CLEAN WATER FUND

Clean Water Fund White Paper
Carbon Capture and Storage- Policy Considerations

This White Paper outlines some potential implications to water resources and other considerations from potential large-scale commercial carbon capture and geologic storage. A great deal of private and government effort and investment is going in to Carbon Capture and Storage (CCS), particularly at coal burning power plants which produce electricity. Rapid deployment of the technology is a key "clean energy innovation" component of the March 2011 White House Blueprint for a Secure Energy Future. *While it is critical that the United States reduce emissions of heat-trapping gases, including carbon dioxide (CO2), it is also imperative that strains on already-stressed water resources not be exacerbated.*

Carbon capture and storage (CCS) refers to a variety of technologies for capturing and storing carbon dioxide (CO2) from power plants and other industrial sources rather than releasing it into the atmosphere. Storage underground, or geologic storage, is the technology most likely to be used at a commercial scale in the reasonably near future and the method with the potential to store the greatest amount of CO2.

The United States Department of Energy National Energy Technology Laboratory's *2008 Carbon Sequestration Atlas* estimates the United States and Canada has the potential to store a total of 82.4 billion metric tons of CO_2 in oil and gas reservoirs, between 156 and 183 billion metric tons in unminable coal seams and between 919 and 3,300 *billion* metric tons in deep saline formations. To put this in perspective, stationary sources in the United States, which include power plants, refineries and industrial facilities, accounted for 3800 *million* metric tons out of total of 7100 million metric tons emitted annually[1]. In theory, sequestration in North America could hold more than 900 years worth of emissions from US stationary sources.

Advocates of carbon capture and storage (CCS) for power plants see it as a way to continue to burn fossil fuels like coal while meeting restrictions on heat-trapping carbon dioxide (CO_2) pollution. The regulatory framework is being put in to place on a relatively fast track, and US government agencies are funding and overseeing several pilot projects.

The capture and storage processes pose very real challenges to water resources, as well as other natural resource and public health considerations. It is imperative that these potential impacts of the technology are understood and that strict government policies are in place before commercialization of this technology.

Considerations for Carbon Capture at Power Plants

The process of capturing carbon at a coal-burning plant producing electricity will pose challenges in terms of increased coal use, overall energy consumption, air and water pollution, water consumption, and cost. While the technology is evolving and there may be improvements in overall energy and water consumption, full lifecycle resource issues need to be factored in to

[1] National Energy Technology Laboratory, *2008 Carbon Sequestration Atlas*, p. 11.

decisions about the future of carbon capture at coal-burning power plants.

Carbon Capture Means More Coal Use and More Coal Impacts

Capturing carbon at a coal plant will increase overall coal use. Capture is presumed to be most likely at a new generation of Integrated Gasification Combined Cycle (IGCC) plants. [See below for more on the possibility of retrofitting older plants.] Because the gasification process at IGCC plants is more energy-intensive, even without carbon capture these plants will use more coal to produce each unit of electricity. The 2005 Intergovernmental Panel on Climate Change's (IPCC) *Special Report: Carbon Dioxide Capture and Storage* estimated that adding carbon capture equipment to an IGCC plant would increase energy usage between 14 and 25 percent. The IPCC estimated that for a new higher-efficiency "supercritical" pulverized coal plant, capturing CO_2 would reduce plant efficiency between 24 and 40 percent.

This means that to make up for energy used for capturing CO_2, a plant would need to burn 14 to 40 percent more coal. This increases environmental impacts from the entire coal lifecycle, and these impacts primarily involve already-strained water resources.

Coal's impacts on water resources begin at the point of extraction. Most notorious is mountain-top removal mining. For example, the US Environmental Protection Agency (EPA) has revised its guidance on permitting in the face of scientific evidence of significant damage to local streams impacted by mountaintop removal mining.

Increased coal consumption also increases air pollution from the plant. Smog-forming nitrogen oxide pollution and ammonia will increase from the capture process increase while sulfur oxides will decrease. Increased nitrogen oxide and ammonia function as nutrients, which can lead to algae blooms that decay and leave the water without oxygen and unable to sustain fish and shellfish. These nutrients also post challenges for drinking water treatment plants. (WRI 37)

Greater coal use also increases the amount of coal ash and other solid waste products left over from coal combustion. Coal ash waste from coal plants is the second-largest industrial waste stream (after mining waste) and contains some of the most toxic heavy metals (arsenic, cadmium, mercury, lead, chromium, selenium). While coal ash has come under increasing scrutiny since a 2008 accidental spill in Tennessee, it remains unregulated and routine leakage of contamination into waterways is an-going and serious concern.

Carbon Capture Means More Water Use

The World Resources Institute (WRI) compared estimated raw water usage for a variety of configurations of pulverized coal and IGCC plants. The addition of carbon capture equipment **more than doubled water usage** for pulverized coal plants while increasing it between 10 and 20% for IGCC plants.[2] The use of air cooling can avoid much of this water use, but at the expense of further reductions in plant efficiency, which means even more coal would be needed to produce the same amount of power and with it more ash, nitrogen and coal mining-related pollution.

Higher Costs

There are multiple approaches for capturing CO_2 from a power plant. Several years ago it appeared that capturing CO_2 from "Integrated Gasification Combined Cycle" (IGCC) coal power

[2] WRI 38.

plants before the fuel is combusted would be the only technically and economically feasible way to reduce CO_2. That is no longer the case.

It is technically feasible to retrofit traditional pulverized coal (PC) power plants with amine scrubbers or chilled ammonia to separate CO_2 from the plant's exhaust. In addition, there are also experimental technologies available to build new power plants which isolate CO_2 by combusting coal in an oxygen rich environment ("oxy-combustion").

There are tradeoffs for each type of plant technology including initial construction cost versus operating cost, reductions in plant operating efficiency and increases in water use. **The separation of carbon dioxide and compression for transport is expected to consume large amounts of both energy and water** and also take up space- an estimated additional 6 acres for a 500MW power plant.[3]

IGCC-type coal plants cost significantly more to construct than traditional or higher-efficiency "supercritical" pulverized coal (PC) plants. The benefits of IGCC plants are that by turning the coal into a gas, pollutants can be separated and removed from the gas stream before combustion, enabling a higher percentage of mercury and SO_2 pollution to be captured than ordinary plants. CO_2 is also more economical to capture from these plants than from traditional coal plants, though the water and energy use, as well as increased coal use, considerations noted above still apply.

Plant Type	**Water Use**[4]	**Coal/Fuel Use**[5]	**Construction Cost**	**Added Operating Cost/ton of Co2** [6]	**Added Operating Cost in $/MWh** [7]
PC-CCS	Up 123%	Up 24-40%	Baseline	$80/ton of CO_2	Up 75-78%
IGCC-CCS	Up 10-20%	Up 14-25%	Much Greater	$60/ton of CO_2	Up 39%

Capture Process and Transportation Concerns

Once CO2 is captured at a coal-burning power plant or other facility, it will be transformed by pressure until it is nearly a fluid ("supercritical CO_2") before it is transported to the storage site. Potential problems resulting from the capture processes itself are not well understood, though one concern is coincidental release of hazardous substances which may be present in the waste stream or used in the capture or pressurization processes.

Transportation is likely to be by pipeline, about which there are numerous logistical and economic considerations.

[3] WRI 34.
[4] Based on averages from WRI table 6 "Estimated Raw Water Usage with and without CO2 Capture" p. 38
[5] Intergovernmental Panel on Climate Change, *Special Report on Carbon Dioxide Capture and Storage: Summary for Policymakers*, 2005.
[6] Stu Dalton, EPRI 9th Annual Carbon Capture and Sequestration Conference
[7] Global CCS Institute, *Strategic Analysis of the Global Status of Carbon Capture and Storage Report 2: Economic Assessment of Carbon Capture and Storage Technologies. Final Report,* 2009.

Recommendations for Policy-Makers

- All aspects of the capture and transportation processes must be subject to appropriate health and environmental laws including but limited to the Clean Water Act and the Resource Conservation and Recovery Act.

Recommendations for Policy-Makers

- Ensure that laws and permits account for the availability of water for coal plants using capture technology over the plant's entire period of operation, taking into account future water needs for other uses as well as potential changes in water supply over the plant's life from drawing down aquifers and climate change.
- Decisions about coal power plant construction need to consider full costs with and without CCS technology given that widespread commercial CCS is not yet a reality. Economic analysis should also include the initial cost to construct the plant, ongoing operating costs and the cost of water usage as well as an alternatives analysis to compare the costs of the coal plant (with and without CCS) to other energy sources.
- Decisions about the future of coal-burning power plants and CCS technology need to be made with full consideration for life-cycle greenhouse gas, water and health implications as with all other energy choices. Investment in the form of subsidies should be weighted toward technologies with the least negative impacts on public health and natural resources, those that are most cost effective and those that can reduce greenhouse gas emissions as quickly as possible.

Considerations for **Underground CO_2 Storage (Geologic Sequestration)**

Deep saline formations are the most likely storage sites in the near term because their ability to hold the stored carbon dioxide is relatively well understood compared to other geologic formations. The fluid will be injected into the geologic formations, where it will displace brine (saltwater) held in porous rock. While the CO_2 is buoyant (less dense than water found underground), the technology is based on the idea that a layer of impenetrable rock over the formation will keep the stored CO2 from escaping. Over time some of the CO_2 will become permanently stored as it dissolves into the brine and loses its buoyancy. Some of the CO_2 will also bind to rocks or minerals within the reservoir and become part of the rock.[8]

Regulatory Framework

The Regulatory Framework under which large-scale geologic sequestration operates is critical for protecting underground sources of drinking water, ensuring proper operation and maintenance, protecting communities from financial liability and meeting global warming pollution goals. Geologic sequestration wells will be regulated by the U.S. Environmental Protection Agency (EPA) under the Safe Drinking Water Act's Underground Injection Control (UIC) Program. EPA issued the Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells Proposed Rule in 2008 and the final rule was published in November 2010. The Rule creates a new class of wells for geologic sequestration and sets out a regulatory framework built around nine key UIC program elements: site construction, well construction, well operation, site monitoring, Area of Review, Post-Injection Site Care, Public Participation, Financial Responsibility and Site closure.

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[8] Herzog, Howard, *Carbon Dioxide Capture and Storage*, Chapter 13 in *The Economics and Politics of Climate Change*, Oxford University Press, 2009, p. 273 Accessed from http://sequestration.mit.edu/pdf/2009_CO2_Capture_and_Storage_Ch13_book.pdf

Strong provisions in each of these areas are key for protecting underground sources of drinking water. (See "Policy Recommendations" for issues of particular concern.)

The regulatory framework for geologic sequestration will also include provisions for quantifying how much C02 is injected and stored. EPA finalized the Mandatory Reporting Rule for Greenhouse Gases (MRR) in October of 2009 and proposed an amendment to that rule (Subpart RR) for Carbon Dioxide Injection and Geologic Sequestration in March 2011.

Important Drinking Water Protection Considerations

Water quality impacts and disruption of current or potential drinking water sources are one of the key areas of concerns around geologic sequestration. Stored carbon dioxide can harm groundwater quality through acidification, by forcing saline groundwater into aquifers used now or potentially usable in the future as drinking water sources or by introducing toxic contaminants into current or potential drinking water sources. Site selection and characterization, well construction and other provisions of EPA's Rule are key to ensure protection of water resources.

Acidification and Contamination

As CO_2 makes existing groundwater more acidic, it facilitates the leaching of silicates and metals from rock including iron, aluminum, manganese, and to a lesser extent arsenic, lead, copper, molybdenum, and zinc as well as carcinogenic polycyclic aromatic hydrocarbons (PAHs).[9] (WRF 99, 105, 108, 117-18). The injected CO_2 stream may be much more acidic if it contains sulfur dioxide (SO_2) and hydrogen sulfide (H_2S) from the power plants, which are also pollutants in their own right.[10] The presence of silica can increase water treatment costs and make arsenic removal harder.[11]

If saline groundwater is displaced by injected CO_2 and forced into contact with drinking water, it can increase alkalinity, total dissolved solids and also boron, the latter of which is frequently found in saline aquifers but not normal drinking water aquifers.[12] All of these water quality issues can affect whether a ground water source is suitable as a drinking water source or lead to the need for additional treatment if the source is being used by a public water system.

Today's Saline Formations - Tomorrow's Drinking Water?

In some parts of the country, aquifers used for drinking water are being degraded and depleted to the point that treated water from moderately saline aquifers are being considered as an alternative. Such aquifers may not be usable both for drinking water and for carbon storage. Contamination from leached metals can make treatment overly expensive or difficult. If the stored CO_2 itself is present in the brine, it cannot be pumped to the surface for use as water without negating the global warming benefits of pumping it underground in the first place.

An additional consideration is that it is technically possible to extract brine from near a CO_2 injection site to reduce underground pressure, increase CO_2 storage volume and control the

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[9] Water Research Foundation, John Norton, Chris Peterson et al., *Potential Groundwater Impacts Resulting from Geologic Carbon Sequestration*, 2009, pp. 99, 105, 108, 117-18.

[10] Water Research Foundation 101.

[11] "Addressing Critical Technical Aspects of CCS that Will Attract Public Scrutiny: A Drinking Water Perspective," Joe Drago, Kennedy/Jenks Consultants for American Water Works Association, presentation at the Ninth Annual Conference on Carbon Capture & Sequestration, May 12, 2010.

[12] Water Research Foundation 99.

movement of CO_2. The brine could be treated and used as a drinking water source, or used in the carbon capture process. There may be energy savings when removing salt from brine that is already under pressure from the carbon injection process, and concentrated saltwater from the treatment process could be returned underground.[13]

Proper Site Selection and Characterization

Proper siting and characterization is crucial to successful carbon dioxide storage as no two sites are identical. Unlike well-studied oil and gas fields, the only place where commercial CO_2 storage currently takes place, the geology of individual saline formations is not well known and needs to be studied and modeled in detail before CO_2 is injected. (WRF 13, 14) Issues which need to be addressed include the ability of the reservoir to permanently contain CO_2, whether the caprock seal is continuous and how far it extends, the strength of the rock and ability to withstand increased pressure from injected CO_2 and whether there are other leakage pathways for CO_2 and brine such as faults, fractures and existing wells. (WRF 24, 68, 69). It is also critical to consider proximity to other CO_2 injection wells, so that there are not unexpected pressure increases that could fracture the caprock. As noted above, proximity to current and potential sources of underground drinking water must be analyzed to prevent water quality problems.

Well Integrity and Operation

Leakage of stored C02 fluid poses risks to underground sources of drinking water and possibly to human health in the case of large releases. In addition, the climate benefit of storage is lost if leakage occurs. Leakage can occur if impurities in the capture CO2 corrode the injection well. Acidity can result from SO2 or H2S in the injection fluid or from CO2 coming contact with brine and forming carbonic acid. Acidity can degrade the cement and steel commonly used to construct wells. If the well structure becomes compromised it can provide a ready path for significant CO_2 leakage back to the surface or for incursion into other underground formations. (WRI 67)

Operational considerations are also important for protecting underground sources of drinking water and ensuring that stored CO2 remains underground. If too much CO_2 is injected into a formation, it can cause faults and fractures through which CO_2 and brine can move. As the injected CO_2 displaces brine, there is a danger of forcing brine through fractures into other aquifers, including those used for drinking water. (WRF 98,99) There is also the danger of high injection pressure causing faults to become transmissive, or open, and able to provide a conduit for CO2 to escape from a storage site. With transmissive faults or fractures in the caprock, less dense CO2 could rise into an overlying aquifer or escape to the surface.

There is also the danger of seismic activity compromising the integrity of the injection well and allowing leakage.

Liability

The public should not bear any financial burdens from accidents related to CO_2 storage. Liability should rest with the site operator both during the injection period and long after injection is complete. Risks of leakage are highest while injection is underway, as these are the times of highest pressure, but it is also important to ensure recourse if there is unwanted movement of CO_2 and brine in the post-injection period.

[13] Fresh Water Generation from Aquifer-Pressured Carbon Storage, Roger Aines, Lawrence Livermore National Laboratory, presentation at the Ninth Annual Conference on Carbon Capture & Sequestration, May 12, 2010.

Recommendations for Policy-Makers

- Prohibit storage in basalts, coal seams, salt caverns or shale until further research demonstrates that these formations are suitable for large-scale commercial storage.
- Ensure that communities, public water systems have heightened role in the siting and operating process with prompt public disclosure of any leakage or groundwater impacts
- Prevent storage at risky sites, especially those that could endanger communities served by a sole underground drinking water aquifer
- Require oversight to ensure that injection pressure is never close to rock fracture pressure and require monitoring for faults
- Create strict limits for contaminants in the CO_2 stream, including water.
- Make industry, not the public, pay for monitoring of the storage site during and after injection and until there is affirmative evidence the CO2 will remain permanently stored and the site is deemed closed. Monitoring should cover underground seepage detection, and if seepage is found, additional monitoring to quantify the extent of the leakage and any real or potential impacts.
- Hold the site operator liable for any damages caused or remediation needed from operation of a storage site. Liability should not be transferred to the public after injection is complete.
- Create a "superfund" through user fees from storage sites to pay for any necessary remediation if the site owner/operator no longer exists and to ensure timely remedial action.
- Require regulation and independent inspection of the capture, transport, injection and storage processes.
- Ensure that under global warming regulations, particularly cap and trade systems, are not undermined by unreported emissions. The CO_2 credited as stored should be net of any CO_2 emissions associated with above ground leakage from the capture, transport and injection process; indirect emissions from CCS-related energy use and any leakage from the storage site.

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