



INSTITUTE OF
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**CARBON CAPTURE CONTROL
TECHNOLOGY
FOCUS PAPER**

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Forward: This focus paper attempts to leverage the collective expertise of our member companies to inform the policy debate on the quickest and most cost-effective way to commercialize carbon capture (CC) technologies and processes for both new and existing coal-fired electrical generating units (EGUs) in the U.S.

Our observations for bringing CC to commercialization are based on our experience with the commercialization path for the current suite of air pollution control technologies that reduce emissions of both the criteria pollutants and their precursors, and hazardous air pollutants. Except for monitoring capabilities, our member companies' technical expertise does not extend to the sequestration issues of transport and storage.

When the federal government moves forward with greenhouse gas (GHG) control legislation or regulations, we think the following Key Considerations should be kept in mind:

- 1) Less efficient carbon capture technologies, but not integrated with storage, have been demonstrated at the small-scale (<50MW).
- 2) Six to eight CC demonstration projects, integrated with storage, in the U.S. by 2015 will establish the commercial marketability of CC technology by our member companies for their utility customers.
- 3) Our definition of a CC demonstration project is processing the flue gas from at least 200-300MW and capturing more than 50% of the CO₂. An alternative metric is capturing at least 300,000 tons per year of CO₂.
- 4) Financial incentives and regulatory certainty will accelerate the timeline to achieving commercially marketable CC technologies.
- 5) First movers galvanize the commercialization of CC technology; they face higher costs than those who wait for others to act. Therefore, it is an appropriate use of federal funds to spur the advancement of CC technology and to offset the financial penalty that first movers face for taking the initiative.
- 6) Early distribution of funding is paramount to meet the 2015 date as the lead time and duration of the demonstration projects is 3-5 years. In the absence of federal cap-and-trade legislation, accelerated funding via assessments on retail consumers of fossil-fuel based electricity on the order of \$1 billion per year for ten years with targeted, stand-alone legislation should be considered as a placeholder to provide a clear path to incentivizing CC demonstration projects.
- 7) Increasing supply side energy efficiency is a necessary first step to satisfy near-term GHG stabilization and reduction goals. Therefore, the U.S. Environmental Protection Agency needs to determine a mechanism or framework for the existing fleet to prepare for CC retrofits.
- 8) Non-CO₂ GHG industrial sources represent a near-term opportunity to retrofit existing sources using a wide range of commercially demonstrated technologies that do not rely on CCS
- 9) Continued long-term public and private investment in CC technology is vital to the success of stabilizing atmospheric CO₂ concentrations.

I. ICAC Introduction

The Institute of Clean Air Companies (ICAC) is the national trade association of over one hundred companies that supply air pollution control and monitoring technologies for all stationary sources, including electric power plants and other large industrial facilities. For the nearly 50 years of its existence, ICAC and its member companies have installed the air pollution control equipment that has resulted in significant absolute reductions in emissions of both criteria and hazardous air pollutants and their precursors despite enormous economic and population growth in the U.S. during that time period. The current annual air pollution control market, including equipment and reagents, is about \$4 billion, and is expected to increase to nearly \$6 billion in 2012.¹

Despite the success of the air pollution control (APC) industry to date, possibly its biggest technical challenge still looms – the deployment of technology for capturing the millions of tons of carbon dioxide (CO₂) emitted from the coal-fired electrical generating units (EGUs) that contribute to anthropogenic CO₂ in the atmosphere. In the traditional RDD&D (Research, Development, Demonstration, and Deployment) pathway for technical innovation, what is now needed, as of the last half of 2009, is the regulatory certainty that will provide the policy objectives and financial incentives for “Demonstration” (6-8 projects allowing commercial marketability) which can ultimately be ramped up to the “Deployment” (many large-scale projects) phase. The multi-faceted challenges and opportunities to reduce or eliminate anthropogenic GHG emissions will require the collective energy and knowledge of many industries and stakeholders, and we at ICAC stand ready to do our part.

II. Economic Impacts and Job Creation Potential of CC Implementation

The National Coal Council (NCC) and others have reported on the breadth and reach of the coal industry throughout the U.S. economy. Direct jobs come from mining, transportation (rail / truck) and power plant operations. Indirect jobs come from the support of these operations both from the local communities, services and equipment/supplies. Secondary economic activity comes from universities, national labs, and research organizations that develop the talent and inventions that allow for cleaner and more efficient use of the largest indigenous and secure energy source in the U.S.

This investment in CC technology will also spur extensive job growth and economic stimulus:

- The \$10 billion invested over ten years due to Section 114 of H.R. 2454 will stimulate \$36 billion in economic output and \$12 billion in labor income from the construction phase and 7,500 permanent jobs throughout the economy from ongoing CC operations and maintenance.
- Section 115 bonus allowances in H.R. 2454 (4.6% of total) would support 72GW CC capacity according to EPA’s June 2009 analysis of H.R. 2454, but would replace only one-fourth of the U.S. coal fleet. The construction of

72GW of CC capacity would yield \$266 billion of total labor and add 152,500 jobs throughout the economy from ongoing operations and maintenance.

- Substantial job and economic benefits are associated with an expanded allocation of CC bonus allowances. For example, increasing the bonus allowances to 7% of the total would support 100GW of CC capacity, yield \$370 billion of total labor from construction alone, and add 235,000 jobs throughout the economy from ongoing operations and maintenance.²

III. Carbon Capture: Commercial Availability

New technology development requires the rigors of proven development paths: lab-scale discovery and proof of concept; pilot scale proof of engineering; and commercial-scale demonstration. Each is important and has its own specific purpose, and short-cutting or skipping steps can increase future risk. Carbon capture and storage is a technology that has followed this path and is now in the phase of commercial-scale demonstration. This phase is the most critical, and capital intensive, and requires a push from technology providers and a pull by power plant owners and government funding. The success of these demonstrations will lead to the first-movers (or early adopters) to start building the first wave of commercial plants. This has been outlined by the Coal Utilization Research Council (in their Five Point Coal w/CCS Program). Since the lead time and duration of these demonstrations can be 3-5 years, action must be taken now if the U.S. is to meet expected CO₂ reduction goals in 2030.

It has been shown by Carnegie Mellon University (Rubin) and others that the true cost reductions in new technology do not occur until they are deployed at-scale and in sufficient quantity. This cost reduction (estimated to be 40-50% for CCS by 2030) comes not solely due to R&D, but to many other factors. These include: learning by doing (engineering and construction), learning by using (operations and maintenance), supply chain (shop capacity, mass production), competition (more sub-vendors for major equipment) and economies of scale (optimal unit sizing). R&D is still important to find the next generation of solutions beyond 2030, but for the near-term, we have the technology required to get the job done. Commercial demonstration and first-mover plants are needed, now.

Following a successful demonstration phase, and early adopter deployments, commercial availability would include: confidence in the core technology, assurances the plant will operate as designed and that emissions levels are acceptable, and confidence the plant is safe to operate. In essence financial and technical risks are mitigated or managed.

1) Near Term Technologies

a. Industrial CO₂ Non-CO₂ GHG Sources

There are non-energy producing industrial sources of CO₂ and non- CO₂ emissions in which regulatory certainty will provide opportunities for controlling greenhouse gases.

All those highlighted are commercially demonstrated, or are in final full scale demonstration to allow adoption by 2012.

Scrubbing CO₂ from natural gas production using an amine solvent, and then either sequestering the CO₂ or using it for enhanced oil recovery, is commercially demonstrated. For more than 10 years in over 200 gas treatment plants around the world, this process absorbs CO₂ from natural gas by means of a special amine-based solvent and then collected for underground storage, including depleted natural gas or oil reservoirs. Also, converting thermal systems to catalytic systems for VOC abatement can improve energy efficiency and lower CO₂ emissions.

The control of non-CO₂ greenhouse gas emissions is significant, due to their global warming potential (GWP) as a greenhouse gas. The GWP of non-CO₂ greenhouse gases range from 21 -24,000 times more potent than CO₂. The most prominent such gases are methane, nitrous oxide, and selected fluorocarbons.

Significant sources of U.S. methane emissions include; enteric fermentation, coal mining, landfills and natural gas systems. In the case of coal mining, methane emissions can be controlled utilizing proven thermal and catalytic combustion technologies.

Nitrous oxide (N₂O) is 310 times more potent than CO₂ as a greenhouse gas, and the largest source of emissions is from nitric acid production (~28 Tg CO₂EQ). N₂O concentrations typically range from 300 to 1,700ppmv, and a variety of catalytic technologies have been deployed to control N₂O.

Fluorocarbons are another source of highly potent greenhouse gases, with CO₂EQ values ranging from 140 (certain hydrofluorocarbons) to 24,000 (sulfur hexafluoride). The major sources include aluminum and semiconductor manufacturing, and substitutes for ozone depleting substances. These compounds are also often found during groundwater remediation activities. Fluorocarbons can be controlled to over 95% using catalytic or thermal destruction.

b. Opportunities and Barriers to Supply-Side Efficiency Improvements

There currently exists in the U.S. approximately 340GW of coal-fired capacity. This fleet operates at roughly 34% efficiency. New supercritical capacity can be installed with 38% efficiency, and ultrasupercritical (USC) units exist overseas that generate at 43% efficiency. Even without CCS, new USC coal units therefore emit 2.74mtpy CO₂ as opposed to 3.47mtpy for current new subcritical units (based on 500MW capacity). Therefore, new coal-fired capacity with upgraded technology saves 1.46 million tons CO₂ emissions per GW annually because of these higher efficiency steam cycles. More importantly, however, there is a need for controls on the 340GW of current capacity that will take decades to turnover. Given the inherent efficiencies gained through the use of newer boiler technologies it stands to reason the next step is the optimization of generation efficiency in the current fleet. This is particularly true since CCS program designs, to date, have parasitic power demands.

Currently, legislative provisions focus on demand side management efficiency programs (which certainly have some merit) while largely neglecting generation side improvements. Both are needed to have the most cost effective aggregate CO₂ reduction program and to show maximum CO₂ reduction progress in the near term. According to the DOE's NETL, generation side efficiency improvements of 4% are possible with current technology on all vintages of existing units.³ Coal-fired plants currently emit 1.9 billion tons per year CO₂, growing to 2.2 billion by 2030. The benefits of optimized efficiency at the generation sites and consumer sites are several: greater CO₂ percent reduction from the current fleet in the near term, lower aggregate cost for future CCS capital because of a lower CO₂ "baseline" than otherwise, and lower emissions of the criteria pollutants (NO_x, SO₂, and PM) because less coal is being burned to meet demand.

The reason why the seemingly obvious strategy of increasing generation efficiency has not been more widely adopted is largely two-fold: New Source Review (NSR) policy relative to boiler modifications, and state ratemaking policies.

Many efficiency improving modifications such as coal pulverizer modifications, superheater/reheater tube section replacement, steam turbine blade redesign/ replacement, surface condenser cleaning systems, and boiler fireside ash cleaning systems are all potential triggers for NSR. These system improvements present potential risk to the owners as well as lost opportunities for reducing both CO₂ and criteria pollutants. Therefore, the best available control technology (BACT) review process imposed through NSR should be reviewed in consideration of this overall societal benefit.

Another impediment to increasing generation efficiency occurs when state Public Service Commissions present difficulties for regulated power generators to recover capital and operating expenses for CO₂ reduction processes. Generators need expedited capital and operating expense recovery to reduce CO₂ or improve efficiency. A suggested solution is for regulated states to model CO₂ reduction and efficiency improvement cost recovery after their existing fuel adjustment clauses for cost recovery of higher fuel or purchased power costs.

2) Longer-term technologies

Longer term technologies (2030-2050) must follow the same RDD&D pathway that the current technologies are following. Some will be evolutionary changes that can be readily adopted, while some will be revolutionary and require new learning and applications. Research is active in all areas of CO₂ capture from power generation, including storage and beneficial use. The U.S. DOE's National Energy Technical Laboratory (NETL) has extensive lists of fundamental research projects that are on-going at the national labs and universities, and technology providers are pursuing advances in carbon capture. These innovations include: membranes, low cost oxygen production, solid sorbents, metallo-organic frameworks, advanced solvents, ionic liquids, chemical looping, enzymes, and biomimetic processes. They will need pilot scale funding, followed by demonstration funding, and the government should continue to support these

efforts in earnest. The value is not just to the U.S. economy, but also to the world economy and U.S. leadership.

IV. Carbon Capture Ready: Preparing for the Future

The APC industry finds itself in limbo where legislation or regulations are moving inevitably toward requiring the capture of carbon dioxide and the subsequent sequestration of CO₂, yet the technologies that comprise carbon capture are not ready for full commercial deployment. Nevertheless, permitting authorities feel an obligation to insure that any new plant that gets permitted will have carbon capture. At the same time many generators are reviewing their long-term capital investment needs and recognize that it will be necessary to operate their existing plants well past 2030, and perhaps even longer.

These twin pressures have the same solution – both new and existing coal-fired units must be “carbon capture ready.” This solution provides the commitment that the permitting authorities seek and allows the utility to stretch its capital investments over a longer period of time.

The International Energy Agency (IEA) defines “capture ready” as a power plant that can include capture when the necessary regulatory and economic drivers are in place. They further state that the aim is “building plants that are capture ready to avoid the risk of stranded assets or carbon lock-in”. This concept includes studying options for capture retrofit and potential pre-investment, including sufficient space and access for the carbon capture equipment as well as reasonable routes to storage.

The European Union has defined “CC Ready” in the EU Energy and Climate Change Package of December 2008 as “To avoid a lock-in of technology, Member States have to insure that operators of all combustion plants with a rated electrical output of 300 MW or more for which a construction license is granted after entry into force of the Directive (by 2011), have assessed whether the following conditions are met:

- 1) Suitable storage sites are available
- 2) Transport facilities are technically and economically available
- 3) It is technically and economically feasible to retrofit for capture.”

These studies should include the following as a minimum.

Pre-investment for plant interface and connection:

- a) Providing either the maximum level of control of SO_x and NO_x technologies or the upgrading of existing equipment to the lowest achievable limits given the fuel and plant configuration.
- b) Upgrading and optimizing the boiler heat transfer surfaces to maximize unit output and reduce parasitic load impact.
- c) Providing adequate transformer area and switch yard capacity.

- d) Upgrading the steam path and turbine to maximize electrical production and minimize parasitic load impacts, and providing the necessary steam or electric power for the process selected.
- e) Optimizing the cooling system and providing access to all recoverable heat sources.
- f) Evaluating water and wastewater treatment interconnections and capacity.
- g) Providing adequate space and arrangements for all necessary interface connections.
- h) Providing adequate control system capacity.

V. Path to GHG Stabilization and Reductions

1) Certainty: Requirements Create Certainty Which In Turn Advances Technology Solutions

Clear requirements create certainty which advances technology solutions and expectations for GHG reductions. During the previous administration, major sources, particularly the electric industry, sought promulgation of clear, comprehensive, and unhindered environmental requirements. Affected industries largely supported proposed legislation such as Clear Skies and other proposed multipollutant legislation. Many special interest environmental groups, while always seeking deeper reductions, also supported early, clear, and still substantial plans for cleaning the air. Finally then, the APC industry could gear up in a more cost effective manner to provide solutions and services, invent better control methods, and create high tech jobs while promoting greater use of local labor.

The benefits such as those stated above are best achieved by Congress legislating climate change provisions, as opposed to EPA promulgating regulations. The historical record on this issue is clear. Significant success was achieved with reductions of sulfur dioxide and oxides of nitrogen under the acid deposition provisions of the 1990 Clean Air Act Amendments. This success was largely due to the extreme clarity and flexibility of the SO₂ cap and trade system and the reasonable clarity and flexibility provided for NO_x reductions.

In contrast, stakeholder's petitions have derailed several comprehensive, well-intended final rules promulgated by EPA such as the Clean Air Mercury Rule, the Clean Air Interstate Rule, and implementation of the 1997 8-hour ozone standard. The practical effect has been delayed air quality improvements, delayed capital expenditures, and damaged credibility. ICAC strongly encourages this Congress to enact legislation for GHG / Climate Change in order to begin progress towards reducing GHG and creating an environment for developing and deploying CCS programs to full commercial status. The Clean Air Act offers no clear sensible mechanism for regulation of GHG from stationary sources. Legislation providing an appropriately timed, declining cap and trade system would establish a clear market signal to both affected industries and technology providers.

ICAC recognizes the critical need to have wide support for early adopter and first mover technologies. In order to promote the early adoption of carbon capture technologies, ICAC supports a legislative initiative to establish funding mechanisms for 6-8 commercial facilities that integrate carbon capture and sequestration by paying for the CO₂ sequestered. This funding helps reduce the uncertainty and share the risks associated with the cost of developing and deploying technologies, facilitates decisions regarding permitting within states, and reduces initial liability issues. ICAC supports a recommendation that at least \$1 billion be annually allocated for carbon capture for five years, extendable to ten years, which would cover the additional costs of carbon capture and for sequestration for at least 6-8 full-scale early commercial demonstrations of various technologies. The fund could be established through various mechanisms including a temporary charge assessed on fossil fuel-fired electricity, or setting aside a portion of proceeds from the auction of allowances. As in the past, industry would be prepared to shoulder some of the development cost, collaboratively. ICAC strongly believes that early investments will also return rewards in future jobs, stable and affordable energy, and improved air quality.

2) Near Term Legislative Requirements

Carbon capture must, like any emerging technology be nurtured and supported as it moves from pilot phases and demonstration through scale up to full commercial deployment. In order to achieve successful deployment, there are many hurdles and barriers to be overcome. Most of these are controlled or influenced by the regulatory or legislative process in one way or another.

It is, first and foremost, necessary to have the overall carbon reduction regulatory framework in place. It is necessary that this framework be reasonable in its timing of reductions, be flexible (with respect to trading, banking, offsets and early action credits), have adequate allocation of allowances across all sectors, have international linkage, and provide appropriate support for technology development and deployment including bonuses for early movers.

A major key to the success of any carbon reduction program will be the deployment of CC. The U.S. utility industry needs to maintain its position with respect to coal for reasons of market security (coal is the principle energy resource under U.S. control), financial security (neither the utilities nor the financial markets nor the supply chain could entertain the idea of replacing the coal fleet and meet future growth power projections), and the speed necessary to meet the GHG reduction goals the scientists have called for in order to stabilize atmospheric CO₂ concentrations.

CC has the promise to achieve widespread deployment in the most rapid manner of any technology. David Sandalow, Assistant Secretary of Energy for Policy and International Affairs, recently testified that we could convert the entire coal fleet by 2035 at the latest. Unlike renewable energy sources, there is no maximum penetration rate for CC. Further, coal and gas with CC can operate any time without regard for whether the wind blows,

the sun shines or the current temperature (all of which dictate both whether renewables generate and their efficiency).

Most importantly of all, CC offers the greatest opportunity to control the increase in the cost of electricity through the foreseeable future. According to the Electric Power Research Institute's PRISM Study released in August 2009, a natural gas dependent generation future will increase cost of electricity (COE) by 90% in 2030 and 210% in 2050 compared to a coal-with-CC COE of 50% and 80%, respectively.⁴

The future of CC deployment lies in the legislative process. Technology development and deployment will need to be subsidized by the government as the large cost of full scale up of the technology is a difficult cost to expect the utility sector to bear alone. The current legislation introduced to date contains provisions that are a good start but insufficient to support the full 6-8 demonstration projects many believe needs to be deployed prior to full commercialization. Additionally, support for early movers on operating cost, as is done with all wind generation, will be needed to allow dispatch in the current competitive markets for power.

Finally, the issues of liability must be addressed. Short term liability can be covered by insurance products and other mechanisms. Long term liability including post closure must be addressed so that utilities can maintain an adequate balance sheet and to insure there is proper accountability, monitoring and maintenance for the future. Creative models are already being spearheaded by states such as Pennsylvania and Texas. Use of federal and state lands for sequestration is an excellent opportunity to provide the controls and long term maintenance needed as well as providing excellent dual use of the land while avoiding the quagmire of legal issues associated with mineral rights and CO₂ spread/penetration.

VI. Sequestration Issues

Roughly one third of U.S. carbon dioxide emissions come from power plants and other large point sources. To stabilize and ultimately reduce concentrations of this greenhouse gas, it will be necessary to employ carbon capture for storage or reuse. To be successful, the techniques and practices to sequester carbon must be effective and cost-competitive, provide stable, long term storage, and be environmentally benign. There are several promising technologies to address capture of CO₂ from the use of fossil fuels and all are dependent upon development of a safe means of permanent storage. Enhanced oil recovery (EOR) is a practice with limited but high value potential, and EOR is estimated to have a market using as much as 7,500 million metric tons of CO₂ through 2030, compared to the billions of tons being emitted each year. However, for permanent storage technologies, the policy issues, particularly liabilities governing the geologic storage of carbon dioxide, are equally as important as the technical challenge of capturing and storing carbon dioxide. Important issues concerning liability include establishing the protocol for cradle-to-grave liabilities that define what corrective action is required in case of leakage or accident, the need for insurance, and the determination of potentially

responsible parties. These issues are complicated and will likely be analogous to similar regulatory protocols for natural gas and enhanced oil recovery. Some of the CO₂ storage and transport readiness issues include:

- a) Storage sites location and availability
- b) Storage sites capacity
- c) Transportation options (pipeline and routes)
- d) Proximity to other CO₂ sources for economy of scale
- e) Preliminary technical storage assessment (injection potential, containment, etc)
- f) Public acceptance and barriers
- g) Economics of selected options
- h) Implementation plan.

As carbon capture technologies are demonstrated and reach commercial maturity, it is imperative that policies are in place to completely address the viability of permanent storage.

End Notes

- 1 *Air Pollution Control Equipment Market Forecasts*, Institute of Clean Air Companies, Number 28, July 2009.
- 2 *Employment and Other Economic Benefits from Advanced Coal Electric Generation with Carbon Capture and Storage*, BB&C Research and Consulting, February 12, 2009 (see http://www.boilermakers.org/resources/news/New_study_shows_advanced_coal_technology_will_create_jobs).
- 3 *Benefits of Improving the Efficiency of the Existing Coal-fired Power Plant Fleet*, Presentation by Chris Nichols, DOE NETL, at EUEC, Tucson, AZ, January 28, 2008.
- 4 EPRI Prism/MERGE Analyses 2009 Update (see <http://my.epri.com/portal/server.pt?>).
- 5 *Potential for Improvement in Gasification Combined Cycle Power Generation with CO₂ Capture*. IEA GHG Report, May 2003.
- 6 *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007*, April 2009 (see www.epa.gov/climatechange/emissions/usinventoryreport.html).