

CARBON CAPTURE AND STORAGE

Balancing Electricity Generation and Greenhouse Gas Emissions

Carbon capture and storage technology is becoming more important across the U.S. as policymakers deal with a balancing act—how to mitigate climate change while keeping the cost of electricity down. That is especially challenging since 42 percent of all carbon dioxide—or CO₂—emissions in the U.S. come from electricity generation,¹ and coal-fired power plants constitute the largest source of greenhouse gas emissions from the electricity sector, producing 27 percent of all U.S. emissions.² These coal-fired plants represent a significant target for policymakers because they are stationary, unlike transportation sources, and thus simpler to monitor and control. Coal-derived electricity makes up nearly 50 percent of the electricity generation market and cannot simply be abandoned. Carbon capture and storage technology can help ensure that relatively low-cost electricity will continue to be produced from America's abundant supply of coal while capturing and sequestering approximately 90 percent of emissions.

Numerous technical, regulatory and legal obstacles, however, must first be overcome. This brief provides an overview of carbon capture and storage technology, the challenges it faces, and what state leaders can do to advance carbon capture and storage into widespread application.

How Carbon Capture and Storage Works

The idea behind carbon capture and storage is this: CO₂ emissions from power plants are captured after—or in some cases before—coal is burned for electricity. The emissions are compressed, then transported in pipelines and stored deep underground—most likely in saline reservoirs—for an indefinite period of time. The processes are in fact still evolving. Different capture technologies provide unique challenges, and storage and regulatory uncertainties remain.

Capture

Two different capture technologies exist today, with a third—oxy-fuel—now in the demonstration phase.³ Post-combustion capture is the primary method used for pulverized coal plants, which represent the majority of plants in operation. This type of capture involves using a chemical solvent to separate CO₂ from the flue gas (the gases that are produced during the combustion of coal).⁴



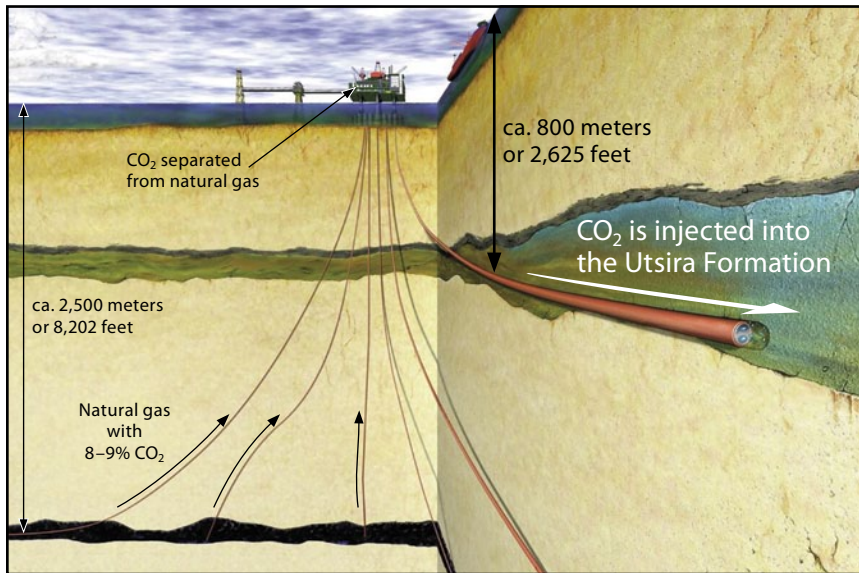
Pre-combustion capture, meanwhile, will likely be applied to new Integrated Gasification Combined Cycle plants. The process involves gasifying coal to create a synthesis gas rather than burning it directly. Though pre-combustion capture is a more expensive and complicated method, it allows more CO₂ to be captured because higher concentrations of CO₂ exist in the gas stream, thus making removal more efficient.⁵

Because energy is required to capture and compress CO₂, power plants need an additional 10 to 40 percent capacity, depending on the type of generating technology used at the plant, to achieve the same output of a generating plant without carbon capture and storage.⁶ Expanding output to remain at current levels will therefore increase the cost of electricity. A study by the Electric Power Research Institute—a non-profit firm that conducts research on electricity generation and delivery as well as related policy analyses—found that implementing carbon capture and storage would raise the cost of electricity between 40 and 60 percent depending on the plant and capture technology used.⁷

Transport

In addition to capture technology, more pipeline infrastructure is needed to transport the CO₂ to storage sites. Approximately 3,600 miles of CO₂ pipelines in the U.S. bring the gas to oil fields for enhanced oil recovery,⁸ so

Norway's Sleipner Project



Source for Illustration: Statoil

Source for Illustration Notations: The Ocean Acidification Network, <http://ioc3.unesco.org/oanet/FAQocs.html>

Source for Directional Arrows: Bellona, "Security of CO₂ Storage in Norway," Semere Solomon, <http://www.bellona.org/factsheets/1191928198.67>, and Intergovernmental Panel on Climate Change (IPCC), <http://www.ipcc.ch/>

there is already significant expertise in the design and construction of pipeline infrastructure. Many more thousands of miles will need to be added to sufficiently address CO₂ transportation from the nearly 500 point sources that exist for coal-fired power generation.⁹ The demand for additional CO₂ pipeline capacity will likely unfold relatively slowly and in a geographically dispersed manner. Growth in the pipeline system is estimated to grow between 100 and 1,000 miles per year. By comparison, from 1950 to 2000, the U.S. natural gas pipeline distribution system grew at rates that far exceed these projections.¹⁰

Storage

The majority of storage is expected to be in saline reservoirs, which will trap the CO₂ in porous rock formations deep underground. (The CO₂—which becomes a liquid when pressurized at depths—will migrate through these spaces horizontally and eventually will either form solid carbonates with minerals in the saline or dissolve in the brine, making storage permanent.¹¹) Other potential storage sites

include declining or depleted oil and gas fields, which are useful for enhanced oil recovery and will offset some of the costs associated with carbon capture and storage, unmineable coal seams and basalt formations—solidified lava fields typically found in the upper Northwest.

Once the CO₂ is pumped deep underground (around 800 meters), a cap rock—a nonporous rock layer—above the injection site prevents the CO₂ from migrating to the surface and seeping into groundwater or dispersing into the air. Experience with CO₂ injected for enhanced oil recovery shows that leakage is highly unlikely. Norway's Sleipner Project, for example, has been injecting approximately 1 million tons of CO₂—considered commercial scale—into a North Sea saline reservoir over the past 13 years with no leaks and none projected through computer modeling.¹² The other primary concern associated with storage is the effect of increased pressure from the gas on the surrounding geology.¹³

To help set guidelines and facilitate carbon capture and storage deployment, the

Department of Energy's National Energy Technology Laboratory's goal is creation of a system that captures 90 percent of emissions, stores those emissions with 99 percent permanence (i.e. less than one percent of all CO₂ captured is permitted to escape), and results in only a 10 percent increase in the cost of electricity by 2012.¹⁴ Competition among technologies is expected to result in selection of the most efficient method.¹⁵

Impediments to Deployment

Cost is perhaps the most prominent hurdle for carbon capture and storage. A study by the National Energy Technology Laboratory found that the cost of electricity could increase by 70 to 100 percent.¹⁶ Older plants in particular are subject to higher overall costs, as conducting retrofits will require extensive upgrades. For newer plants, especially Integrated Gasification Combined Cycle plants, much of the technology will already come pre-installed and adding carbon capture systems will be cheaper. However, the cost of carbon avoided is expected to be around \$150 per ton,¹⁷ which leaves little incentive for electricity producers to deploy carbon capture and storage technologies until mandated to do so.

The existing technology for carbon capture and storage has not been applied on a commercial scale—that is, to plants larger than 500 megawatts—raising questions about full-scale implementation. In addition to those economic and technical hurdles, regulatory obstacles also remain. For example, legal issues surrounding liability for the storage site—who holds it and for how much and how long—need to be addressed. Because the carbon is supposed to remain underground for thousands of years and companies that capture and store carbon are unlikely to be around for the geologic time scales expected to contain the carbon, a governmental body will likely be needed.¹⁸

Additional questions arise over how, and to what extent, monitoring and verification of stored CO₂ will need to be

done,¹⁹ to what extent states and the federal government should be involved in setting regulations, and whether the federal government should have primacy to ensure compatible design.

States' Role

As is often the case, states are taking the initiative in drafting legislation that supports and defines activities related to carbon capture and storage. In 2008, Wyoming enacted pore-space legislation that grants surface owners rights to subsurface space and legislation requiring the state Department of Environmental Quality to develop regulations for long-term CO₂ storage,²⁰ both of which will help clarify and guide carbon capture and storage development for power generators.

The Carbon Capture and Storage Regulatory Project—a partnership between Carnegie Mellon University, the University of Minnesota, Vermont Law School and the law firm of Van Ness Feldman to draft policy recommendations and regulatory approaches for carbon capture and stor-

age—identified 21 states as of July 2009 that have adopted legislation that covers permitting and/or property rights (defining who owns the subsurface space and what permits are needed to move forward), or that establishes incentives such as tax breaks.²¹

States have taken a varied approach to aspects of carbon capture and storage legislation, such as setting performance standards for performance measurement (Washington requires 99 percent permanence for 1,000 years; Kansas' legislation does not quantify length of time or containment requirements²²) and specifying the oversight agency. Risk assessments—such as health and environmental impact studies—are also essential, though costs of conducting the assessments need to be weighed against potential benefits.²³ Those potential risks will require states to carefully consider expectations for geological sequestration, how it will function, and what rules neighboring states have since most geological repositories cross state boundaries.

The Federal Role in Carbon Capture and Storage

The American Recovery and Reinvestment Act of 2009 provided \$3.4 billion for carbon capture and storage research.²⁴ In addition, the federal government made available \$8 billion in loan guarantees and a little more than \$3 billion in tax credits.²⁵ The government hopes that these measures will help advance research to improve system efficiency and create cheaper capture methods, thereby reducing costs and spurring deployment. But that is unlikely to happen until there is a price for carbon, because utilities will be reluctant to undertake any excess cost, regardless of how cheap it is,²⁶ with one exception, which is discussed below. Cap and trade legislation, which the House approved in June and the Senate will consider this fall, addresses that issue.

Beginning in 2003, the Department of Energy created seven regional partnerships with industry to explore carbon capture and storage. Those partnerships are beginning to use injection wells to determine storage permanence at a commercial scale. Because different circumstances including geology prevail in each region, the partnerships were created to address these issues on a regional basis. In total, the partnerships encompass 97 percent of coal-fired CO₂ emissions and all of the different geologies available for sequestration. Large scale injections of CO₂, the third phase of the project, will begin in spring 2010. Phases one and two estimated the potential for CO₂ storage and validated that potential through small-scale tests.²⁷

To address legal uncertainties, the Environmental Protection Agency is proposing to regulate CO₂ under its Underground Injection Control program. This falls under the Safe Drinking Water Act, which regulates well injections and would require a stringent Class VI well for geological sequestration.²⁸ The Underground Injection Control program will likely set baseline standards for injection and allow states

AEP Mountaineer Plant in West Virginia



Carbon capture facility at American Electric Power's Mountaineer Plant in New Haven, West Virginia. The facility arose from a partnership between American Electric Power (AEP) and Alstom, an international company providing technologies for power generation and rail transport. The facility's post-combustion process is designed to capture at least 100,000 metric tons of CO₂ annually.

Source for Photo and Caption Information: AEP, <http://www.aep.com>

to adopt more stringent rules if desired. There is a concern, however, that the program is not extensive enough for application here because its focus is on protecting groundwater and does not specifically address climate. It may be that an agency specifically tasked with regulating CO₂ might be better suited to the task.²⁹

The Role of Partial Capture

A recent Massachusetts Institute of Technology study indicated that partial capture—capturing 20 percent or less of emissions—might be the best initial option for pulverized coal plants, which would run a post-combustion system. The benefit of partial capture is that it can allow power generators to install capture systems at substantially lower capital costs than the cost of installing full capture systems. In addition, it allows time to determine how well capture and storage systems work and what changes, if any, are needed. The MIT study maintains that incremental steps will help spur deployment of carbon capture and storage. (In anticipation of a cap and trade system, utilities, reluctant to experiment with full-scale carbon capture and storage, may take advantage of partial capture to gain advantage over competitors.) Systems that run on partial capture could then be upgraded to full capture.³⁰

Policy Checklist

Policymakers should consider the following checklist for advancing carbon capture and storage:

1. Define pore-space ownership (i.e. who owns the subsurface area where CO₂ will be stored);
2. Establish liability limits;
3. Provide incentives such as cost-recovery and property and income tax breaks;
4. Facilitate pipeline development and siting;
5. Determine appropriate oversight agency; and
6. Encourage partial capture.

Conclusion

Carbon capture and storage presents a real opportunity to reduce carbon dioxide emissions and maintain continued use of coal at an affordable price. However, carbon capture and storage technology will not be deployed until clear requirements to do so are enacted—either in the form of a price on carbon or a regulatory performance mandate for power plants. Federal research and development funding will help drive down the cost by improving efficiency and creating new methods, especially for capture, but state officials can help further drive carbon capture and storage deployment by enacting legislation that defines requirements for transport and storage of CO₂ and that establishes liability limits, defines pore-space ownership, and sets up monitoring and verification protocols.

Resources

The following sites contain useful information for state officials interested in acquiring greater knowledge about carbon capture and storage regulations and research:

CCSReg:

<http://www.ccsreg.org/>

World Resources Institute:

<http://www.wri.org/publication/ccs-guidelines>

National Energy
Technology Laboratory:

http://www.netl.doe.gov/technologies/carbon_seq/index.html

Department of Energy
Regional Partnerships:

<http://fossil.energy.gov/sequestration/partnerships/index.html>

CSG Carbon Capture and
Storage Resolution:

<http://www.csg.org/knowledgecenter/docs/ResolutiononCarbonCaptureStoragePolicy.pdf>

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² Pew Center on Global Climate Change (Pew), "Carbon Capture and Storage," Climate TechBook, May 2009, p. 1.

³ IPCC Special Report, "Carbon Dioxide Capture and Storage, Summary for Policymakers, A Special Report of Working Group III of the Intergovernmental Panel on Climate Change," September 2005, p. 5.

⁴ Ibid, 5.

⁵ Pew, 2; IPCC, 5.

⁶ IPCC, 4.

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¹³ Pollack, Melissa and Wilson, Elizabeth, "Regulating Geologic Sequestration in the United States: Early Rules Take Divergent Approaches," *Environmental Science & Technology*, Vol. 43, No. 9, 2009, 3039.

¹⁴ NETL, "Carbon Sequestration Program Goals," Accessed from: http://www.netl.doe.gov/technologies/carbon_seq/overview/program_goals.html on September 4, 2009.

¹⁵ CEED (Center for Energy and Economic Development, now ACCCE, the American Coalition for a Clean Coal Electricity), Carbon Capture.

¹⁶ NETL, Carbon Sequestration FAQ Portal, "What are the Costs and Benefits of Carbon Capture and Sequestration?" Accessed from: http://www.netl.doe.gov/technologies/carbon_seq/FAQs/benefits.html on September 4, 2009.

¹⁷ Department of Energy (DOE), "Carbon Capture Research," accessed from: <http://www.fe.doe.gov/sequestration/capture/index.html> on September 4, 2009.

¹⁸ Pollack, 3039.

¹⁹ Pollack, 3039.

²⁰ CSG *Suggested State Legislation (SSL)*, 2010 Cycle, Docket Book B, accessed from: <http://ssl.csg.org/dockets/2010cycle/30B/30Bdocmins/docket30Bfinal.pdf> on September 4, 2009, p. 24.

²¹ CCS Reg, List of U.S. State Bills on CCS (last updated July 14, 2009), accessed from: http://www.ccsreg.org/working_papers.html on September 4, 2009.

²² Pollack, 3036, 3039.

²³ Pollack, 3039.

²⁴ CRS, 2.

²⁵ CRS, 2.

²⁶ CRS, summary.

²⁷ DOE, "Carbon Sequestration Regional Partnerships," accessed from: <http://www.fe.doe.gov/sequestration/partnerships/index.html> on September 4, 2009.

²⁸ Pollack, 3035.

²⁹ Pollack, 3040.

³⁰ Hildebrand, Ashleigh, "Strategies for Demonstration and Early Deployment of Carbon Capture and Storage: A Technical and Economic Assessment of Capture Percentage," June 2009, p. 111, 112.

Doug Myers is senior energy & environment policy analyst at The Council of State Governments.

