance focused on understanding environmental impacts. For offshore sequestration, the guidance noted the need for agencies to collaborate on studies of the impacts that CCUS could have on marine resources. In direct response to concerns from communities about cumulative pollution, the guidance highlighted the need to assess and quantify impacts on local criteria pollutants and other emissions, and agencies are studying those impacts. (There are likely to be real pollution co-benefits from CCUS retrofits, but there is not a lot of data.) There is also a need for agencies to share best practices on project data collection and reporting.
- Fourth, the guidance focused on CO_2 utilization and on carbon removal. The guidance flagged the need for public confidence to be built with transparent information and encouraged agencies to form a repository of lifecycle analysis information. The guidance also acknowledged the opportunity for agencies to think about what needs to happen to incentivize federal procurement.

Regulation

With respect to CO_2 pipelines, there is little federal regulatory authority, other than the Pipeline and Hazardous Materials Safety Administration (PHMSA) for safety. CO_2 is colorless, odorless, and tasteless. It is stable, but it can be much heavier than air, which means it can be an asphyxiant. When it encounters water, it can be corrosive. PHMSA regulates about 5,000 miles of CO_2 pipelines (mostly for enhanced oil recovery), in which CO_2 is a supercritical fluid. There have been 60 or so safety incidents with CO_2 pipelines since 2004, with no fatalities. (Fatalities tied to CO_2 have been in confined spaces, not related to pipelines.) PHMSA regulates a range of safety issues, including corrosion and failure, but it also permits primacy to the states, which can add their own regulatory oversight.

Hydrogen is analogous to CO_2 in many ways. PHSMA regulates it under the same code (and has since the 1970s), and there are 700 hydrogen pipelines in the country, including some in Pennsylvania (to serve industrial loads, not as public utilities). From a safety perspective, there is thorough safety oversight that can be easily adapted to whatever is built.

There are growing needs, including how to regulate subcritical and gaseous CO_2 and what kind of regulatory oversight is appropriate in considering whether to blend hydrogen into the natural gas distribution system. These issues remain unsettled.

If there is federal interest in more broadly regulating CO_2 pipelines, there are potential models to consider. CO_2 is in some ways like natural gas, so that could be a regulatory model. In the natural gas model, the Federal Energy Regulatory Commission (FERC) has exclusive federal jurisdiction in interstate commerce and full siting jurisdiction. FERC's electricity regulation is a different model; under the Federal Power Act, there is limited federal jurisdiction, and siting jurisdiction lies with the states. Other approaches are also possible (e.g., multi-state compacts). This is open ground that has yet to be addressed.

CCUS Potential in Pennsylvania

Pennsylvania's Positioning

While the energy transition and the need to decarbonize are global in scope, the solutions will inherently be local in nature. Pennsylvania has been part of every energy transition since the colonization of America, from wood/timber supplies in the 18th century to the fossil fuels that have made up most of U.S. energy consumption for more than a century. Other states are just beginning the CCUS journey, and there is no reason Pennsylvania should be left behind.

Pennsylvania has multiple point sources of CO_2 pollution all over the state, including in energy, power, industry, and manufacturing. Pennsylvania was the fourth-largest emitting state in 2019, with power and industry accounting for more than half of emissions. The region has a huge amount of emissions, which means getting CCUS up and running could make a big difference. Pennsylvania also has energy resources, a strong workforce with a rich history of building infrastructure, decarbonization goals, and a governor that will champion CCUS.

There are already CCUS projects being pursued in the region, including the KeyState to Zero project in Clinton County (to synthesize gas and do local carbon sequestration) and the 21st Century Power Plant project in southwestern Pennsylvania or the West Virginia panhandle (to produce power with biomass and coal waste and do local carbon sequestration).

Geology & Storage Potential

Pennsylvania has an advantageous, diverse subsurface geology. There are sedimentary rocks in the western part of the state. As one moves to the central and southeastern parts, there are mountains and, in the Southeast, a few different geologies, with igneous and metamorphic types. The first 1,000 feet or so of the Appalachian Basin subsurface have coal seams that have been mined, and there are shallow oil and gas reservoirs around 3,000-4,000 feet deep. As one goes deeper, one encounters organic-rich shales and some laterals into the Marcellus and, deeper, the Utica. The deepest rocks are the ones about which the least is known.

Layering the different types and sizes of CO_2 point sources over the different types of rocks is a key part of thinking about Pennsylvania's CCUS opportunities. CO_2 transport and storage infrastructure has to be coordinated not only at the ground level, but also in the subsurface, with multiple wells injecting CO_2 into various deep formations (below the Marcellus, in the second or third mile of depth). Challenges (which other natural resource development has faced as well) include private water supplies (which are not regulated or protected like public sources), the extraordinary number of legacy oil and gas wells in the state (many but not all of which have a paper trail), modern horizontal drilling (which is deeper, longer, and more complex in the subsurface), surface and subsurface rights often being separated, variable subsurface geology (even within the sedimentary basin), and the need for new pipeline infrastructure (with the associated struggles, opposition, and bad press). For the range of potential needs going forward —permanent CO_2 storage, hydrogen storage, and so forth — it will be important to figure out how to coordinate usage of subsurface real estate. There are already regulations to ensure coordination happens with coal, oil, and gas, and there will have to be enhanced coordination going forward.

Some shallow oil and gas reservoirs, in the right circumstances, could be repurposed for enhanced oil recovery with associated CO_2 storage, but that is not the main target. Stacked

reservoirs are more likely to be needed to afford enough storage. In the broader Midwest Regional Carbon Sequestration Partnership (MRCSP) region (covering Delaware, Indiana, Kentucky, Maryland, Michigan, New Jersey, New York, Ohio, Pennsylvania, and West Virginia), long-term storage opportunities could be $5-10 or less per ton, which is key to making the system work. There are hundreds or thousands of years' worth of CO_2 emissions that could be stored underground in the multi-state region. (For the East Coast, offshore Atlantic areas could also provide a huge storage option.) The storage estimates, though, are preliminary ones from years ago. There is a need for more exploration, characterization wells, test wells, coring, and so forth. Local characterization of storage opportunities is really needed, not just high-level national and regional assessments.

There will similarly be a need for test wells, remote sensing, and the like to learn more about safe CO_2 injection. Wastewater injection related to hydraulic fracturing has led to seismicity issues in some places, but wastewater injection occurs much closer to the surface. The depth for CO_2 injection and storage would be much further down. Still, induced seismicity has to be built into the modeling for site selection, and permitted injection pressures have to be enforced. One does not want to get too close to bedrock, and there is some faulting to avoid. Pennsylvania already has seismic monitoring stations it will be relying on.

CCUS / Hydrogen Hubs

Pennsylvania's path to decarbonization, especially in the industrial sector, may well look different than in other parts of the United States and the world. At the same time, Pennsylvania and the mid-Atlantic region as a whole have a huge opportunity to offer a vision to others of what decarbonization across sectors could look like by being a first mover in state-of-the-art decarbonization hubs. There is the potential to create an end-to-end decarbonization hub, linking CCUS, renewables, hydrogen, circular plastics, advanced energy management, nature-based solutions, direct air capture, and more. Somewhat more narrowly, CCUS / hydrogen hubs could involve several industrial manufacturing sectors that use hydrogen to some extent, have carbon capture retrofitted on, produce clean hydrogen (using carbon capture and zero-carbon electricity), and utilize DAC and other CO_2 removal (which goes into permanent geologic storage). All the different pieces can combine to produce a low-carbon region. The majority of technologies needed to create such a hub exist today at the necessary scale, and next-generation technologies can enter into the hub as they are developed.

Potential sites for CCUS / hydrogen hubs exist around the country (and are mapped in GPI's 2022 atlas). Ideal hub locations would have high concentrations of industrial emitters, high amounts of fossil fuel use for on-site energy production and manufacturing, concentrations of facilities that meet 45Q tax credit thresholds, near-term investment opportunities, current hydrogen (and ammonia) production and use, large geological saline and fossil formations for storage, existing multi-modal commodity distribution infrastructure to deliver products, and conventional fossil fuel infrastructure (e.g., gas pipelines) that could provide rights of way.

The western part of Pennsylvania (plus nearby Ohio and West Virginia) could be a good hub location. There is a concentration of industrial fuel use in the region, as well as an abundance of natural gas and associated infrastructure. Western Pennsylvania also has a substantial amount of CO_2 that is relatively easy to capture from a technical standpoint. (There are harder cases too that will take longer to become viable, but there is no shortage of relatively easy, near-term CO_2 abatement opportunities in the region.) Pennsylvania has 279 facilities reporting to the EPA Greenhouse Gas Reporting Program, with natural gas power plants both the most numerous and the highest source of CO_2 emissions on the list, though the industrial sector (e.g.,

steel, cement, pulp and paper, gas processing) is also important. Of the 279, 41 meet 45Q thresholds (more than 100,000 tons of CO_2 per year for industry, more than 500,000 for power), emitting a combined 57.4 million tons of CO_2, of which 41.6 million tons are potentially capturable. Of those facilities, 17 could be near-term retrofit candidates, with high-volume, high-concentration CO_2 in the flue gas. Connecting those 17 facilities to potential hubs in the region could hypothetically require 864 miles of pipe, moving 18.8 $MMtCO_2$/yr. By midcentury, serving all 41 facilities that meet 45Q thresholds could require 1,341 miles of pipe, moving 41.6 MMt/yr. (As a point of comparison, there are about 12,000 miles of existing fossil pipelines in the state.)

CCUS / hydrogen hubs (as well as CCUS on its own) will require lots of pipelines, which are incredibly challenging to get built these days. Pipelines of any sort are a big, controversial issue in Pennsylvania. Even where there is an existing right of way, it may or may not be viable from a permitting and contractual standpoint to put a CO_2 pipeline on it. Ideally, though, pipeline networks would be planned for the long term. Designing a pipeline for a point-to-point project will result in a smaller pipe than what would be needed for later, whereas regional pipelines that can aggregate CO_2 from multiple sites (i.e., trunk lines) can achieve economies of scale, reduce costs, and maximize carbon reduction. That said, someone needs to move first, and a network can then be built around anchor projects and early movers.

CCUS and clean hydrogen production were more peripheral to the conversation even five years ago, but now they are driving strategic decisions. Gov. Wolf's administration is very supportive of CCUS and clean hydrogen, with the most recent budget proposal including funding for continued planning and capacity building in the space. If CCUS can be utilized with the abundance of natural gas to create hydrogen, it creates an opportunity to decarbonize some really difficult sectors that are also abundant in the region, such as steel, cement, and heavy transport. The impact of a hub will be decidedly regional, both in terms of subsurface pore space and the linked industries. CCUS / hydrogen hubs could allow low-carbon continuation of regional industrial sectors and attract additional investment to the area.

Jobs

The movement toward low- and zero-carbon power, manufacturing, and products has resulted in a loss of work opportunities for some union members in Pennsylvania (though other factors have contributed too). CCUS deployment creates the potential for union members to continue using their skills and training during the transition to a low- and zero-carbon economy, thereby preserving and creating good-paying, middle-class jobs. Each CCUS retrofit of a facility can generate hundreds or thousands of jobs (both project jobs and operation jobs). As CCUS costs come down and supportive policies increase, the potential for more retrofits and the associated jobs will grow. There is also significant job creation potential related to the buildout of CO_2 transport infrastructure (i.e., pipelines). Pennsylvania could thus see near-term benefits in job creation and retention.

Unions will be advocating for the use of prevailing wage and labor agreements on publicly funded CCUS projects. Industry-wide, though, there is a big shortage of available construction workers (e.g., welders, mechanics), and all levels of government are paying attention to that. It is important to increase the number of people entering into construction trades, apprenticeship programs, pre-apprenticeship programs, and the like.

Collaborative Work Underway

Pennsylvania's economy has to be prepared for the transition to a decarbonized future. That requires lots of strategic collaboration, resources, and leadership.

Within the Commonwealth, Pennsylvania formed a CCUS Inter-Agency Work Group in 2019 as a vehicle for collaborative work among the Department of Conservation and Natural Resources (DCNR), the Department of Community & Economic Development (DCED), and the Department of Environmental Protection (DEP). The Group's work is framed around four pillars: technical, regulatory, economic, and policy drivers. Agencies can provide input and consultation on each other's action plans and projects. An inter-agency memorandum of understanding is in place among the agencies, to galvanize work beyond Governor Wolf's administration.

Multi-state collaboration is also important. For example, the Inter-Agency Work Group signed up Pennsylvania to join seven other states (Kansas, Louisiana, Maryland, Montana, North Dakota, Oklahoma, and Wyoming) in developing a regional CO_2 transport infrastructure action plan, coordinated by GPI. The plan, released in October 2021, includes recommendations for state and federal actions (described in the next section), and the participating states will be working this year on a plan appendix that will describe existing laws and policies in states, as well as on a pipeline safety report to explain what other projects in operation have experienced. Pennsylvania could be part of multiple multi-state initiatives and efforts on CCUS. Collaborations on the western part of the state could include Ohio and West Virginia, but collaborations in the eastern half should not be discounted, given the momentum out of New York (driven by diverse partners and stakeholders).

Government needs to partner with business and industry as well. CCUS is a pre-competitive environment in many ways, and companies that might otherwise be in competition can come together to solve problems. There is a unique opportunity to collaborate — to grow the size of the pie so the companies involved can eventually fight over bigger slices. Industry and government can also collaborate one-on-one; developers can try to have conversations with agencies well in advance of permitting to build trust and discuss the work that needs to be done.

Policy Needs to Operationalize Carbon Management in Pennsylvania

Federal Support

To make CCUS deployment a reality in Pennsylvania, there is a need for strong federal policies, as well as funding (e.g., to support CCUS / hydrogen hubs). In general, there is a need for a full policy portfolio to enable commercial levels of deployment of carbon management technologies. Policies are needed related to: investment certainty, project finance, and feasibility (e.g., to close cost gaps); technology deployment and cost reductions; transport, storage, and market development (including CO_2 utilization in products); and jobs, economic development, and affected communities. The regional CO_2 transport infrastructure action plan coordinated by GPI recommended a range of supportive federal policies, including enhancing the 45Q tax credit, robustly funding CCUS pilot projects and demonstrations, facilitating Class VI well primacy for interested states, addressing transport and storage infrastructure on federal lands (including safety concerns), and establishing regulatory frameworks on issues such as pore space ownership and access.

Pennsylvania's Department of Environmental Protection is currently developing an Environmental Justice Policy. With the Biden Administration's Justice 40 initiative and the flood of infrastructure funding, there is an opportunity for the Commonwealth, when applying for grants, to explain how its CCUS work will benefit environmental justice communities.

State Support

A supportive state policy and regulatory framework is crucial, otherwise it will be impossible to put CO_2 sequestration wells in the ground and the other necessary infrastructure in place. Statutory measures and regulations are needed to ensure fast and safe scale-up of carbon management technologies in the Commonwealth.

The regional CO_2 transport infrastructure action plan coordinated by GPI included many fairly granular recommendations for states. Some involved regulatory policy and planning, including not just primacy, but also CO_2 ownership, CO_2 liability, when legal responsibility shifts from one party to another, and siting of infrastructure, facilities, and hubs. Other recommendations involved financial incentives and market development, including grant programs and state procurement standards. Bills are starting to be introduced in Pennsylvania around primacy issues, land ownership, pore ownership, and more. Pennsylvania should not hesitate to look to other states for guidance as it ponders processes, primacy, and other issues; states love to share what worked and what did not in their programs.

These are some of the key issues Pennsylvania needs to address.

Primacy

Currently, North Dakota and Wyoming are the only states that have primacy on Class VI wells. The EPA implements the Class VI program everywhere else. It takes the EPA a long time to get Class VI wells permitted, but state agencies with primacy have started to see the beginnings of successfully making the process easier and faster for developers. In Wyoming, the state can hire for whatever capacity the state lacks with respect to its primary authority for Class VI wells, and it can pass the costs on to applicants. Pennsylvania could take a similar approach if it wanted to, defraying costs on to developers.

Pore Space Ownership

Property is like a bundle of sticks, and the individual sticks can have different owners. Where there are different owners for the mineral estate and the surface estate, a big question is which one the pore space goes with. Pennsylvania relies on case law on the subject, and there is only one Pennsylvania Supreme Court case (from 1983), which people interpret differently. The question in that case was about who owns coalbed methane. The Court said the owner of the right to mine the coal owns the coalbed methane because it is inside the coal; in addition, the coalbed methane was not a marketable commodity at the time the grant was made, so the surface owner would not have wanted to retain the right to it. The Court, however, also said the surface owner owned everything surrounding the coal. It is unclear how the holding of this case would apply to pore space for CO_2 sequestration. In 1990, there was a decision by an intermediate appeals court (not the Supreme Court) that said an oil and gas lessee could not store natural gas in the well because the lease did not mention storage at all. In 2015, there was another coalbed methane case, in which the court said the owner of the coal seam owns the coalbed methane. None of these cases are particularly helpful in figuring out who owns the pore space in Pennsylvania. (Likewise, on federal lands, there are two U.S. Supreme Court decisions on pore space that kind of conflict with each other and have been interpreted differently by different people.)

If Pennsylvania wants to move forward, the best way is via a state statutory provision clarifying who owns the pore space. As an example, West Virginia recently addressed this problem. In March, the West Virginia legislature passed a bill (HB 4491) that says the surface owner owns the pore space. (The bill also addresses some liability issues.) Since it could not apply retroactively, the bill creates a rebuttable presumption that prior conveyances did not sever the surface estate from the pore space, and the presumption is very hard to rebut (i.e., clear and convincing evidence of intent). The federal government may do the same, as there is a bill in Congress (which may or may not move) to clarify that the surface owner owns the pore space. If Pennsylvania chooses to adopt a statutory provision, though, it has to be crafted well. In another case, a Pennsylvania statute on hydraulic fracturing that allowed eminent domain over pore space and storage space for natural and manufactured gas was ruled unconstitutional because (1) the law allowed private entities, not public utilities, to exercise eminent domain, and (2) the projected public benefit was speculative and incidental. With respect to CO_2 sequestration and pore space, the first problem can be solved by letting common carriers do the sequestration. Solving the second problem is a little murkier.

Pooling Pore Space

It is difficult to assemble adequate pore space for CO_2 sequestration, just as it is to assemble acreage for drilling. For CCUS to work, developers will have to sign up a lot of owners, will have to get a large enough percentage of them to agree, and will have to educate them about CO_2 sequestration. Pennsylvania knows how to incentivize assembly for oil and gas, but it has not yet contemplated it for pore space.

In terms of signing up owners, education about CCUS will be key. Identifying all the property owners — which is made more challenging with heirs' property that is passed down and divided through generations — can also be a hurdle. In addition, folks in Pennsylvania are used to shale, where they get royalties, signing bonuses, and the like. If sequestering CO_2 has financial value, developers will have to decide that the value is enough to share, and landowners will have to weigh their options. Pore space could be thought of like landfill space in some states, in terms of selling space to fill and incentives being offered to enable that to occur. Some

companies that have attempted pore space agreements used natural gas storage as a benchmark, given the lack of other precedent regarding the value of pore space. Given the lack of precedent, those agreements become the precedent.

Some states are enacting forced pooling. Developers just have to try to come to agreement with landowners, but if they cannot, the decision goes to a state agency, and the presumption is to authorize the project, with fair compensation to landowners. That is a strong incentive for CCUS developers to look at those states. Other states have some sort of pooling threshold — a percentage of owners that developers have to get on board in order for the project to proceed. Pooling thresholds required in oil and gas (e.g., 75%) may or may not be replicated for CO_2 sequestration. Some feel those thresholds are too high, while others do not. No matter what the pooling threshold is, having one can effectively disarm all those up to the point of the threshold; landowners who want to do something can be stopped by those who do not. On the other hand, disarming landowners of economic leverage would cause heartburn and political pushback. It is worth recalling, though, that even with relatively high pooling thresholds and heirs' property issues, shale leases have been prolific in Pennsylvania. As with any new system, there is a learning curve, but obtaining leasing rights can become fairly frictionless.

To get CCUS deployment moving, some states are simplifying the process by utilizing lands where they are the landowner. Wyoming, for instance, decided it wanted to be a first mover on CCUS and so will be drilling a well on state property and offering access to its Class VI well like a landfill — sequestration as a service. If the idea works, and if developers and the public respond positively, other actors will come into the space behind the state more quickly.

Liability

Resolving the question of long-term liability for sequestered CO_2 is important to accelerating CCUS deployment. Ultimately, if the government is mandating carbon storage for the public good, the state is going to have to address long-term liability. However, developers should not be let off the hook for doing a bad job. There are insurance and enforcement mechanisms to address such situations. For nuclear, for instance, all operators pay in to provide additional financial assurance. Something similar could be done for CCUS, on a state or federal basis.

For developers, the liability issue is also related to the question of whether to buy or lease pore space for CO_2 sequestration. In oil and gas, companies generally lease the right to go into the pore space for a temporary time to extract the resources, and then they leave. In contrast, the expectation for CO_2 sequestration is that the CO_2 is staying in place, so some responsible entity is never leaving (whether the developer, a government, or some other entity to do the necessary monitoring). Until it is decided who is never leaving, it will be hard to make decisions about buying pore space access versus leasing it.

CO_2 Pipeline Regulation

In Pennsylvania, there is little (or no) comprehensive regulation of CO_2 pipelines. They are regulated like any other construction activity. There are some carbon sequestration provisions in Act 129 that have not been tested or broadened, but otherwise there are just the usual, limited permits and approvals from DEP, DCNR, the Department of Transportation, and so forth. The Public Utility Commission does not currently regulate CO_2 (or hydrogen) pipelines, but it could under existing statutory authority; CO_2 transport would qualify as a public utility.

Human Capacity

With shale gas development, building human capacity and knowledge was a necessary challenge. Once it ramped up, Pennsylvania regulated shale rather well, but there was tough sledding in the early years. Agencies will similarly need to start building the human capital for CCUS development before it happens at a large scale. Recent federal funding includes set-asides to hire more people, including outside consultants to provide technical expertise and to do some of the grunt work of reviewing and analyzing the stacks of submitted data. In Pennsylvania, where the subsurface geology is not simple, agencies will lean on the institutional knowledge of state geologists, engineers, and others within the state agency structure. If Pennsylvania wants to stand up an effective CCUS program, it will need to invest in its personnel.

Public Education & Engagement

The state may want to help the public understand the CCUS pathway in the greater decarbonization context. It is important to explain the science and the need for CCUS in ways people can grasp. There is a need to meet people where they are, with both technical and story-telling elements

At the same time, industry has a pivotal role here as well. Stakeholder engagement is fundamental. In the past, pipeline, shale, and other projects have become train wrecks without local community engagement. Public acceptance can shift with good community engagement.