

Carbon Capture and Storage in the U.S.: A Sinking Climate Solution

by

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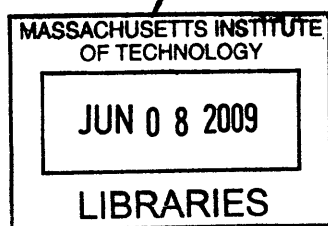
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Abstract

Coal-fired power plants produce half of the United States' electricity and are also the country's largest emitter of carbon dioxide, the greenhouse gas responsible for climate change. Carbon Capture and Storage (CCS) is a proposed technological solution that will sequester CO₂ in the ground. Proponents of CCS have framed it as a "clean coal technology" and broadcast the story that it will solve both our dependence on coal and prevent future climate change impacts. However, the technology is not a practicable solution for climate change, even with the most generous timetables and goals for atmospheric carbon. It cannot be scaled in time, costs too much, has serious environmental risks, and will face public resistance. Yet, CCS remains a part of future U.S. energy policy because the coal and electric utility industries have funded an attractive message and story for it. Environmental advocacy organizations are unable to create an effective counter-story because they are split into two coalitions. Therefore, the public is not mobilized and there is no incentive for legislators to challenge coal and CCS.

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INTRODUCTION

Coal is the backbone of the American electricity sector. It fuels 48.5 percent of the United States' electricity generation (EIA 2009a) at one-sixth the cost of natural gas or oil (MIT 2007).¹ It is abundant domestically and has therefore become central to the discussion of "energy independence." At the same time, coal emits 1.5 billion tons of carbon dioxide (CO₂) per year, accounting for 41 percent of the United States' (U.S.) total CO₂ emissions (MIT 2007). CO₂ is a greenhouse gas (GHG) that causes climate change. In 2007, the United Nations' Intergovernmental Panel on Climate Change (IPCC) projected that climate change will cause a rise in the global temperature of three degrees Celsius, plus or minus 1.5 degrees. The rising global temperature will cause sea-level rise, drought, and changes in the distribution of fresh water (Lemonick 2008).

In hopes of perpetuating the use of a cheap, secure fuel, fossil fuel interests and their allies have urged the development of subterranean CO₂ sequestration using a technology called Carbon Capture and Storage (CCS). The coal industry has branded CCS as "clean coal technology" and depicted it as a solution to climate change that will allow the country to continue burning coal without emitting CO₂. Utilities and industry have pledged \$3.5 billion for clean coal projects while the government has pledged an additional \$2.8 billion (Center for American Progress 2009). Support for "clean coal" goes all the way to the top: President Barack Obama advocated it during his campaign, saying, "This is America, we figured out how to put a man on the moon in ten years.

¹ Prices based \$1–2 per million Btu for coal, compared to \$6–12 per million Btu for natural gas and oil (MIT 2007).

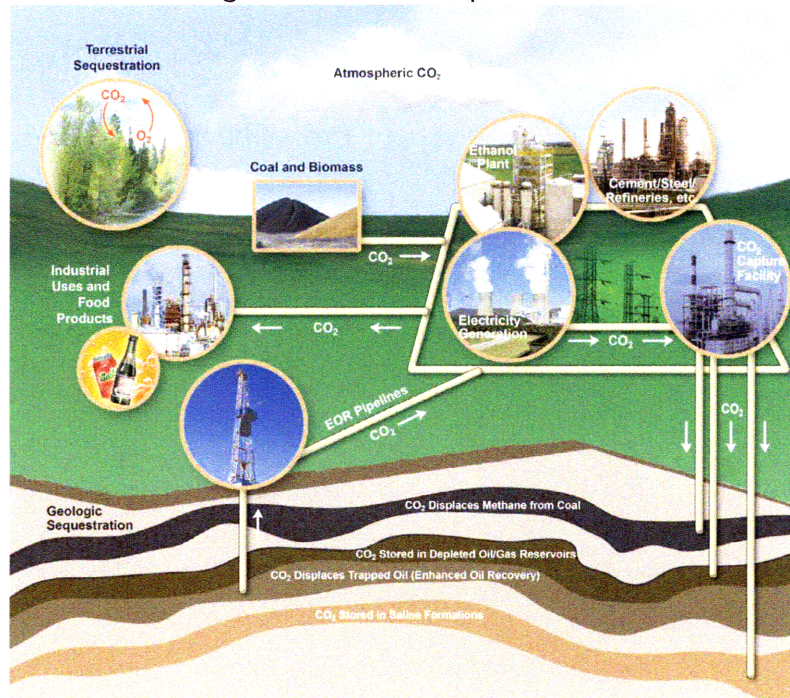
You can't tell me we can't figure out how to burn coal that we mine right here in the United States of America, and make it work" (Obama 2008). Even some environmentalists support CCS, believing that the technology is integral to addressing climate change because it maintains a sense of energy security.

But some environmentalists are beginning to tell a different story—one that portrays clean coal as a myth. For example, former Vice President Al Gore calls clean coal an oxymoron, saying: "at present there is no such thing as clean coal. There is a very cynical, massive advertising by the coal companies to promote the mean clean coal. It really is deceptive" (Gore 2008). In fact, CCS should not be part of the climate change solution, for several reasons. First, the technology cannot be built and scaled in time to stay within the most risk tolerant range of carbon emissions. Second, CCS will be so expensive to build and costly to consumers that utilities will not choose to invest in it. Third, CCS poses potentially serious, if uncertain, environmental risks. As a result, efforts to implement CCS on a large scale are almost certain to encounter massive public resistance. Nevertheless, the U.S. continues to pursue CCS as a central feature of its energy policy because environmental advocates are split, with some reluctantly supporting CCS and others unable to devise a compelling counter-story. As a result, they have been unable to mobilize the public—a necessary ingredient for defeating a well-funded coalition of industry interests and their political allies.

CARBON CAPTURE AND STORAGE

The IPCC defines CCS as a “process consisting of the separation of CO₂ from industrial and energy-related sources, transport to a storage location and long-term isolation from the atmosphere” (IPCC 2005, 108). There are three stages in the CCS process: capturing, transporting, and storing carbon (see Figure 1).

Figure 1: Carbon Sequestration



Source: National Energy Technology Laboratory, U.S. Department of Energy. 2007. *Carbon Sequestration Technology Roadmap and Program Plan 2007*, 21.

First, systems that capture CO₂ are integrated into coal-burning power plants.

There are three types of systems that can capture CO₂: post-combustion, oxy-fuel combustion, and pre-combustion systems (IPCC 2005). At a pulverized-coal power plant (PC) or natural gas combined-cycle power plant (NGCC), a post-combustion system would be used. During the second phase of the CCS process, waste gas from the power plant passes to a CO₂ capture facility. Third, the gaseous CO₂ is compressed and

liquefied, then piped to the disposal site where it is injected into subterranean caverns such as saline aquifers, depleted gas or oil fields, or coal beds (Lemonick 2008).

According to the MIT study *The Future of Coal*, a successful demonstration of CCS should have five elements: it would use CO₂ produced by coal conversion projects, produce one million tons of CO₂ per year for three to five sequestration projects, include pipeline transport facilities, include injection and sequestration, and have a monitoring system for the reservoir (MIT 2007). The MIT study warns that this will be “an enormous and complex task and it is not helpful to assume that it can be done quickly or on a fixed schedule” (101).

EVALUATING CCS

If CCS is a solution for U.S. dependence on coal and climate change implications, then it will have to be feasible, affordable, safe, and publicly accepted, all within an appropriate timeframe.

Criteria for Evaluating CCS

The goal of CCS is to end CO₂ emissions from coal sector in hopes of lowering overall atmospheric emissions in time to maintain a livable planet. Yet experts do not agree on an acceptable level of atmospheric emissions or a timeframe with which to meet those levels. Instead, experts make predictions based on acceptable levels of risk. In the most risk adverse scenario, carbon emissions must stay under 350 parts per million (ppm) by 2030. This precautionary prediction is based on maintaining an

atmosphere that allows for biological adaptation. “If humanity wishes to preserve a planet similar to that on which civilization developed and to which life on Earth adapted, CO₂ will need to be reduced from its current 385 ppm [parts per million] to 350 ppm,” says climatologist and director of the NASA Goddard Institute for Space studies James Hansen and his colleagues (Hansen et al. 2008, 217). Phasing out coal emissions by 2030 would keep maximum CO₂ levels close to 400 ppm.

The most risk tolerant scenario is capping emissions at 550 ppm by 2050. Proponents of CCS often quote this scenario because it is aligned with the IPCC’s goal of reducing CO₂ emissions by 50 to 80 percent by 2050 (Nichols 2007).² Whereas Hansen’s 350 ppm goal is based on preserving temperatures that allow for biological adaptation, the IPCC goal is based on least-cost reductions for stabilization between 450 and 700ppm over the next 100 years (Hill 2008). The IPCC goal is based on the assumption that stabilizing atmospheric CO₂ between 500 and 550ppm will prevent the most dangerous effects of climate change.

There is no international agreement for achieving any level of atmospheric carbon. At the latest UN Framework Convention on Climate Change in Bali held in December 2007, countries did not agree on carbon reduction goals, but they did agree to create a work plan for CCS during 2008 (Stavins and Aldy 2008). Without an international agreement, debate over an acceptable level of risk for capping atmospheric CO₂ will continue. As Lars Josefsson, President and CEO of Vattenfall, a

² Proponents of CCS include the oil and gas industry and some prominent academic experts, such as Dr. Robert Socolow and Dr. Stephen Pacala of Princeton University’s Carbon Mitigation Initiative, both of whom are funded by British Petroleum (BP) and Ford (Nicholls 2007). Socolow and Pacala famously authored “Stabilizing Wedges,” which appeared in *Science* in 2004.

Swedish-owned electric utility building Europe's first CCS coal plant, says "it is an uninteresting question because whatever we choose will be difficult" (Josefsson 2009).

The Feasibility of CCS as an Energy Solution

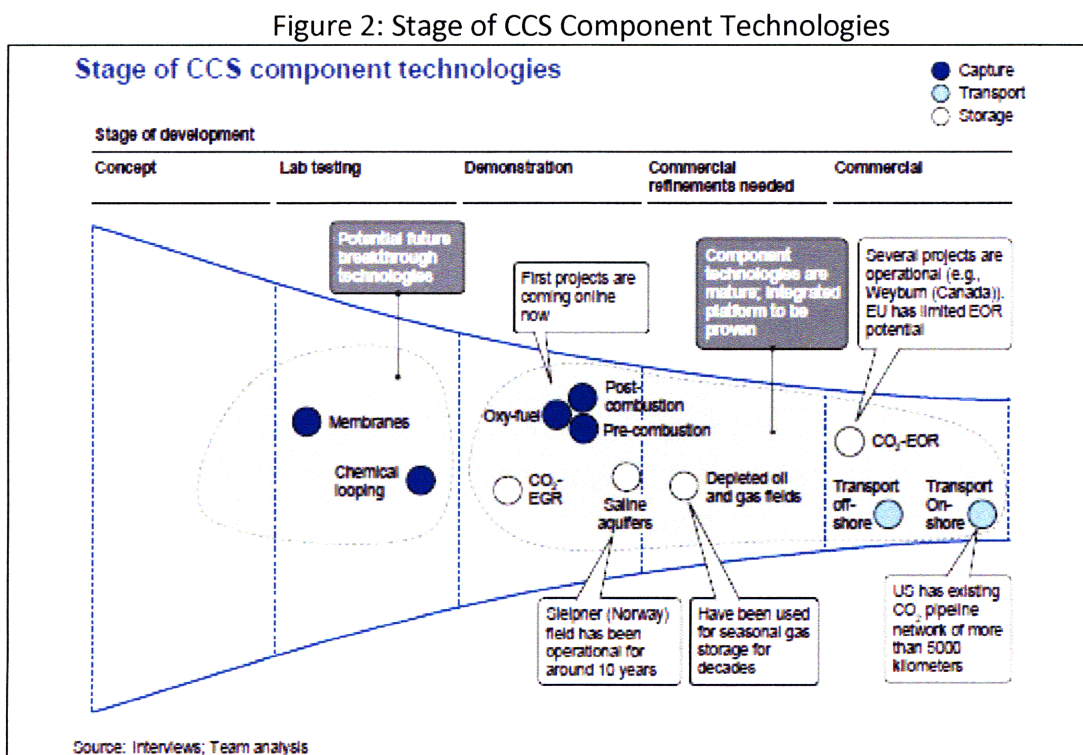
CCS Uses More Energy

The CCS design creates a barrier because putting CCS on a coal-burning power plant decreases its efficiency, thus requiring a 25 percent increase in fuel or a decrease in the amount of power produced. The IPCC predicts that post-combustion coal plants with CCS will require increased fuel to run to CO₂ separation and purification processes (IPCC 2005). In an integrated gasification combined-cycle (IGCC) plant, the two processes and the fuel gassing process require more fuel. In a hypothetical scenario, MIT scientists found that if a supercritical PC plant producing 500 megawatt hours (MWh) at 38.5 percent efficiency were retrofitted with CO₂ capture systems, output would decrease 30.4 percent or 152 MW (Bohm, Herzog, Parsons, and Sekar 2007).

Such efficiency losses have serious financial implications: before a retrofit, the average plant cost \$665 million with an estimated retrofit cost of \$277 million (Bohm, Herzog, Parsons, and Sekar 2007). The plant could then either produce less power than before, or choose to make up the 152 MW by adding an additional CCS plant for \$325 million. Either way is extremely costly and leads many experts to believe that retrofitting existing coal plants will not be possible (Golay 2008). Demand for power is growing, but retrofitting existing coal plants is not an approach for generating more power.

CCS Technological Readiness

The coal industry admits it will be more than a decade before they know if the theory of CCS works (Ross and Rhee 2009). That is because integrating individual technologies into a CCS system may prove challenging. The individual technologies that support the three processes – capturing, transporting, and storing – involved in CCS are mature enough for demonstration but are not commercially viable. Figure 2 illustrates the development stages of CCS technologies.



Source: McKinsey Climate Change Initiative. 2008. "Carbon Capture and Storage: Assessing the Economics." Available: http://www.mckinsey.com/client-service/ccsi/pdf/CCS_Assessing_the_Economics.pdf

Technologies for capturing CO₂ at power plants need further development in order to be commercially viable. One factor that is delaying the emergence of commercially viable capture technologies is that industries and experts are splitting their time developing three types of capture processes: pre-combustion, post-

combustion, and oxy-fuel. Industry and academic experts have not reached a consensus on the best form of carbon capture technology; in fact many CCS experts believe that the technology is too premature to select the most cost-effective form (MIT 2007). Without a preferred form, there is less likelihood for technology lock-in, and that is essential to creating economies of scale in massive technological projects. Instead, industry competitors are still vying to prove that their technology should gain acceptance. For example, Babcock & Wilcox, a company that makes boilers, is partnering with a utility to demonstrate a technology that removes nitrogen from the air during pre-combustion. American Electric Power (AEP) is exploring an ammonia-based post-combustion technology at its plant in West Virginia (Wald 2009). The Electric Power Research Institute (EPRI) is studying five competing post-combustion technologies (EPRI 2009). Finally, Duke Energy has begun building an oxy-fired plant in Indiana with the goal of capturing 18 percent of its CO₂ emissions by 2014 (Wald 2009).

Further complicating matters, each sequestration site will have unique geologic makeup and features, and as a result engineers will have to design site-specific specifications. The lack of a learning curve will increase the amount of time in which CCS can be installed commercially.

CCS experts believe that successful implementation in the U.S. will require 55 gigawatts (GW) of installed generation by 2030, or 17 percent of coal's current capacity (Geman and Gronewold 2009). This goal is aligned with policies that favor the most risk tolerant scenario for carbon emissions, capping them at 550ppm by 2050. It is an unachievable goal because currently there is not enough money to fund all of the

competing technologies, and 55 GW by 2030 is not enough time to develop commercial-level technologies. “Experts say that before new methods can be commercialized, projects need three to five years of planning and construction, followed by eight to 10 years of actual pumping of carbon dioxide into the ground,” (Wald 2009, 2). At this rate, even if results of the three previously mentioned demonstrations were perfect, capture technology lock-in would not occur until sometime between 2020 and 2025.

Furthermore, although CO₂ transporting and compressing technologies have been used for decades as part of the Enhanced Oil Recovery (EOR) in the oil industry, lessons learned there are not necessarily transferable to utility sector storage. Coal-burning plants need to store CO₂ in saline aquifers, not oil beds. In theory, saline aquifers can sequester a huge amount of CO₂ because they are located closer to emission sources (Benson 2007). However, demonstrations have turned up surprising results, like CO₂ mixing with the saline formation, creating carbonic acid and eating away at surrounding rock (Biello 2007). Monitoring technologies need to be developed in order to determine if storage in saline formations is safe. Few of these monitoring technologies exist today and the U.S. Department of Energy (DOE) predicts it will take ten years of scientific research to better understand the effects of CO₂ storage.

The three processes involved in CCS from a coal plant were integrated into a single platform for the first time in June 2008. The Commonwealth Scientific and Industrial Research Organization (CSIRO) successfully used post-combustion technology to capture CO₂ from a power plant in Australia (DOE 2008a). The pilot project is miniscule in scale compared to the averaged size coal-burning plant because it can only

capture 1,000 metric tons of CO₂ per year.³ The U.S. plans to demonstrate and pursue CCS in IGCC plants because they use pre-combustion processes, since it is cheaper than using a post-combustion technology to retrofit an existing plant. Therefore, the CSIRO project does not demonstrate all of the facets needed in pre-combustion integration.

Challenges to CCS Scaling Up

For CCS to be an effective part of the solution for capping atmospheric CO₂ from coal-fired power plants, a dramatic scaling up of technology, infrastructure, and identifiable sinks will have to take place. All the sequestration projects operating in the world today capture .003 percent of the world's CO₂ emissions in one year – and emissions are expected to rise (Fehler 2008). The Sleipner gas field in the North Sea is the largest CO₂ sequestration project operating today, and it captures one million tons of CO₂ per year for a total of 11 million tons since it began (MIT 2007). Assuming that successful implementation of CCS is the experts' goal of 17 percent of current coal capacity by 2030, and then the U.S. will need to capture 255 million tons of CO₂ annually by that time. In order to sequester that amount of CO₂, it would take 255 projects the size of Sleipner.

In order for atmospheric carbon to stay under 550ppm by 2050, the U.S. would need to shut down or retrofit 96 percent of its existing coal generators (Dooley et al. 2005), equaling approximately 1,400 coal generators (EIA 2009b).⁴ That means 62 large

³ An average-sized 500 MW coal-fired power plant emits 3 million tons per year of CO₂ (MIT 2007). The U.S. has more than 220 coal-fired power plants with a capacity above 500 MW (Sourcewatch.org 2008). Therefore, CSIRO is storing .0003% of an average sized coal plant.

⁴ There were 1,470 generators operating in U.S. as of 2007 (EIA, 2009).

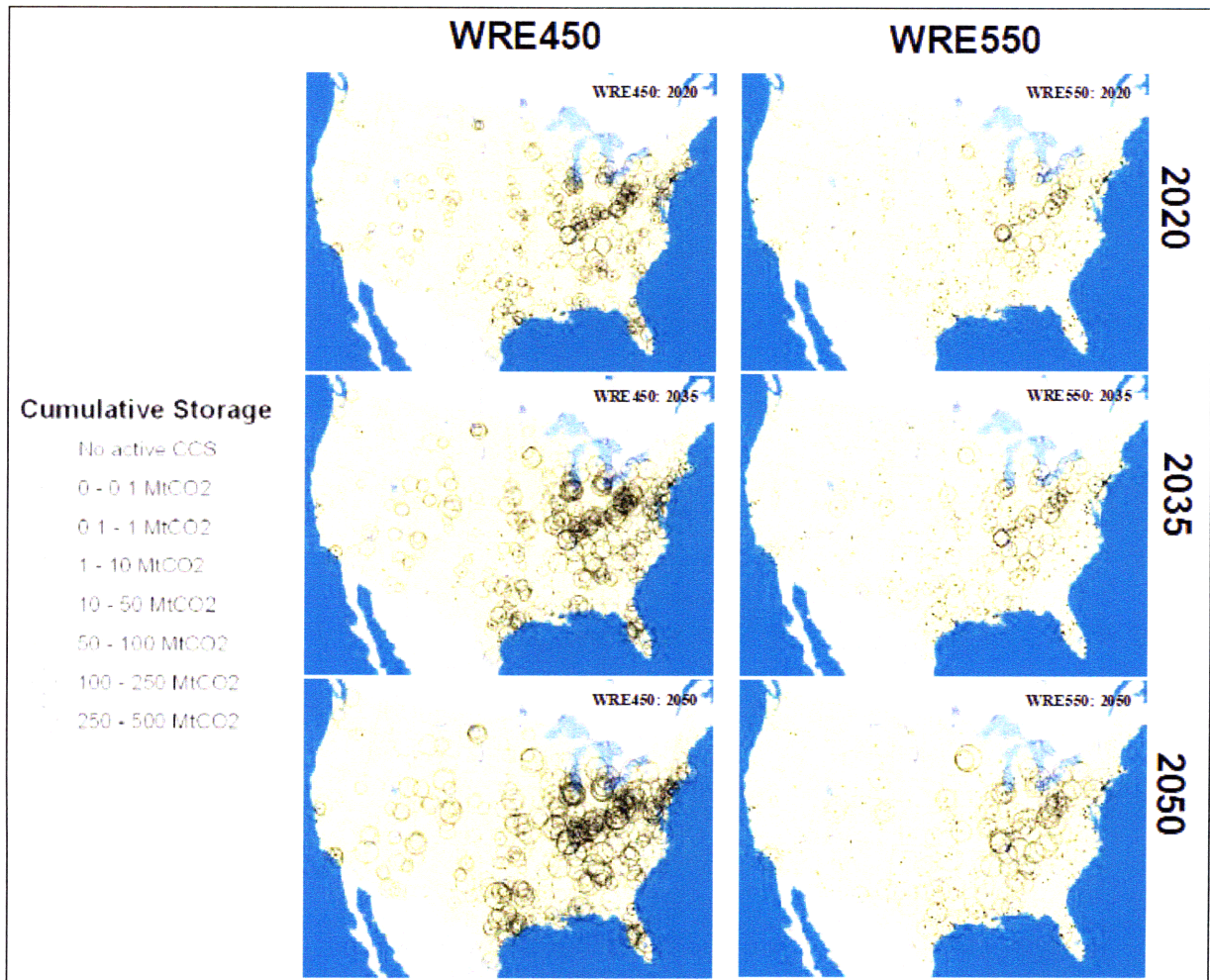
coal plants storing more than 100 megatons (MT) of CO₂ would have to be built along with 23,000 miles of CO₂ pipeline (Dooley et al 2008).⁵ The amount of sequestered CO₂ would be 27 times larger than the amount of oil that the world takes out of the ground today (Fehler 2008).⁶

To illustrate the scale of CCS in the U.S. needed to assist the world in capping atmospheric CO₂ at either 450 ppm or 550 ppm, the Pacific Northwest National Laboratory along with engineers from Battelle, a private engineering firm, developed scenarios based on the Wigley, Richels and Edmonds (WRE) stabilization pathways. The WRE stabilization pathways, published in *Nature* in 1996, were developed to meet the goals of the UN Framework for Climate Change. The Pacific Northwest Lab's model includes several assumptions: CCS is a part of the energy solution along with increased energy efficiency, and nuclear and renewable generation, fossil fuels generate 38 percent or more of electricity, a carbon price exists, and energy demand increases over time (Dooley et al 2005). Their results are illustrated in Figure 3.

⁵ In a more extreme scenario, Dooley et al. state that 262 plants would have to be built to cap atmospheric CO₂ at 450ppm by 2040 (Dooley et al 2005).

⁶ Fehler's explanation is based on world oil production is 30 Billion barrels per year and has a volume of 5 Km³. Thus, the volume required to store one year of CO₂ emissions is a magnitude of 27 times larger than current oil production volume (Fehler 2008).

Figure 3: U.S. Electric Utility Deployment of CCS-Enabled Generation under WRE 450 and WRE 550 Hypothetical Climate Policies



Source: Dooley, JJ, RT Dahowski and CL Davidson. 2008. Comparing Existing Pipeline Networks with the Potential Scale of the Future U.S. CO₂ Pipeline Network. *Energy Procedia*, 4.

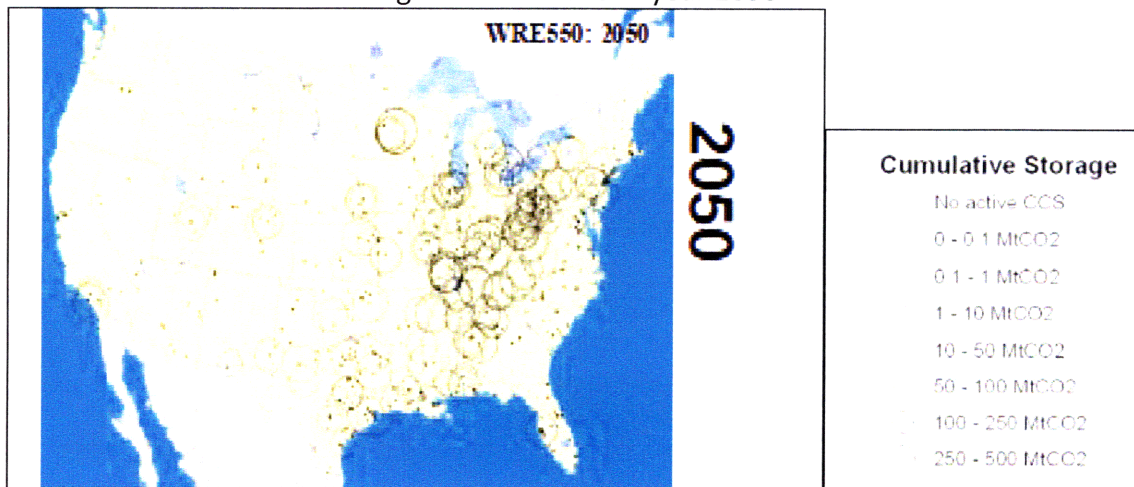
Establishing a CCS infrastructure that keeps atmospheric carbon below the most risk tolerant level, 550ppm by 2050, will be challenging. According to the Pacific Northwest Lab's results, the U.S. must have 12 coal-fired plants adopt CCS every year to stabilize the world's emissions at 450 ppm by 2050. Nine hundred miles of pipeline would have to be built every year, and 22,000 miles of pipeline would have to be operational by 2030. They found it would be easier to stabilize at 550 ppm, where one

to three plants must adopt CCS every year starting in 2010, while 300 miles of pipeline would be constructed annually (Dooley et al 2008, 6).

The Pacific Northwest Lab's models assume CCS deployment will begin in 2010. However, this is unrealistic. It is more likely that U.S. will deploy CCS plants well after 2020 since the U.S. has not established a date for CCS demonstration nor created a financial incentive through a carbon price. If the models were adjusted for a more realistic timeframe, the number of CCS plants needed each year would increase to 16 to maintain 450ppm by 2050 and three to maintain 550 ppm.

In order to maintain atmospheric CO₂ levels at the most generous levels, 550 by 2050, the scale illustrated in Figure 5 is necessary.

Figure 5: WRE 550 in year 2050



Source: Dooley, JJ, RT Dahowski and CL Davidson. 2008. Comparing Existing Pipeline Networks with the Potential Scale of the Future U.S. CO₂ Pipeline Network. *Energy Procedia*. 2008. Page 4.

There are major barriers that will likely derail establishing a CCS infrastructure at this scale. First, the public is likely to resist the installation of large-scale CCS storage. The Pacific Northwest Lab's model indicates CCS plumes would be located under densely

populated cities including New York City, Los Angeles, Minneapolis, Denver, Dallas, St. Louis as well as beneath the entire populations of New Jersey, Pennsylvania, Ohio, Indiana, Illinois, West Virginia Tennessee, Kentucky, and Alabama. These cities and states represent approximately one-third of the U.S. population.⁷ These cities also represent important economic centers that are home to the country's wealthiest citizens and most expensive real estate.

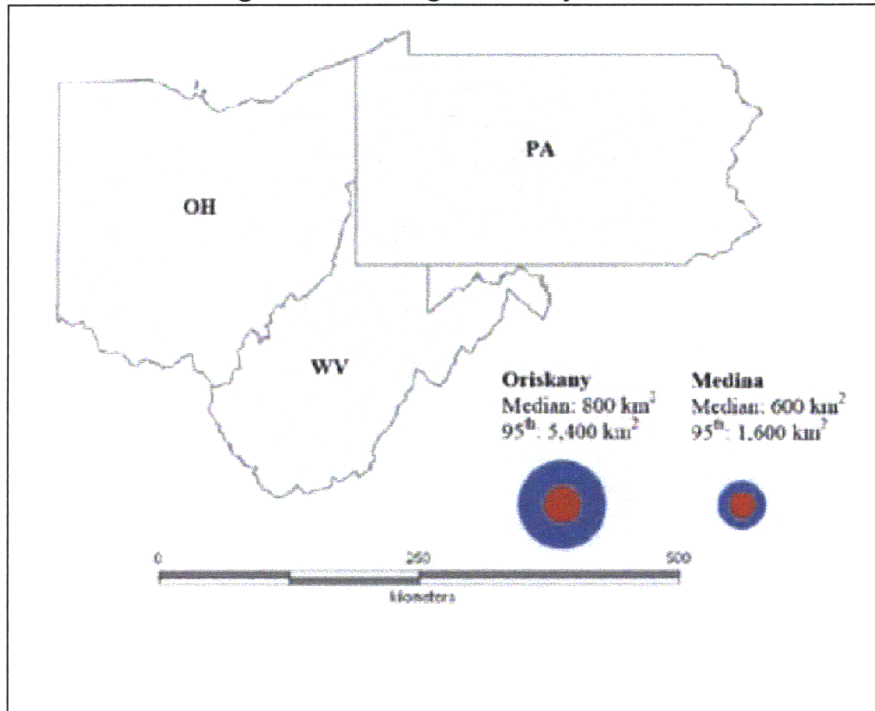
Convincing one-third of U.S. citizens, let alone the country's wealthiest cities, to accept carbon sinks under their home does not seem realistic, especially because coal has waning public support. Florida Governor Charlie Crist, a Republican, said it is politically impossible to support a new coal plant in his state. He canceled plans for two clean coal plants in Florida and said that 63 coal-fired power plants have been scrapped or defeated by public opposition during the last five years (Andrews 2008). In fact, 56 coal fired plants were either cancelled or delayed in 2007 because they either lacked public support and could not get permits or suffered from higher than predicted costs (Synapse 2008). In Europe, it is well understood that the public is reluctant to place storage facilities under their homes and the resistance has created siting complications (Metz and De Coninck 2007).

Second, the sheer size of a CCS plume creates challenges for finding appropriate sites and monitoring safety. Figure 4 illustrates the size of a CO₂ plume that would be sequestered. The median size of a plume may be between 1,000 and 1,600 square miles, can easily spread beneath 10 counties, and may cross state or federal boundaries.

⁷ Using US Census Data, 2007 Estimate, for States and metropolitan areas compared to entire U.S. population.

The size of the plume multiplies the number of citizens and government agencies who have a stake in a single storage site.

Figure 4: How big can an injection field be?

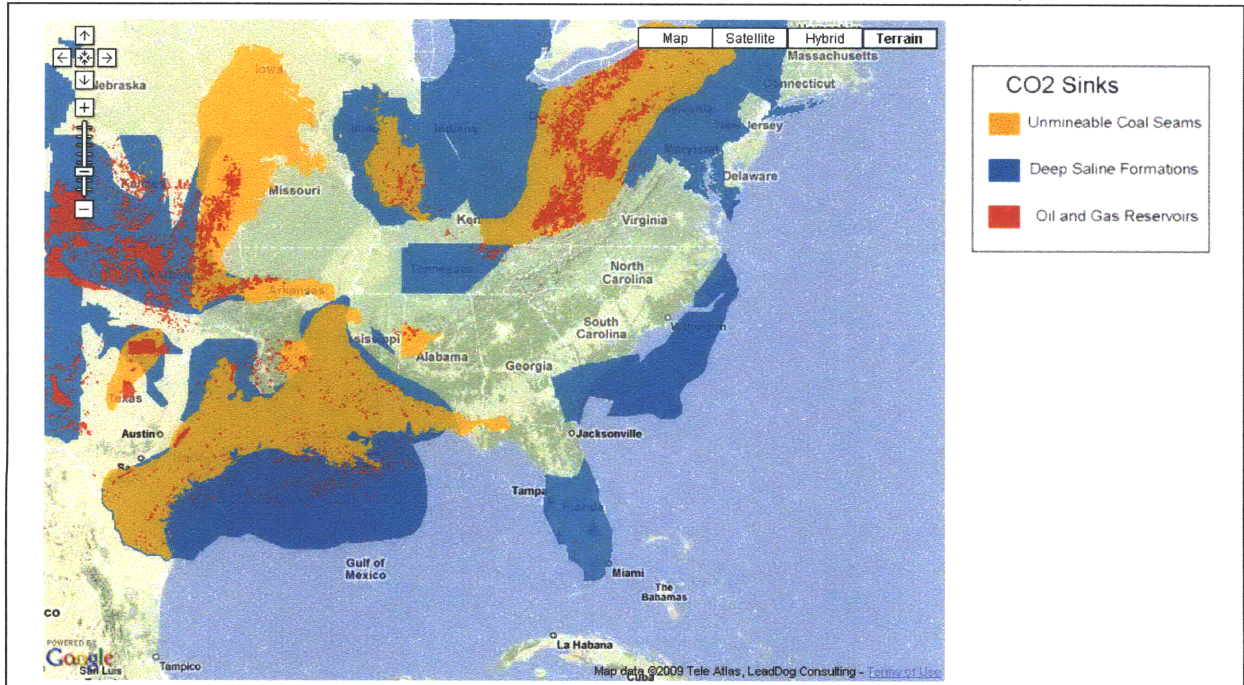


Source: CCRreg Project at Carnegie Mellon University. 2008. *Carbon Capture and Sequestration: Framing the Issues for Regulation*.

Third, the geography of potential storage sites pose a barrier to CCS – especially in the southeast where there are numerous coal-fired power plants but little potential for geological storage. In 2005, DOE’s National Energy Technology Labs (NETL) began exploring the country for geological sites that are able to store carbon. They found very few sites in the southeast, as illustrated in Figure 6. David Ratcliffe, CEO of Southern Company – the country’s second largest emitter of CO₂ located in Georgia – admitted that his utility company does not favor CCS because the south does not have sinks for

sequestration (Pooley 2008). To maintain the southeast's dependence of coal-fired power plants, pipelines would have to transport CO₂ for hundreds of miles.

Figure 6: Map of Possible CO₂ Sinks in Southeastern United States, 2008



Source: DOE, NETL 2008. National Carbon Explorer Interactive Sinks Maps.
<http://www.natcarb.org/>

Even the most prominent CCS research experts question whether scaling up is possible. Before a congressional subcommittee in 2007, Sally Benson, head of Stanford University's carbon sequestration research program warned, "the question of scale cannot be ignored...The potential for unforeseen consequences of large-scale sequestration must be assessed and methods to avoid them developed" (Benson 2007, 2). MIT's Howard Herzog told *Scientific American* in 2009 that "we may have by 2020 a handful, maybe even close to ten, but If your goal is 80 percent cuts [in CO₂ emissions] by 2050, then it's not big enough" (Biello 2009, 1).

In Europe, a variety of actors from different sides of the issue have expressed deep skepticism over whether CCS can be scaled up in time to diminish climate change effects. In a report about CCS viability, Swedish Air Pollution and Climate Secretariat found that “even with the most optimistic projections, CCS won’t become viable on any convincing scale until well after 2030, and how much additional energy and money would be required to bring the technology into worldwide use remains unknown” (von Goerne and Lundberg 2008). Though the United Nations supports CCS development, the UN Development Program, is skeptical about scale, saying “CCS will arrive on the battlefield far too late to help the world avoid the dangerous climate change” (UNDP 2007, 145). McKinsey & Co., a traditional business consulting firm and proponent of CCS said, “if the first commercial projects do not start until well after the demonstration phase, or if projects are delayed due to difficulties with permits or other uncertainties, CCS could struggle to reach large scale by 2030” (McKinsey 2008a, 7).

The Costs of Implementing Large-Scale CCS

Advocates on all sides of the CCS debate agree: CCS costs are unpredictable and are likely to be very expensive. The proposed costs are so burdensome that it does not make sense for customers, financiers, and investors to choose CCS.

Increased Electricity Costs

CCS’s levelized cost of electricity (COE), an industry term for the anticipated cost of a kilowatt hour (kWh) of electricity, varies widely but is expected to be exorbitant compared to electricity costs today. The IPCC predicted the COE could increase from 21

to 91 percent (IPCC 2005). The DOE predicted that COE would increase by 60 to 100 percent at existing power plants and by 25 to 50 percent at new IGCC plants (DOE Roadmap 2007). MIT's *Future of Coal* report predicted a 58 to 78 percent increase based on the type coal-burning plant (MIT 2007). At Duke Energy's Edwardsport IGCC project in Indiana, the utility predicted that the COE would increase by 69 percent (Synapse 2008).

The price per ton of carbon abated – how much it costs to take one ton of carbon out of the atmosphere – also varies among reports. While the IPCC estimated the cost of carbon abatement to be between \$14 and \$91 per ton, the IEA predicted a much higher cost ranging between \$40 and \$90, and most recently, McKinsey estimated the costs from \$75 to \$115 (Economist 2009). The different price ranges are a result of varying assumptions made when deciding what to include or leave out of the cost models. The reports also use different capture system designs, with various efficiency and storage levels, in their hypothetical cases which create inconsistent answers. Further complicating price assessments are rising material costs (McKinsey 2008a).

For CCS to be economically viable, the U.S. must have some form of a price on CO₂ emission abatement, otherwise there is no incentive to invest in the technology. Since 2005, the European Union (EU) has had a cap on CO₂ emissions through their Emissions Trading Scheme (ETS). The CO₂ allowances are traded for a monetary value, establishing a cost for abating one ton of CO₂. A 2008 report by McKinsey & Company analyzing the EU electricity market predicts that in 2030, the ETS price will be lower than the actual cost of abating CO₂ using CCS. Thus, they predict an economic gap that must

be filled by subsidies in order to make CCS economically viable. McKinsey assumes that the ETS price for abating one ton of CO₂ will be approximately \$50 dollars in 2030, whereas it will cost between \$85 to \$127 dollars to abate.⁸ There is a \$35 to \$78 dollar difference that amounts to a \$705 million to \$15.5 billion dollar gap, depending on project size. If CCS is to be an option, governments will have to subsidize up to \$1.4 billion dollars per project (McKinsey 2008a). MIT Physicist Ernest Moniz argues we will not know the price until after several demonstrations (Biello, 2008), putting price certainty at 2020 or later. In a separate report, McKinsey (2008b) also calls CCS one of the most expensive technologies available for abating carbon emissions.

In one of their television commercials, the American Coalition for Clean Coal Electricity (ACCCE) says “with new technologies we can reduce greenhouse gas emissions and keep energy costs affordable” (ACCCE 2008). But there is no guarantee that energy prices will remain low if CCS is installed. In fact, AEP CEO Michael Morris has said COE will increase 20 to 30 percent with IGCC plants but price is “different based on location; in Ohio, there are storage options but in the south it would be more expensive because of transportation.” He continued, “it would be silly to say we are comfortable with a price prediction” (Pooley, 2008).

Increased Capital Costs

Furthermore, capital costs of new coal plants are skyrocketing because supply prices are volatile. The estimated cost of a new coal plant today is \$3,500 dollars per

⁸ All Euro costs are expressed as dollars using the average 2008 exchange rate of €1 = \$1.41, www.forecast.org/euro.

kW, meaning it could take a \$3 billion capital investment to build a 600 MW plant.

There are several reasons prices for coal-fired power plant construction have increased so dramatically: increased demand for power plant construction around the world has strained the supply of design and construction resources; there are fewer firms and manufacturers bidding for the work today compared to a decade ago; and commodity prices for steel, nickel copper and cement have increased up to 70 percent since 2003. Duke Energy found that capital costs have increased 90 to 100 percent since 2002, and more specifically at their future CCS project in Edwardsport, Indiana, construction estimates increased 18 percent between 2007 and 2008 (Synapse 2008). It may also be difficult for utilities to find financing for capital costs because several major lending institutions in the U.S. have signed the Carbon Principles, thus agreeing to a more prudent set of standards when evaluating lending practices for carbon intensive capital investments (Ceres 2008). CCS, with its unproven results, may not meet the new evaluation standards and is considered a high-risk investment for lenders.

CCS is a Risky Investment

Coal itself is proving to be a risky investment for shareholders. In the utility sector, expenses from regulations have typically been paid for out of operating costs, not passed on to customers. Impending legislation for CO₂ pollution will drive up operating costs, cutting shareholder profits. When the Lieberman-Warner carbon cap-and-trade bill was proposed in 2007, Duke Energy estimated that they would owe

between “\$930 million and \$2.8 billion during the first year of allowances” (Duke Energy 10-k 2008, 80).

Specifically, CCS will be a risk for investors because there is no evidence that the high capital costs of building CCS will be returned to investors – the technology could fail. Standard & Poor’s issued a market report in 2009 calling CCS a “potential large ticket item that electric utilities might have to confront,” and it “leaves utilities sweating over the risk to their credit quality” (Schlissel 2008, 6).

Meanwhile, utility companies are telling a very positive CCS story to their investors. That story is part of an effort to allay investor concerns over company preparedness for long-term risk like GHG regulation and carbon prices. The utility companies’ story glosses over financial risks posed by CCS feasibility, uncertain costs, and risk, however. For example, Duke Energy only mentioned CCS in a positive light in its 2008 Annual Report and proxy statement to investors. Yet, in their 10-K filing to the SEC, in which they are legally obliged to discuss long-term risk honestly, the company acknowledged it was uncertain about CCS’s technological development, legal and liability issues affecting its cost and availability (Duke Energy 2008). Furthermore, Duke Energy CEO James Rogers told CBS’s *60 Minutes*, “we have not invested any dollars in the technology, per say” (Weiss and Kougentakis 2009).

Duke Energy and other utilities will have options for how they meet GHG regulation, including efficiency, renewables, and using less carbon-intensive generation such as natural gas or nuclear power. Coal producers will not have options, and they are fighting for their very existence. That is why they are some of the country’s biggest CCS

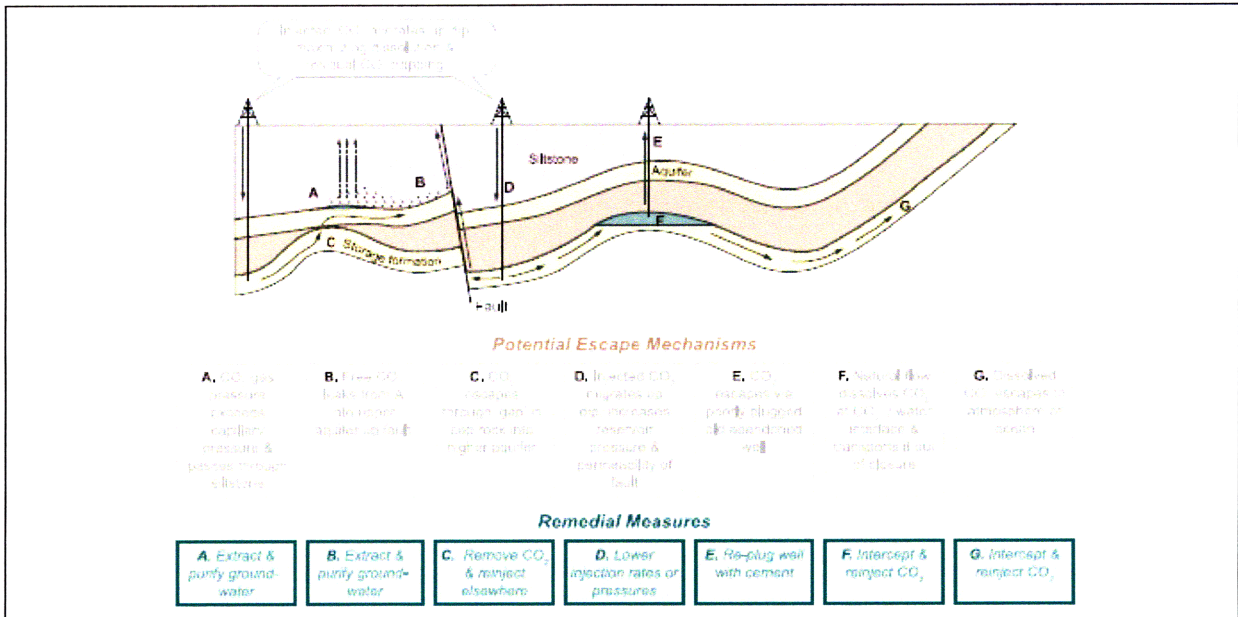
supporters. Steven Leer, CEO of Arch Coal – the country’s second largest coal producer – told an audience at Harvard that his goal was to ensure CCS helped solve the energy crisis (Leer 2009). David Ratcliffe, CEO of Southern Company – the country’s second largest emitter of CO₂ – says his business will have face hard times if CCS does not succeed.

The Environmental Risks Posed by Large-Scale CCS

Risk of Environmental Impacts from Storage

CO₂ leakage is possible during injection and storage because it is buoyant and it is always pushing upward. If there is a pathway available, CO₂ will find it and flow upwards (Bachu 2008a). Some of the pathways in which CO₂ can flow are illustrated in Figure 7 from the IPCC report on CCS. Essentially, CO₂ stored in geologic formations can escape in several ways: through pore systems in low-permeability caprocks, openings between caprocks, fractures, faults, or through previously drilled wells (IPCC 2005).

Figure 7: Potential escape routes for CO₂ injected into saline formations.



Source: IPCC. 2005. Carbon Dioxide Capture and Storage. Cambridge: Cambridge University Press, 243.

The risk of leakage varies depending on the type of geologic formation in which CO₂ is stored. For example, in a coal seam, CO₂ will be absorbed into the coal surface and the likelihood of leaking is minimal. However, if the coal is mined or depressurized, the CO₂ will escape (Bachu 2008a). Storage in or near aquifers is a risk because if CO₂ escapes, then the water in the aquifer can become saturated with CO₂. Water saturated with CO₂ is slightly heavier than water and will settle at the bottom of an aquifer. If certain conditions are present, the CO₂ saturated water will migrate downwards in the aquifer (Bachu 2008a). This can cause water source contamination (Van der Meer 1992).

CO₂ is dangerous at high concentrations and accumulated CO₂ from slow leaks can cause asphyxiation in humans. Acute exposure to CO₂ above three percent can

seriously affect a person's health or cause death. In 1986, naturally occurring CO₂ stored at the bottom of Lake Nyos in Cameroon escaped after volcanic activity. The CO₂ killed 1700 people over a 25 kilometer range (Greenpeace 2008).

If CCS is stored beneath densely populated areas, then CO₂ escaping from storage can accumulate at high concentrations in pits, tanks, and buildings (Bachu 2008a). Risk assessments of CO₂ release rates have been conducted and they found that there is minimal escape from storage in oil and gas, and natural gas formations but highly fractured systems experience significantly higher rates of leakage (IPCC 2005; Stevens et al. 2001). In current CO₂ storage projects, there is not enough data to conclude the rate at which CO₂ is escaping and researchers believe that current monitoring techniques are unable to detect CO₂ movement (IPCC 2005; Chadwick, et al. 2005).

In 1995, an earthquake measuring 4.9 on the Richter scale occurred in Rangely, Colorado. It was the nineteenth earthquake to occur in the area since 1963. It is not a coincidence that Rangely, Colorado is home to the Rangely oil field where fluids are injected into oil fields to produce higher yields. It has long been established that injecting fluids injection into the subsurface can cause earthquakes (Gibbs et al. 1973; Raleigh et al.1976). Fluid-induced earthquakes are typically the result of increased pressure in critical regions (Healy, et al. 1968).

There are numerous regulations established to monitor fluid injection pressure rates to prevent earthquakes. In the U.S., the EPA has an Underground Injection Control Program that studies and monitors injection pressures (IPCC 2005). States have been

delegated the authority to establish maximum injection pressure in the oil and gas industry (IPCC 2005). The IPCC Report states that earthquakes in the Rangely Oil Field have demonstrated that the risk of earthquakes are low, and “regulatory limits are sufficient to avoid significant injection-induced seismicity” (2005). However, seismic events will have to be considered when selecting geographical locations for sequestration that are close to densely populated areas.

Though the risk of CCS leakage and earthquakes may be small, there is no legal framework for regulating either risk. Recently, the EPA began considering regulation that they expect to make final in 2010 or 2011. The EPA’s UIC program has proposed a new category of injection wells called Class VI. Under this classification, UIC will establish rules to monitor the long-term, geologic storage of CO₂ (DOE 2008a). “The proposed regulation will build on the existing UIC program by including requirements to ensure wells are properly located, constructed, tested, monitored, and closed with proper funding” (DOE 2008a).

Environmental Tradeoffs of CCS

There are several environmental tradeoffs involved with building CCS coal-fired plants. While the technology may prevent additional CO₂ from accumulating in the atmosphere, the technology will consume more water and coal. The DOE’s National Energy Technology Laboratory (NETL) found that a CCS coal-fired plant will use 2.16 times more water than a traditional coal-fired plant because the capture process uses water for cooling (Synapse 2008). Water resources are already constrained in the U.S.

due to increased demand and changes in weather patterns. Since CCS plants use more water, water scarcity must be considered when siting future plants because it can jeopardize energy production. During the southern drought in 2007, Duke Energy was days away from shutting off water intensive power plants in Charlotte, North Carolina (Robbins 2007).

CCS plants will also require more coal to be burned per MWh because of their efficiency loss, meaning mountaintop removal could increase (Jacobson 1998). Mountaintop removal is a dirty method of extracting coal that literally blasts off the tops of mountains in order to access the coal without mining. It destroys forests and wildlife, and the increased runoff causes watershed contamination. Coal extraction is notoriously hazardous for coal miners who suffer from black lung and risk their lives. Ultimately, a CCS plant will emit the same types of pollution that traditional coal plants do, including SOX, NOX, mercury and coal ash. Some CCS technologies will produce more liquid and solid wastes than traditional coal plants (Jacobson 2008).

Mark Jacobson, an engineering professor at Stanford and a skeptic of CCS not funded by industry or government, conducted a life cycle assessment of carbon-reducing technologies. Jacobson used the following categories in descending weight order: CO2 emissions, mortality rate, footprint, power reliability, power supply disruption, water consumption, resource availability and other pollutions. CCS tied with nuclear energy for ninth out of twelve places, with only biofuels ranked below it. Jacobson concluded that CCS is not beneficial (Jacobson 2008). Furthermore, European researchers funded by the European Union research arm found that the life cycle of CCS

will actually produce more GHG emissions than created today because of increased material and energy uses (Dones et al. 2008).

Further Scientific Research Needed

Proposed sequestration sites are complex natural systems that were not designed to be pressurized storage warehouses. Unfortunately, very little is known about subsurface caverns and immense research is still needed to understand how CCS will affect natural systems. The amount of research left to be done is staggering, it equals millions of dollars, will take more than a decade to complete, and without it, public safety is uncertain.

Sequestration projects operating today are industrial projects where monitoring procedures were an afterthought. It turns out that CO₂ storage is turning up “surprises” such as CO₂ mixing with saline, forming carbonic acid, and eating away surrounding rock (MIT 2007). MIT physicist Ernest Moniz says that “the long-term, chemical fate of CO₂ remains to be understood,” (Biello 2008a, 1).

There is a lot of science and engineering involved with understanding the subsurface. It involves geophysical imaging, computer simulation models, and geophysical monitoring systems – and some of these tools still need development and innovation (Benson 2008). CCS proponent Sally Benson told Congress that “convincing answers about safety and effectiveness may not be available for more than a decade,” (2008, 4).

Fortunately, the DOE has prepared a report on the remaining critical questions for CCS.⁹ However, according to the DOE “it will take ‘dream teams’ of highly educated talent...to increase the rate of discovery” (DOE 2008c, 13). The report goes on to list three grand challenges and six priorities for geosciences research, which are attached as Appendix 1.

Liability

In a presentation at MIT, Burt Lauderdale (2008) of Kentuckians for the Commonwealth said, when it comes to CCS, “the first piece of legislation the coal industry wants is liability coverage.” Liability is one of many political decisions that will need to be made about CCS using the incomplete science and opposing research findings. It is also the first major decision to be made; as a result, analyzing it is like a litmus test.

CCS has five categories of risk that shape liability: toxicological effects, environmental effects, induced seismicity, subsurface trespass, and climate effects (di Figueiredo et al. 2006). Without a clear regulatory administration to oversee CCS, the industry is exposed to the legal risk that comes with transporting liquid CO₂ and sequestering it under expansive areas of land. “One of the most significant barriers to

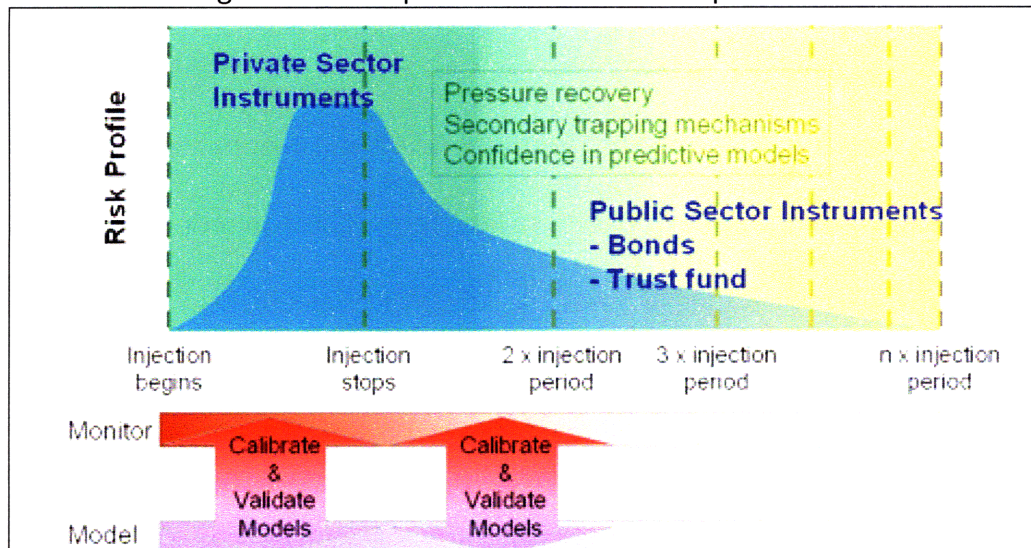
⁹ Those questions include: “Can carbon dioxide be efficiently injected into tiny pores in rocks deep underground? How much of it would be released back to the atmosphere? Would release occur slowly or catastrophically? Can the carbon dioxide be confined to rock formations that have no other use; or might it leak into and permanently foul fresh water aquifers? What is needed to answer these and other important questions are major scientific advances that will allow us to control the injection of carbon dioxide fluids into rock formations so that it goes where we want it to go, and stays there permanently with minimal negative impact on the subsurface environment” (DOE 2007, 9).

large-scale CCS implementation is the definition and management of post abandonment liabilities,” (Bachu 2008b, 267).

The question of who will pay for these risks is still unanswered. Naturally, industry wants the government to ensure long-term liability in order to defray the costs of maintaining and operating CCS storage. The environmental risks associated with long-term storage have created a sense of fear among industry over liability risk. They will not store CO₂ without assurance that the government will cover disaster-related costs, as is done under the Price-Anderson Nuclear Industries Indemnities Act (Goodell 2008).

Academics and advocacy organizations that support CCS, such as the World Resources Institute, have proposed frameworks in numerous articles and books. Their frameworks are typically aligned with industry’s desire to not be liable for long-term storage. For example, Stanford University Professor Sally Benson’s conceptual framework is illustrated in Figure 8.

Figure 8: Conceptual Risk Profile for Sequestration



Source: World Resources Institute. 2007. Liability and Financial Responsibility Frameworks for Carbon Capture and Sequestration. *WRI Issue Brief*, 2007 (3), 1.

How federal and state regulators address liability will have an impact on CCS costs and public perception (di Figueiredo et al., 2006). Currently, EPA’s drafted regulation does not cover liability issues such as property rights, insurance requirements, and financial responsibility (Davis et al. 2008).

CCS is much riskier investment than meets the eye. It has the potential to leak, cause earthquakes, poison aquifers and kill people. It uses more water and creates pollution. Unfortunately, with incomplete research on storage sites and a lack of monitoring systems, it is impossible right now to know CCS’s potential for harm and who will have to pay for it. The science will take another decade, and after that regulators will take another long time development legal frameworks. The risks may not be fully understood and planned for until 2020, much too late for CCS to be a practicable solution for climate change.

Public Acceptance

The opportunity for CCS to be framed as a solution exists because U.S. citizens know very little about it. In Europe, where CCS demonstrations are further along and there is a carbon price creating incentives for CCS, studies of public perception have shown that the general public is “reluctant rather than enthusiastic about CCS and that ‘not in my back yard’ [NIMBY] feelings play a role” in the reluctance (Metz and De Coninck 2007, 169). While numerous studies of public perception on CCS have been conducted in Australia, Canada, Europe and Japan, there have been few studies conducted in the U.S.

In fact, most of the published academic articles about CCS and public perception can be linked to one author at MIT, Howard Herzog. He is the program manager for MIT’s Carbon Sequestration Initiative and an active proponent of CCS. In 2004, a member of Herzog’s lab conducted a survey of approximately 1,000 people found that few U.S. citizens had ever heard of CCS. In 2007, Clark University Professor Jennie Stephens invited more than 100 stakeholders in Wiscasset, Maine, to learn about CCS from experts during a day-long seminar. Surveys were given before and after the seminar to determine changes in perception (Stephens 2008). DOE, MIT, and Princeton representatives all made presentations, and admittedly all were “enthusiastic about CCS and presented a very positive story” (Stephens 2009). Survey results indicated that after the presentations, stakeholders agreed that they had more concerns about CCS technology than before. Stephens noted the results could have been drastically different if stakeholders thought carbon storage was going to occur in their

neighborhood. Instead, stakeholders were told that CCS would not be viable in Maine, after which they seemed more relaxed and asked fewer questions (Stephens 2009). In 2009, a third approach to measure public perception was used by Howard Herzog and his graduate student, Gregory Singleton. They noted that earlier surveys could not accurately measure attitudes toward CCS and earlier informational sessions, like the one in Maine, were biased. Instead, they forecasted CCS public perception using theoretical risk models. They found that sequestration will be perceived as having higher risk than fossil fuels, asbestos, and pollution from coal combustion, while noting that there is insufficient data to be completely conclusive (Singleton, Herzog and Ansolabehere 2009).

As of today, very little data is available about how communities will perceive risk when storage sites will be located beneath them (Shackley et al 2006). The DOE regional partnership programs do include an element of public education; however, assessment data on those programs is not publicly available. Upcoming demonstrations plan to incorporate public meetings and stakeholder activities, though the DOE does not explain what will occur during the activities nor how the results will be used. For example, Duke Energy plans to hold a public meeting and continue stakeholder communication for their demonstration in Indiana (Radcliffe 2008). AEP will hold meetings that are required under permitting processes including town hall meetings with local leaders and meeting (Hammond 2008). How these projects will incorporate stakeholder feedback is unknown, as is how perception will affect implementation.

In Europe, where public perception has been more thoroughly documented, CCS proponents recognize that perception of CCS is unpredictable and malleable. CCS proponents recognize that advocates and the media can shape perception about the environment, as was the case with public reaction to Brent Spar and genetically modified organisms (GMOs) (Shackley et al 2006). Previous protests and media criticisms have created a sense of vulnerability among industry and governments pushing CCS. That is why numerous CCS researchers have stated that the story of CCS must be linked with climate change (Shackley, et al 206; Singleton et al 2009; Stephens 2006) instead of allowing it to be linked to the continued use of coal. Concern about negative public perception may also explain why there has been little research done on it.

THE POLITICAL BATTLE OVER CCS IN THE U.S.

A realistic assessment of the costs, risks, feasibility, and public acceptance suggests that CCS is not likely to enable us to use coal-fired power plants while mitigating climate change. Why, then, do U.S. legislators, industries, and advocacy organizations continue to package CCS as a solution? The reason is that coal is a high stakes political issues. Coal and utility companies have the resources to craft and disseminate their “clean coal” story. Many politicians are aligned with the story because it makes it easy to postpone difficult economic decisions. Meanwhile, environmentalists are divided, and those who are skeptical have struggled to come up

with an effective counter-story—one that would mobilize the public sufficiently so that politicians can challenge CCS proponents.

Overview of CCS in the U.S.

In addition to the challenges CCS faces when it comes to feasibility and costs, the case of the sole U.S. CCS demonstration, formerly known as FutureGen, highlights many of the political barriers to developing a national CCS system. In 2003, the DOE joined with industry to form the FutureGen Alliance in order to build an IGCC plant with pre-combustion carbon capture technology. The project was canceled five years later (Mufson 2008). FutureGen's had several goals: demonstrate by 2012, capture 90 percent of CO₂, store 99 percent of CO₂, and increase energy costs by no more than 10 percent (DOE Roadmap 2007). According to the DOE, "the technologies developed in this program will also serve as test components in the FutureGen Initiative, aimed at building the first power plant in the world to integrate permanent carbon storage with coal-to-energy conversion and hydrogen production" (DOE Roadmap 2007, 5).

FutureGen was important to the DOE because they hoped to use the demonstration to prove that costs, which have been perceived as the largest barrier to CCS investment and deployment, would be less than predicted. The DOE estimated that existing CCS technology costs were between \$100 to \$300 per ton of carbon avoided and that FutureGen would reduce that cost to \$10 or less by 2015 (Peltier 2003). However, the DOE failed to demonstrate cost reductions; in fact, journalist Steven Mufson reported that "Deputy Energy Secretary Clay Sell said the administration was

dropping the FutureGen Alliance project because costs for the planned 275-megawatt coal-fired plant had risen to \$1.8 billion and because of advances in technology” (2008, 1). The DOE had already spent \$50 million dollars and selected a site in southern Illinois for the project (Biello 2008). However, in 2009 the DOE claimed that it had overestimated the cost of FutureGen due to a “math error” (Wald 2009, 2). Allegations have also emerged that FutureGen was cancelled because industry alliance members were unwilling to share the cost burden. The General Accountability Office (GAO) and Congress are currently investigating these allegations (Kindy 2009).

FutureGen’s expanding costs and subsequent cancellation illustrate the challenge CCS faces proving it will be a cost-effective or even an affordable solution. Without a price on carbon, CCS will not be financially viable. In June 2008, the Senate defeated the Lieberman-Warner Climate Security Act which proposed a price on carbon through cap-and-trade.

During these decisions in 2008, an energy policy window was opening because of high fuel prices and the presidential campaign. As a result, controversy over CCS reached a fever pitch. Both pro-coal and anti-coal advocates launched advertising campaigns.¹⁰ Both environmental groups and fossil-fuel companies released research reports bolstering their claims that CCS will or will not work.¹¹ Major electric utilities

¹⁰ Americaspower.org launched national television ads, they are sponsored by American Coalition for Clean Coal Electricity (Americaspower.org 2008); The Reality Coalition launched an aggressive ad campaign in December 2008, members included Alliance for Climate Protection, National Wildlife Federation, NRDC, and League of Conservation Voters (Thisisreality.org 2008).

¹¹ Greenpeace published “False Hope: Why Carbon Capture and Storage Won’t Save the Climate” in May 2008, Sierra Club’s launched Coalisnottheanswer.org in October 2008; Sweden’s Air Pollution and Climate Secretariat published “Last Gasp of the Coal Industry” in October 2008.

and coal-mining organizations lobbied the House of Representatives to pass a Carbon Capture and Storage Early Development Act.¹²

As of February 2009, the idea of a U.S. demonstration has been resurrected, and there is a good chance that it will take the form of FutureGen. The American Reinvestment and Recovery Act awarded \$3.4 billion to the DOE's Office of Fossil Energy for the development of clean coal technologies (DOE 2009). There has not been an official announcement as to how the money will be spent, but there are indications that it will fund FutureGen. During joint negotiations for the Recovery Act, the House and Senate agreed on language that described a FutureGen-like project with the caveat that \$1 billion could be used for other projects (Kindy 2009). On March 5, 2009, Energy Secretary Steven Chu told a Senate committee that he would support reprising FutureGen with a few modifications. Senator Tom Coburn told the *Washington Post* that the money was an obvious earmark for FutureGen (Kindy 2009).

In March 2009, a bill proposing a carbon price was reintroduced in Congressional subcommittees. Representatives Henry Waxman and Ed Markey drafted the American Clean Energy and Security Act (ACES), which mandates a 17 percent reduction in 2005 carbon levels by 2020 through a cap-and-trade mechanism. Debate on the bill begins May 18.

Compared to Europe, the US is severely behind on the trajectory necessary to establish a CCS infrastructure. In December 2008, the EU established a directive to

¹² HR Bill 6258 is supported by Duke Energy, Progress Energy, American Electric Power (AEP), Dominion Power, Southern Company in addition to the National Mining Association and the United Mine workers of America (Sheppard 2008).

create a CCS legal framework and to use €6 billion of ETS set-asides to fund 10-12 CCS demonstrations by 2015. In April 2009, England announced a moratorium on coal plants that do not have CCS. England plans to build four demonstrations while The Netherlands plans to build one (Hogan 2009).

Actors Packaging the CCS Solution

Throughout CCS's history in the U.S., there have been a number of actors from various arenas involved in packaging its hopeful story as a solution. On the industry side are utilities that currently use coal and coal mining companies whose profits are threatened by legislation putting a price on carbon. They are joined by oil and gas companies that see sequestration as a strategic opportunity because they have experience in subsurface geological businesses. Many of these industries are represented by lobbying organizations such as the ACCCE.

In the political arena, there are legislators and regulators with difference interests. Some legislators are interested in protecting their regional economic interests in coal development while others are interested in protecting the environment with carbon policies. CCS is also important to regulators at the DOE and Environmental Protection Agency (EPA). Under the Bush Administration, the DOE was pro-CCS. They invested billions of dollars in CCS research and development, and identifying geologic sinks. It appears DOE will continue on this path because on May 15, 2009, DOE Secretary Steven Chu told the National Coal Council that the DOE will "expand and accelerate" CCS technology (DOE 2009b). For almost forty years, EPA has regulated

pollution from electric utilities and fluids injected into subsurface areas. Under the Bush Administration, the EPA was not allowed to regulate CO₂ emissions under the Clean Air Act. That has since been reversed and EPA is preparing regulation. Thus far, the EPA has played only a minor role shaping the CCS story by announcing injection regulatory framework.

Researchers in academia and at national laboratories are usually considered experts on CCS. In this arena, expert researchers are typically proponents of CCS. Additional actors packaging CCS as a solution include international governing bodies, and the media. Since 2000, media coverage of CCS has generally framed CCS as an engineering solution that the coal industry is pursuing. Articles rarely appear in popular media outlets. After the Recovery Act and environmental advocacy advertising campaigns, a more investigative tone emerged in media coverage questioning whether CCS was a good idea or investment. Articles questioning the feasibility of CCS appeared on the ABC Evening News, CBS *60 Minutes*, and in *The Economist*.

Coal, Oil and Gas Influence on Society and Politics

An ad sponsored by the ACCCE (2008b) touts, “Throughout history, new ideas have often been met with skepticism, but technology born from American ingenuity can achieve amazing things. We’re committed to a future in which our most abundant fuel, coal, generates our electricity with even lower emissions including the capture and storage of CO₂.” Although the feasibility, risks, costs and public acceptance shed doubt on the role CCS can play as part of the solution, the CCS story enables the coal industry

to have a future after CO₂ emission legislation is enacted. Policy changes that affect the coal industry have great costs in terms of dollars and people, and are therefore considered high stakes. CCS is part of the greater policy battle over the continued use of coal.

Coal mining accounts for approximately .3 percent of the U.S. GDP while utility generation from all fuel sources accounts for 2.0 percent. With such large financial stakes based on CO₂, leaders of coal-fired utilities have created legislative agendas so that they may be included in policy changes. In an interview with Frontline, AEP CEO Michael Morris said, "I am certain we'll get our voice heard" (Morris 2008).

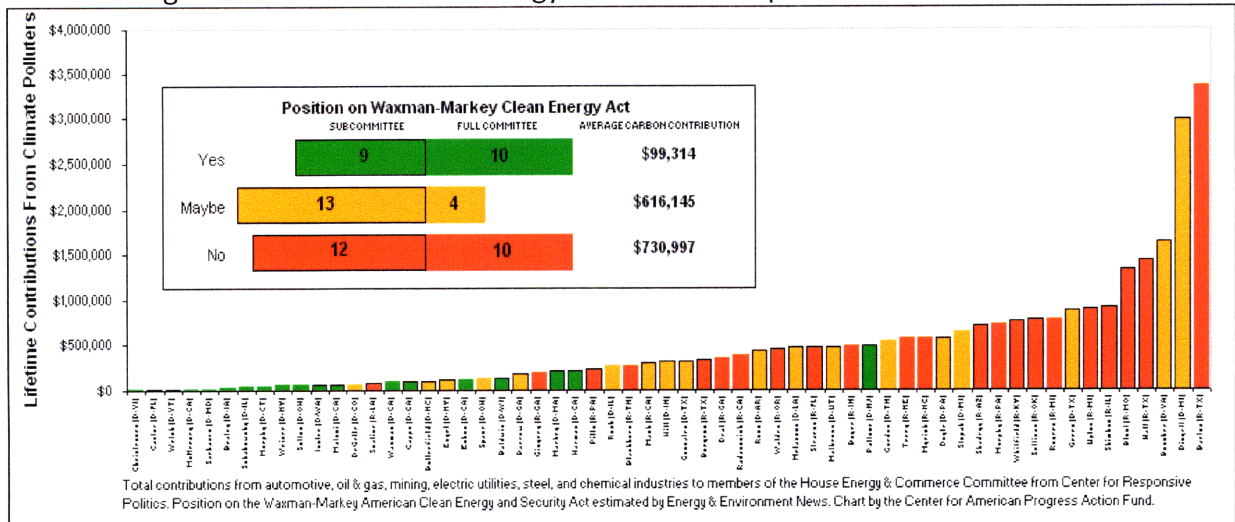
"The whole notion of a viable future for coal in a climate-constrained world hinges on the viability of CO₂ storage on a gigascale," says Princeton Professors Robert Williams (Goodell 2006, 222). With their viability at stake, the coal industry is vehemently publicizing CCS. The coal industry understands that they can maintain power by generating and repeating "a consistent set of attractive, coherent messages," (West and Loomis 1998, 8). In order to create an attractive campaign for coal dependence and CCS, the ACCCE has established the America's Power project. Public policy scholars Darrell West and Burdett Loomis note that "the ability to deliver a message has become increasingly dependent on the ability to pay for that delivery as well as to create content," (West and Loomis 1998, 8). The ACCCE has proven it is flush with funds to deliver its message.

They spent \$40 million in 2008 on advertising and \$1.7 million at the Democratic and Republican National Conventions (Sourcewatch.org 2009a). The money was raised

from member companies in the mining, transportation and utility sectors (Why Clean Coal 2009). They are joined by oil and gas companies who have funded the FutureGen alliance and numerous academic studies. A *Washington Post* analysis found that members of the alliance donated \$3 million to congressional and presidential candidates in 2008 and more than \$20 million was spent lobbying congress on FutureGen and other clean coal issues (Kindy 2009).

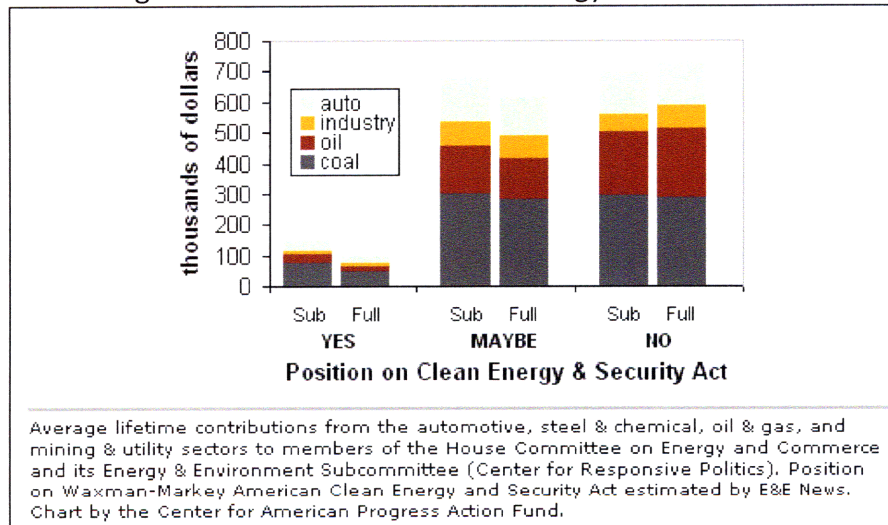
In addition to repeating their message, the industry is also trying to directly influence legislators through campaign contributions. There is ample evidence that utilities, coal companies, oil and gas companies in addition to auto and steel companies are financing votes against Waxman and Markey's ACES bill. The Center for American Progress analyzed campaign contributions for subcommittee members who will debate and markup the bill. They found that millions more has gone to Representatives who are likely to defeat the bill, as illustrated in Figure 9. Coal companies have made the majority of the contributions, as demonstrated in Figure 10.

Figure 9: Carbon Cash to Energy Committee Shapes Climate Debate



Source: Center for American Progress. *Think Progress*.
<http://thinkprogress.org/2009/05/12/carbon-cash/>

Figure 10: Average Pollution Contributions to Energy Committee Members



Source: Center for American Progress. *Think Progress*.
<http://thinkprogress.org/2009/05/12/carbon-cash/>

Coal is a deeply political issue that affects many legislative decisions, even without incentives from campaign contributions. Coal accounts for approximately 174,000 jobs in mining, transportation, and power generation (Sourcewatch.org 2009b). It is mined in 25 states (EIA 2008) and generates more than 50 percent of electricity in

25 states (Americaspower.org 2009). The number of states with a coal-mining tradition or a dependence on coal-fired power plants means that protecting coal is a local and regional concern for many legislators. Coincidentally, of these states are political swing states such as Pennsylvania, Colorado, Ohio, and Indiana. It was essential that both Presidential candidates supported clean coal technologies during the 2008 campaign. “In order to run for president in this country, in 2008, you have to be for clean coal, you can’t go to Indiana and Ohio and say you want to do away with clean coal, you are not going to win votes that way” (Pooley 2007).

There is evidence that the influence of the coal lobbying organizations has reached the highest levels of government. Before Barack Obama was president he said, “So, if somebody wants to build a coal plant, they can - it’s just that it will bankrupt them, because they are going to be charged a huge sum for all that greenhouse gas that’s being emitted” (Hodge, 2009). He changed his story during the primary and said he would support CCS funding “if we can figure out a way to provide coal-generated power cleanly.” Just a few months later, as the official Democratic candidate, he changed his story again and said “there is no reason why we can’t invest in CCS” (Power 2008). ACCCE President Steven Miller calls the day Obama dropped “if” a victory for coal (Power 2008).

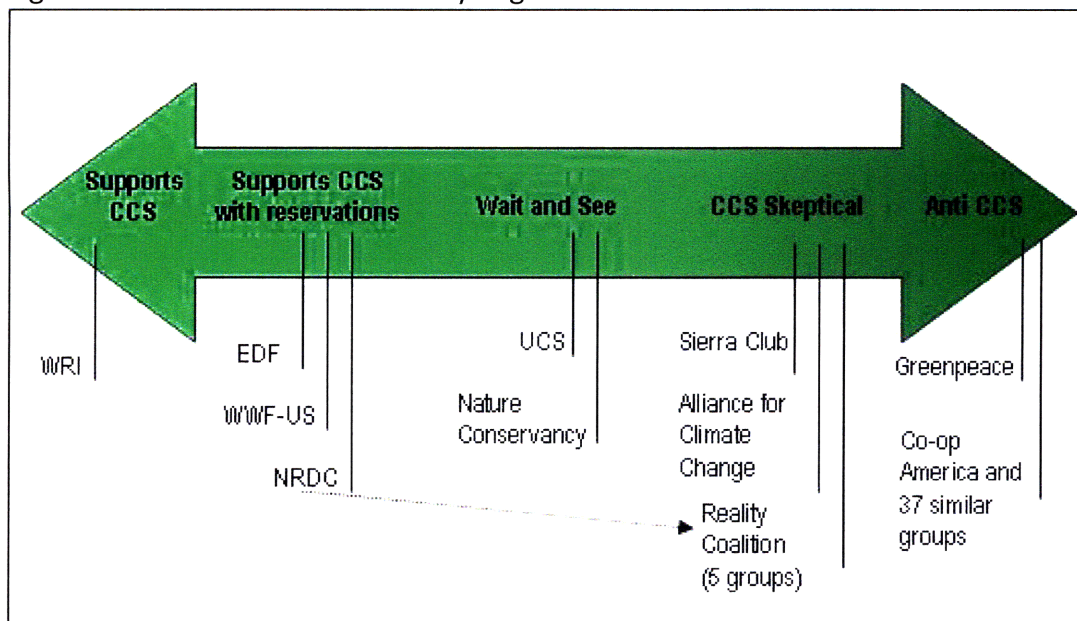
Miller also believes that he single-handedly change Vice-President Joe Biden’s position on clean coal. On the campaign trail, then-Senator Joe Biden suggested that his ticket would not support CCS. Miller called Biden’s office asking for a clarification and

then sent out warnings to coal-heavy swing states. Within three days, Biden said he supported clean coal (Power 2008).

Environmental Advocacy Organization Are Split on Message

The lack of public knowledge and the well-funded campaigns by industry is an opportunity for environmental advocacy organizations to persuade the public that CCS is not a solution for climate change. Yet, that has not been the case because environmental advocacy organizations have not agreed on their CCS positions, or have been hesitant to form positions. Generally, the mainstream environmental organizations have one of four positions on CCS: they believe it is a climate change solution, they are waiting for more certainty, they believe it is a myth, or they are anti-CCS. Organizations can overlap on these positions. There is an important nuance between the latter two groups—myth and anti-CCS. Groups who assert the myth position believe CCS is an untrue message from the coal industry whereas the anti-CCS position asserts that CCS, no matter its reality, should not be part of the solution. Until recently, a lack of consensus, as illustrated in Figure 11, among groups resulted in a fractured approach to framing CCS.

Figure 11: Environmental Advocacy Organization's Positions on CCS



Source: Compiled based on statements from organization's web pages in 2009.

When CCS began to be framed as a climate change solution in the early 2000s, the major environmental advocacy organizations—such as the Sierra Club, the Union of Concerned Scientists (UCS), and the U.S. World Wildlife Fund (WWF U.S.)—did not take official positions because they were torn between skepticism about CCS and the need to shift to energy technologies that would reduce climate change impacts. They remained silent for a variety of reasons. One reason was that the technology was highly uncertain and the groups demonstrated a “cautious hesitancy” (Verma and Stephens 2006). Another reason was the desire for more analysis so they could determine if CCS was as green as renewable technologies.

Since then, these organizations have taken firmer positions on CCS, but still remain cautious, demonstrated by their reluctance to oppose CCS directly, choosing instead to question aspects of it. In 2008, the Union of Concerned Scientists released a

report, *Coal Power in a Warming World*, acknowledging CCS risks including technological breakthroughs, soaring costs, and environmental impacts like the potential for increased atmospheric carbon if the country continues to use fossil fuels. However, the report recommended further research and development on CCS and did not suggest a time frame for deciding CCS's future (UCS 2008).

In 2007, the Sierra Club launched the "Move beyond Coal" campaign to prevent construction of new coal plants and encourage retiring existing coal plants. Though the Sierra Club is anti-coal, they have been very careful to never publish or assert that CCS should not be part of the solution if it actually works—though they do not believe it will. In their report, *The Dirty Truth About Coal*, they say that CCS is an unproven technology with an unknown timeframe (McKeown 2007). They are more tactful in their approach and instead contend that "clean coal" is a myth (Sierra Club 2008).

WWF U.S. has not established an official position on CCS either (WWF in the United Kingdom and Australia support CCS). But WWF U.S. joined other WWF chapters in evaluating CCS in the 2007 report, *Climate Solutions: WWF Vision's for 2050*. The report described CCS as a mitigating technology for climate change while also recognizing concerns with feasibility, scalability, and costs (Mallon et. al 2007).

Only recently have several large environmental organizations begun to take strong positions against CCS. "Advocates are most effective when they form broad coalitions," but in the case of CCS – they have formed two different coalitions, lessening their effectiveness (Layzer 2006, 12). The two coalitions are formed around the "clean coal" myth or being anti-CCS. Greenpeace is the main organization characterizing CCS

as horrific problem and they are anti-CCS. In 2008, Greenpeace released a report, *False Hope*, which called CCS an unproven technology that will not be ready in time – a similar characterization to that of the UCS and The Sierra Club. However, Greenpeace established its anti-CCS position by saying that “concerns about the feasibility, costs, safety and liability of CCS make it a dangerous gamble” (Greenpeace 2008, 5).

Furthermore, Greenpeace joined 38 smaller organizations in sending a letter to Congress asking that no taxpayer funds be used to develop CCS.¹³ Three of these organizations were also responsible for organizing a protest against coal outside the coal-burning Capitol Power Plant in Washington D.C. on March 2, 2009. Anti-coal advocates including Robert F. Kennedy Jr., Bill McKibben, and James Hansen joined the 2,500 protestors, making it the country’s largest protest against coal power (Sheppard 2009).

The Reality Coalition is leading member organizations in characterizing clean coal technologies as a myth. The coalition is made up of the Sierra Club, National Resource Defense Council (NRDC), Al Gore’s Alliance for Climate Protection, the League of Conservation Voters, and the National Wildlife Federation. It has led a national

¹³ The 39 groups include: ActionPA, Alliance for Appalachia, Appalachian Voices, Black Mesa Water Coalition, California Communities Against Toxics, Canary Coalition, Cape & Islands Self-Reliance Corporation, Center for Coalfield Justice, Co-op America, Chesapeake Climate Action Network, Citizens Action Coalition of Indiana, Clean Power Now, Coal River Mountain Watch, Cook Inletkeeper, Energy Justice Network, Environmental Alliance of North Florida, Environmental Research Foundation, Friends of the Earth, Global Exchange, The Grand Canyon Trust, Green Delaware, Greenpeace, Heartwood, Help Our Polluted Environment, Indigenous Environmental Network, Jefferson Action Group, Kentuckians for the Commonwealth, Meigs Citizen Action Now, Mountain Watershed Association, North Carolina Waste Awareness & Reduction Network, Nuclear Information and Resource Service, Ohio Valley Environmental Coalition, Palm Beach County Environmental Coalition, Protect Biodiversity in Public Forests, Rainforest Action Network, Residents Against the Power Plant, Rising Tide North America, Save It Now, Glades!, Save Our Cumberland Mountains, Southern Energy Network, and Valley Watch. (Rainforest Network 2008).

advertising campaign that questions clean coal's message. The coalition's purpose is to challenge the coal industry's catchphrase "clean coal" by revealing that there is nothing clean about coal operations today (Thisisreality.org 2008). The Reality Coalition does not want new coal plants built in the U.S. unless they can capture CO₂, which is not currently feasible.

Although they characterize "clean coal" as a myth, the Reality Coalition does not criticize CCS—not all of coalition members oppose CCS. For instance, The Reality Coalition's Web page seems to endorse CCS by saying "coal cannot be called 'clean' until its CO₂ emissions are captured and store safely" (Thisisreality.org 2008). Yet the web page also quotes IPCC Chairman, Dr. Rajendra Pachauri, as saying that action after 2012 is too late to solve climate problems, and CCS will be demonstrated after 2012.

Environmentalists adopt this conciliatory approach because they believe that coal plays a critical role in the U.S. energy sector and that by endorsing CCS (or not opposing it) they can avoid fighting the coal industry. The myth position is best explained by Environmental Defense Fund (EDF) director Mark Brownstein, who told *Scientific American* that "environmentalists are talking about coal not because we love coal, it's because we have to deal with coal in order to achieve the kind of CO₂ reductions we need to make in the time frame we need to make them" (Biello 2009, 1). Instead, by endorsing CCS, some environmental advocacy organizations, like EDF and NRDC, believe they are bringing coal industry into the greater climate change debate and the inclusive approach will be more effective in the long run.

The case of NRDC as a CCS proponent who believes clean coal is a myth illustrates the complicated role environmental advocacy organizations are facing. David Hawkins, director of NRDC's climate center and respected environmental leader, came out in favor of CCS in the mid-1990s. He has spoken and written about its many qualities and is often cited as the environmental advocate in industry-funded reports about CCS. He was an advisory committee member on MIT's *Future of Coal* report. Additionally, NRDC's legislative director, Michael Goo, commended Congress in 2008 for accelerating CCS deployment efforts and supported bonus allowances for CCS under cap-and-trade and federal price subsidies (Goo 2008). Coal lobbying firms have used NRDC's support of CCS and their environmental brand to legitimize CCS as a green option. For example, ACCCE's blog, "Behind the Plug," reprinted NRDC's call for more federal funding and said "[they] know coal will remain an important fuel for years to come" (Americaspower.org 2009). This is all part of what Hawkins calls a 'grand bargain,' where the coal industry accepts emissions caps and regulation while environmentalists support their permits and ask for federal assistance (Goodell 2006).

Concurrently, Hawkins and the NRDC are trying to undermine the clean coal story. The NRDC is part of the Reality Coalition, who released a national commercial that questions the coal industry's authenticity on 'clean coal.' In the ad, a person tours a clean coal facility that is a desolate desert – illustrating clean coal does not exist. When Greenpeace released *False Hope*, Hawkins told the coal industry that he did not agree with the entire report but it was time the industry acknowledged environmental impacts of CCS (Nace 2008). The organization recognizes that CCS is a bargaining tool

that brings coal and industry stakeholders to the climate change table (Stephens 2009). Yet according to Peabody Energy's spokesperson, Vic Svec, "it's fair to say that Hawkins's real agenda is not to promote IGCC, but to shut down the coal industry," (Goodell 2006, 217).

Implications for Public Mobilization

As a result of the powerful industry message and deep pockets combined with the fractured story from environmental advocacy organizations, there is no public mobilization against CCS. In the environmental movement, advocates traditionally used stories and symbols to quickly inform the general public about problems (Layzer 2006). In the case of CCS, the story-telling tactic has been used by the coal and utility industry and they have persuaded the public that the U.S. dependence on coal is ingenious, patriotic and secure. Environmental advocates are racing to catch up by painting "clean coal" as a myth. Even though CCS cannot make a meaningful contribution to preventing climate change because of its feasibility, costs, and risks, without public mobilization, there is no incentive for politicians to take on coal.

CONCLUSIONS

CCS is not the solution for continuing coal use in a carbon constrained world, even with the most generous timeframes and goals for maintaining a livable planet, 550 ppm by 2050. The technology infrastructure is not feasible within that timeframe. It also carries significant costs and environmental risks such that investors will choose other, easier options, and the public will resist the technology.

Yet, CCS remains part of U.S. energy policy because the coal and electric utility industries crafted an affective message characterizing CCS as an easy, patriotic solution. Environmental advocacy organizations have been unable to craft an effective counter-story because instead of forming one coalition they have formed two around separate positions—CCS as a myth and anti-CCS. As a result, the public is not mobilized and there is not incentive for legislators to challenge the coal tradition in Washington.

In order to maintain business-as-usual, the coal and utility industry has packaged CCS as a solution, but it is false sense of security that will have serious ramifications. The story allows the U.S. to continue a dependence on coal, invest in an unpractical solution, and further delay making tough decisions that will preserve a livable planet.

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APPENDIX 1

Geological Research Needs by DOE

Adopted from DOE Report 2007 Executive Summary

Needs	Reason	Outcome
Grand Challenges		
<i>Computational thermodynamics of complex fluids and solids.</i>	Predictions of geochemical transport in natural materials must start with detailed knowledge of the chemical properties of multicomponent fluids and solids.	
<i>Integrated characterization, modeling, and monitoring of geologic systems.</i>	Characterization of the subsurface is inextricably linked to the modeling and monitoring of processes occurring there.	
<i>Simulation of multiscale geologic systems for ultra-long times.</i>	Anthropogenic perturbations of subsurface storage systems will occur over decades, but predictions of storage performance will be needed that span hundreds to many thousands of years, time scales that reach far beyond standard engineering practice.	
Priority Research Directions		
<i>Mineral-water interface complexity and dynamics.</i>	Natural materials are structurally complex, with variable composition, roughness, defect content, and organic and mineral coatings. There is an overarching need to interrogate the complex structure and dynamics at mineral-water interfaces with increasing spatial and temporal resolution using existing and emerging experimental and computational approaches.	The fundamental objectives are to translate a molecular-scale description of complex mineral surfaces to thermo-dynamic quantities for the purpose of linking with macroscopic models, to follow interfacial reactions in real time, and to understand how minerals grow and dissolve and how the mechanisms couple dynamically to changes at the interface.
<i>Nanoparticulate and colloid chemistry and physics.</i>	Colloidal particles play critical roles in dispersion of contaminants from energy production, use, or waste isolation sites.	
<i>Dynamic imaging of flow and transport.</i>	Improved imaging in the subsurface is needed to allow <i>in situ</i> multiscale measurement of state variables as well as flow, transport, fluid age, and reaction rates.	
<i>Transport properties and in situ characterization of fluid trapping,</i>	Mechanisms of mobilization of injected CO ₂ include buoyancy trapping of fluids by geologic seals, capillary trapping of	Specific advances will be needed in our ability to understand and represent the interplay of

<i>isolation, and immobilization.</i>	fluid phases as isolated bubbles within rock pores, and sorption of CO ₂ or radionuclides on solid surfaces.	interfacial tension, surface properties, buoyancy, the state of stress, and rock heterogeneity in the subsurface.
<i>Fluid-induced rock deformation.</i>	CO ₂ injection affects the thermal, mechanical, hydrological, and chemical state of large volumes of the subsurface.	Accurate forecasting of the effects requires improved understanding of the coupled stress-strain and flow response to injection-induced pressure and hydrologic perturbations in multiphase-fluid saturated systems.
<i>Biogeochemistry in extreme subsurface environments.</i>	Microorganisms strongly influence the mineralogy and chemistry of geologic systems. CO ₂ and nuclear material isolation will perturb the environments for these microorganisms significantly.	Major advances are needed to describe how populations of microbes will respond to the extreme environments of temperature, pH, radiation, and chemistry that will be created, so that a much clearer picture of biogenic products, potential for corrosion, and transport or immobilization of contaminants can be assembled.