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Carbon Capture and Sequestration: How Can It Succeed Commercially?

Innovations Case Discussion:
Powerspan Corp.

In a market economy, people innovate because they think they can develop a comparative advantage selling a new product or service. This principle does not apply to environmental control technology, as its purpose is to limit a negative externality. Unless a regulation directly or indirectly places a price on that externality, there is very limited incentive to innovate.

Recent studies have shown that major innovation occurred in the case of both sulfur emissions control on power plants[1] and on motor vehicles[2] only after emission control regulations were passed, or it had become clear that they were about to be passed.

We have known for more than half a century that rising atmospheric concentrations of carbon dioxide (CO_2) and other greenhouse gasses are trapping heat and changing the climate. Yet despite over a decade of talk, the US government still has not instituted emissions controls for CO_2. Several US states have established limits on the amounts of CO_2 that new power plants can emit. For example, California, Washington, and Maine have all set limits on emissions from new plants to 1, 100 pounds per megawatt-hour. This level is high enough to allow new natural gas plants, but low enough to prevent the building of new conventional coal-fired plants.

Carbon dioxide is not like more conventional air pollution, such as SO_2, NO_X or fine particles. Those pollutants only remain in the atmosphere for a few hours or days. In contrast, much of the CO_2 we emit remains in the atmosphere for over 100 years. Indeed, we are all still breathing molecules of CO_2 released to the atmosphere by Newcomen's and Watt's steam engines, Frick's coke ovens, and Carnegie's steel mills. For this reason, if we want to stabilize the climate system, we are going to have to do far more than stabilize the growing emissions of CO_2. Stabilizing the atmospheric concentration will require something like an 80% reduction in global emissions. That will require a profound transformation in the way we produce

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and use electricity, since the electric sector is the single largest source of CO_2.

Furthermore, coal is not likely to disappear quickly. Many people know little about where our electricity comes from; when they first hear these facts, they typically say "so, make it all with renewables." That simple and appealing prescription faces two problems. First, electricity generation and transmission is a capital-intensive business, involving physical plants whose useful economic lives span many decades. Today most of our electricity comes from coal (~50 percent), natural gas and a little bit of oil (~20 percent), nuclear (~20 percent), and large hydroelectric (~7 percent). Today, wind provides a mere 0.77 percent of total generation, geothermal 0.36 percent, and solar 0.01 percent. It will take decades to get the carbon out of such a capital-intensive industry. Second, renewables, such as wind and solar, are variable (e.g., no sun at night) and intermittent: along with the rapid fluctuations in wind, there are also "droughts." For example, in January 2009, for a period of 10 days, there was no wind at all across the entire Bonneville Power system. Even when distant wind farms are connected together, the remaining variability must be filled in with the use of gas turbines or quick-acting hydro power.

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All this means that, for decades to come, the U.S. will still need to use coal as part of a portfolio that includes improvements in end-use efficiency, along with a mix of low-emission power generation technologies. This in turn means that Powerspan's strategy of developing a CO_2 clean-up system that could be added to the back end of large and relatively new coal plants makes great sense—*if* serious controls are instituted for emissions of CO_2. But that is a big if.

If a profit-maximizing firm is to adopt CCS technology for capturing and sequestering CO_2 in deep geological formations, the effective price on emitted CO_2 will have to be at or above \$50/tonne.[3] It is unclear whether or how soon the U.S. Congress will manage to pass legislation to control CO_2 emissions, but when it does, it will likely work hard to hold the effective price of CO_2 below \$20 to \$30/tonne. That means that to be viable, the market for all types of CCS technology (Figure 1) will depend heavily on subsidies for at least the next several decades. New CCS power plants will cost upwards of a couple of billion dollars. Retrofit technology for existing plants, like Powerspan is developing, will obviously cost less, but we are still talking many hundreds of millions of dollars.

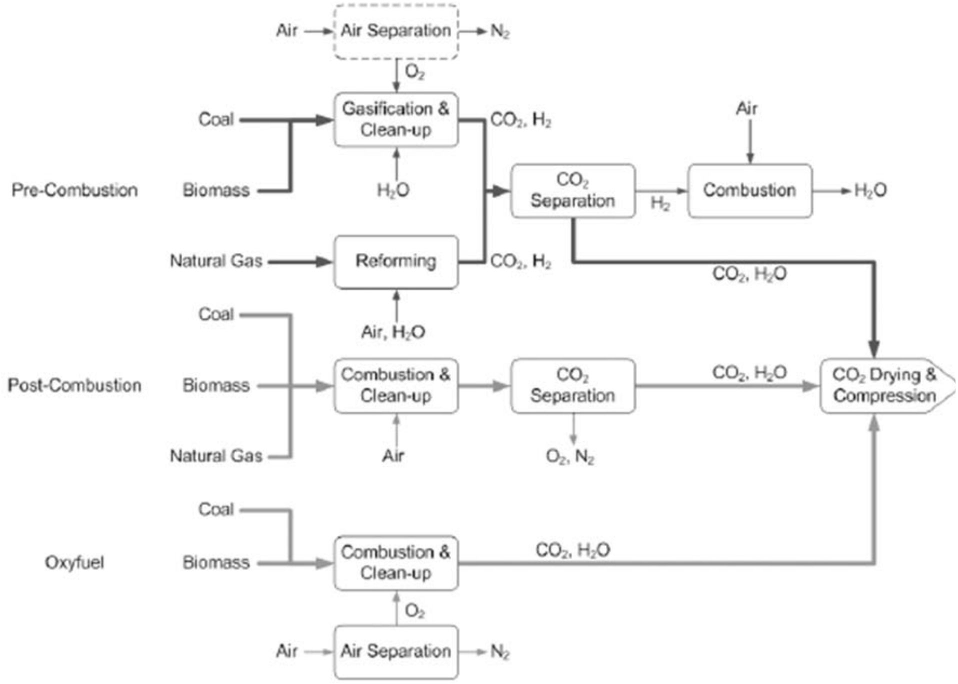

Figure 1. Three Types of Technology for Capturing and Sequestering CO_2 from a Power Plant.

Source: Figure adapted by Sean McCoy, from *IPCC Special Report on Carbon Dioxide Capture and Storage*, 2005. Prepared by Working Group III of the Intergovernmental Panel on Climate Change, eds. B. Metz, O. Davidson, H.C. de Coninck, M. Loos, and L.A. Meyer. Cambridge, U.K., and New York: Cambridge University Press.

Three basic types of technology can be used to capture and sequester CO_2 from a power plant. Post-combustion scrubbing, shown in the middle of the figure, involves removing CO_2 from a rather dilute stream of flue gas using a material to absorb the gas, such as ammonia in the case of the Powerspan system or various types of amines. This technology has an advantage: it can be used with existing plants, assuming physical space is available to build the additional clean-up train. In the second type, pre-combustion separation (top of figure), the coal is first gasified, yielding a more concentrated stream of CO_2. The third alternative (bottom of figure) involves combustion in oxygen, which avoids the large volume of nitrogen present in post-combustion capture thus yielding a concentrated stream of CO_2.

We are accustomed to thinking about learning curves as starting high and decreasing monotonically as more and more units are built. In order to develop insights about how learning curves might evolve for CCS, Edward Rubin and his colleagues looked at how they are developed for SO_2, NO_x and fine particle control for large coal-fired power plants.[4] They found that costs rise over the course of the first several plants while designers deal with unanticipated problems, and only start to decline after experience and refinements have accumulated from several early plants. This is another reason why it is essential to get some commercial-scale CCS plants built sooner rather than later.

After years of talking about CCS, the U.S. is finally showing signs of getting serious. Several bills in Congress would provide resources to get the first several commercial-scale plants built. With luck, companies like Powerspan will be able to hang on long enough to benefit from these subsidies. But subsidies may not last forever. If they start to phase out, we may see the emergence of a different kind of "valley of death": the gap between the moment subsidies start to tail off, and the time when effective CO_2 prices rise high enough to make CCS commercially attractive. On the other hand, once they are established, subsidies have a tendency to persist.[5]

Moreover, technology and cost may not be the largest obstacle. While CCS faces significant technical and economic challenges, in the U.S. the largest challenges may involve the regulations that govern deep geological sequestration of the CO_2 once it has been captured. Today, the U.S. injects large volumes of waste fluid underground. For example, the state of Florida injects roughly three billion tonnes of treated wastewater every year. All such injection is done under licenses granted by the U.S. Underground Injection Control (UIC) Program, which is operated by the EPA (in many cases with delegation to states) under statutory authority provided by the Safe Drinking Water Act. Five different well types are regulated under the UIC program. EPA is working now to develop a sixth well type for sequestering CO_2.

The problem is that the EPA's authority under the Safe Drinking Water Act does not allow it to address the two biggest obstacles to the wide commercial deployment of CCS: legal access to deep pore space, and long-term liability and stewardship for closed-out injection sites.

In much of the rest of the world, the state or "crown" owns the deep subsurface. In the U.S., the situation is much more complex and varies from state to state. Under the present UIC program, no one gets permission from surface property owners to inject waste fluids. However, given the enormous volumes that will be injected by commercial CCS operations, and the fact that the injectors will be big companies with deep pockets, it is a safe bet that as soon as large-scale injection of CO_2 begins, litigators claiming trespass will start appearing. If such suits were decided differently in different states, as they almost certainly would be, access to pore space could become impossibly complex and expensive.

Major insurance companies report that they are perfectly able to insure the operational phase of a CCS injection project. However, once a site is closed out, they are not willing to continue to provide liability coverage indefinitely.

These, and several other problems, are not likely to be addressed adequately without new federal legislation. To this end, the CCS Regulatory Project,[6] a joint effort by engineers and lawyers, has developed a set of six recommendations for new legislation:

- Declare that it is in the public interest to sequester carbon dioxide (CO_2) in geologic formations to mitigate the detrimental effects of climate change.
- Address the issue of access to and use of geologic pore space.
- Amend the Safe Drinking Water Act to direct UIC regulators to promulgate rules for deep geological sequestration (GS) that meet three goals:
  - Address all environmental, health and safety issues associated with GS of CO_2.
  - Be based principally on adaptive, performance-based standards, as opposed to design standards.
  - Include mechanisms to balance and resolve conflicts between multiple environmental objectives.
- Direct UIC regulators to coordinate with regulators in charge of greenhouse gas inventory accounting for the U.S.
- Obligate GS project operators to contribute on the basis of their operating performance to a revolving fund to cover long-term stewardship.
- Create an independent public entity (the Federal Geologic Sequestration Board) to approve and accept responsibility for appropriately closed GS sites.

Each of these recommendations is elaborated in a series of policy briefs developed by the CCSReg Project.[7]

Without elaborating further on such details, the key point is that developing a large US market for CCS will depend on not one but two new legislative initiatives:

1. New rules will have to limit CO_2 emissions with sufficient stringency to result in an effective price of $\geq$\$50/tonne.
2. A new regulatory system must ensure that CCS is safe, comprehensive, environmentally sound, affordable, internationally compatible and socially equitable.

In short, while technical innovation will be a critical part of the successful large-scale deployment of CCS, innovation in public policy and law will likely be as or more important.

Endnotes

1. M.R. Taylor, E.S. Rubin & D.A. Hounshell, 2003. "Effect of Government Actions on Technological Innovation for SO_2 Control," *Environmental Science and Technology,* 37, pp. 4527–4534.
2. Jaegul Lee, Francisco Veloso, David A. Hounshell, & Edward S. Rubin, 2004. "Innovation in Automotive Emission Control Technologies: Government Actions and Inventive Activities." Paper presented at Academy of Management Conference, New Orleans.
3. See the policy brief "Cap and Trade is not Enough," Department of Engineering and Public Policy, Carnegie Mellon University, 2009. www.epp.cmu.edu/Publications/ClimatePolicy.pdf.
4. Edward S. Rubin, Sonia Yeh, Matt Antes, Michael Berkenpas, & John Davison, 2007. "Use of experience curves to estimate the future cost of power plants with CO_2 capture," *International Journal of Greenhouse Gas Control*, 1, pp. 188–197.
5. Environmental Law Institute, 2009. *Estimating US Subsidies to Energy Sources: 2002-2008*. www.elistore.org/Data/products/d19_07.pdf
6. Details on the CCSReg Project are at www.CCSReg.org.
7. Policy briefs from the CCSReg Project are at www.ccsreg.org/policy_briefs.html.