Testimony

Carbon Capture and Sequestration

Subcommittee on Energy and Air Quality

U.S. House of Representatives

Stu Dalton

Electric Power Research Institute

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Introduction

I am Stu Dalton, Director of Generation for the Electric Power Research Institute (EPRI). EPRI is a non-profit, collaborative R&D organization headquartered in Palo Alto, California. EPRI appreciates the opportunity to provide testimony to the Subcommittee on the topic of carbon capture and sequestration.

BACKGROUND

Coal is currently the fuel source for over half of the electricity used in the United States. It is expected to continue to represent over half of the generation mix needed to meet the forecasted U.S. electric demand growth of more than 40% by 2030. In order to address global climate change concerns, we must develop solutions that reduce coal power's net CO_2 emissions. Technologies to reduce coal-based generation's CO_2 emissions are part of a portfolio of CO_2 reducing technologies that also includes energy efficiency, renewables, nuclear power, and plug-in hybrid electric vehicles.

Coal is a stably priced, affordable, domestic fuel that can be used in an environmentally responsible manner. Pollutant emissions from new coal-fired power plants have already been reduced by a factor of ten or more over the last 30 years. By displacing imported natural gas or oil, coal helps address America's energy security and balance-of-payments concerns. With the development of carbon capture and storage (CCS) technologies, coal power becomes part of the solution to satisfying our energy needs in an environmentally responsible fashion.

EPRI's new "Electricity Technology in a Carbon-Constrained Future" study suggests that with aggressive R&D, demonstration, and deployment of advanced technologies, it is technically feasible to slow down and stop the increase in U.S. electric sector CO_2 emissions, and then eventually reduce them over the next 25 years while meeting the increased demand for electricity . Of the technologies that can eventually lead to reductions in CO_2 emissions, the largest single contribution would come from applying CCS technologies to new coal-based power plants coming on-line after 2020.

IMPROVED EFFICIENCY—AN IMPORTANT COMPANION TO CO_2 CAPTURE

In the 1950s and '60s, the United States was the world's pioneer in power plants using thermodynamically efficient "supercritical" and "ultra-supercritical" steam conditions. Exelon's coal-fired Eddystone Unit 1, in service since 1960, still boasts the world's highest steam temperatures and pressures. Because of reliability problems with some of these early units, U.S. designers retreated from the highest supercritical steam conditions until the 1980s and '90s when international efforts involving EPRI and U.S., European, and Japanese researchers concentrated on new, reliable materials for high-efficiency pulverized coal plants. Given the prospect of potential CO_2 regulations (and efforts by power producers to demonstrate voluntary reductions in CO_2 emissions per megawatthour of electricity produced), the impetus for higher efficiency to reduce future CO_2 control costs has gained economic traction worldwide.

The majority of new pulverized coal (PC) plants announced over the last two years will employ high-efficiency supercritical steam cycles, and several will use the ultra-supercritical steam conditions heretofore used only overseas (aside from Eddystone).

EPRI is working with the Department of Energy, the Ohio Coal Development Office, and major equipment suppliers on an important initiative to qualify a whole new class of nickel-based "superalloys," which will enable maximum steam temperatures to rise from an ultra-supercritical steam temperature of 1100ºF to an "advanced" ultra-supercritical steam temperature of 1400ºF. Combined with a modest increase in steam pressure, this provides an efficiency gain that reduces CO_2 emissions per unit of electrical energy produced by about 20% relative to today's plants. It also reduces the required size of any CO_2 capture equipment. Realization of this opportunity, however, is not automatic. It requires a sustained R&D commitment and substantial investment in demonstration facilities. The European Union has embraced this strategy and is midway through a program to demonstrate a pulverized coal plant with 1300ºF steam conditions, which was realistically planned as a 20-year activity.

Efficiency improvement is important for other coal power technologies too. The world's first supercritical circulating fluidized-bed (CFB) plant is currently under construction in Poland. For integrated gasification combined cycle (IGCC) units, supercritical heat recovery steam generators are included in EPRI's CoalFleet RD&D Augmentation Plan.

CO_2 CAPTURE

Carbon capture technologies can be feasibly integrated into virtually all types of new coal-fired power plants, including IGCC, PC, CFB, and variants such as oxy-fuel combustion. For those building new plants, it is unclear which type of plant would be economically preferred if it were built to include CO_2 capture. All have relative competitive advantages under various scenarios of available coal types, plant capacity, location, opportunities for by-product sales, etc. Although CO_2 capture appears technically feasible for all coal power technologies, it poses substantial engineering challenges (requiring major investments in R&D and demonstrations) and comes at considerable cost. But analyses by EPRI and the Coal Utilization Research Council suggest that once these substantial investments are made, the cost of CCS becomes manageable, and ultimately coal-based electricity with CCS can be cost competitive with other low-carbon generation technologies.

Post-combustion CO_2 separation processes (placed after the boiler in the power plant) are currently used commercially in the food and beverage and chemical industries, but these applications are at a scale much smaller than that needed for power producing PC or CFB power plants. These processes themselves are also huge energy consumers, and without investment in their improvement, they would reduce plant electrical output by as much as 30% (creating the need for more new plants).

CO_2 separation processes suitable for IGCC plants are used commercially in the oil and gas and chemical industries at a scale closer to that ultimately needed, but their application necessitates development of modified IGCC plant equipment, including additional chemical process steps and gas turbines that can burn nearly pure hydrogen.

EPRI's most recent cost estimates suggest that for pulverized coal plants, the addition of CO_2 capture using the currently most developed technical option, amine solvents, along with CO_2 drying and compression, pipeline transportation to a nearby storage site, and underground injection, would add about 60–80% to the net present value of life-cycle costs of electricity (expressed as levelized cost-of-electricity, or COE, and excluding storage site monitoring, liability insurance, etc.). This translates into a potentially large hike in consumers' electric bills.

The COE cost premium for including CO_2 capture in IGCC plants, along with drying, compression, transportation, and storage, is about 40–50%. Although this is a lower cost increase in percentage terms than that for PC plants, IGCC plants initially cost more than PC plants. Thus, the bottom-line cost to consumers for power from IGCC plants with capture is likely to be comparable to that for PC plants with capture (the actual relative competitiveness depends on coal moisture content and other factors as described below). It should be noted that IGCC plants (like PC plants) do not capture CO_2 without substantial plant modifications, energy losses, and investments in additional process equipment. As noted above, however, the magnitude of these impacts could likely be reduced substantially through aggressive investments in R&D.

The COE cost premiums listed above vary in real-world applications, depending on available coals and their physical-chemical properties, desired plant size, the CO_2 capture process and its degree of integration with other plant processes, plant elevation, the value of plant co-products, and other factors. Nonetheless, IGCC with CO_2 capture generally shows an economic advantage in studies based on low-moisture bituminous coals. For coals with high moisture and low heating value, such as subbituminous and lignite coals, a recent EPRI study shows PC with CO_2 capture being competitive with or having an advantage over IGCC.[1] EPRI stresses that no single advanced coal generating technology (or any generating technology) has clear-cut economic advantages across the range of U.S. applications. The best strategy for meeting future electricity needs while addressing climate change concerns and economic impact lies in developing multiple technologies from which power producers (and their regulators) can choose the one best suited to local conditions and preferences.

Despite the substantial cost increases for adding CO_2 capture to coal-based IGCC and PC power plants, their resulting cost-of-electricity is still usually less than that for natural gas-based plants at current and forecasted gas prices.

Historical experience with power plant environmental control technologies suggests technological advances rooted in learning-by-doing will lead to significant cost reductions in CO_2 capture technologies as the installed base of plants with CO_2 capture grows. An International Energy Agency study led by Carnegie Mellon University suggested that overall electricity costs from plants with CO_2 capture could come down by 15% relative to the currently predicted costs after about 200 systems were installed.[2]

[1] Feasibility Study for an Integrated Gasification Combined Cycle Facility at a Texas Site, EPRI report 1014510, October 2006.

[2] Edward S. Rubin, et al., "Estimating Future Costs of CO_2 Capture Systems Using Historical Experience Curves," Presented at the 8th Int'l. Conf. on Greenhouse Gas Control Technologies, Trondheim, Norway, June 2006.

Engineering analyses by EPRI, DOE, and the Coal Utilization Research Council suggests that costs could come down faster through CO_2 capture process innovations or, in the case of IGCC plants, fundamental plant improvements—provided sufficient RD&D investments are made. EPRI pathways for reduction in capital cost and improvement in efficiency are embodied in two companion RD&D Augmentation Plans developed under the collaborative *CoalFleet for Tomorrow* program (see figures below).

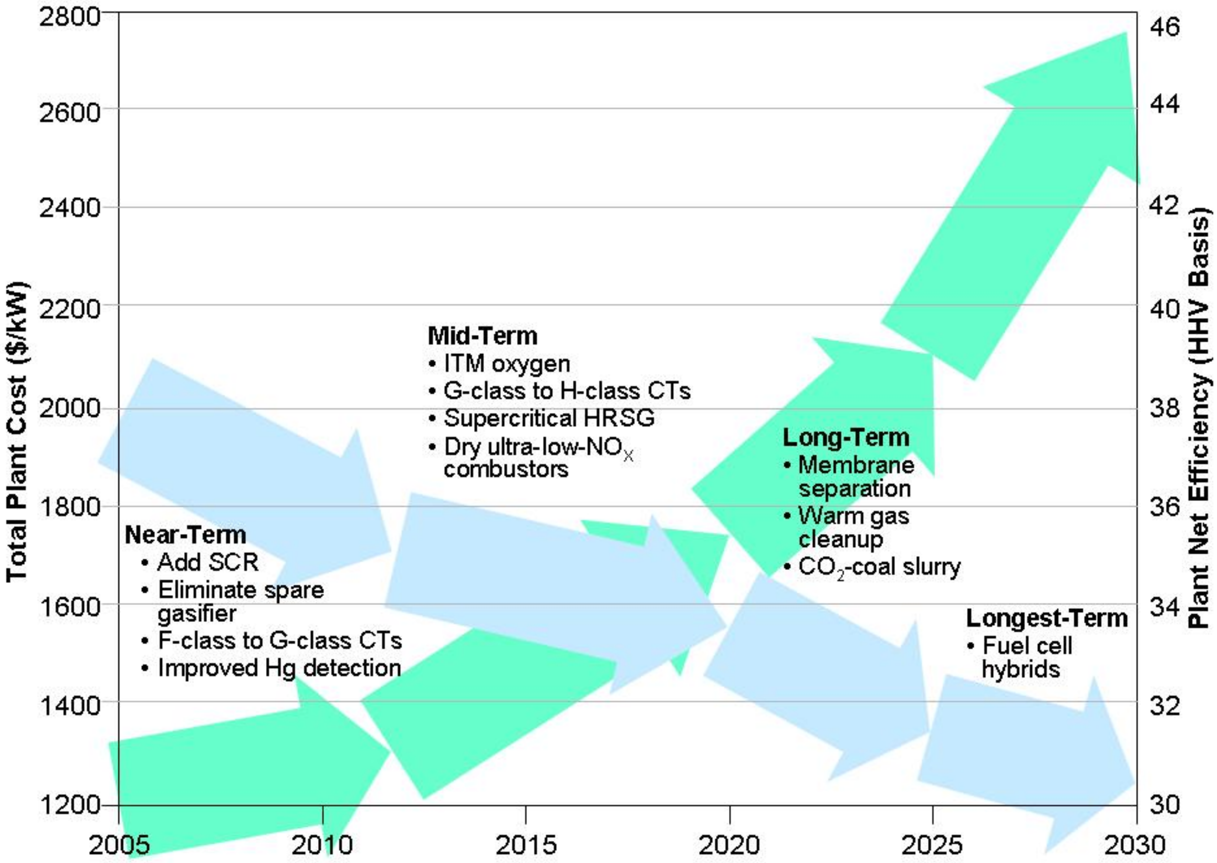


Figure 1: Forecast Reduction in Capital Cost and Improvement in Efficiency Through Implementation of the EPRI CoalFleet IGCC RD&D Augmentation Plan[3]

(Slurry-fed gasifier, Pittsburgh #8 coal, 90% availability, 90% CO_2 capture, 2Q 2005 U.S. dollars)

[3] *CoalFleet RD&D Augmentation Plan for Integrated Gasification Combined Cycle (IGCC) Power Plants,* EPRI report 1013219, January 2007.

Efforts toward reducing the cost of IGCC plants with CO_2 capture will focus on adapting more advanced and larger gas turbines for use with hydrogen-rich fuels, lower-cost oxygen supplies, improved gas clean-up, advanced steam cycle conditions, and more.

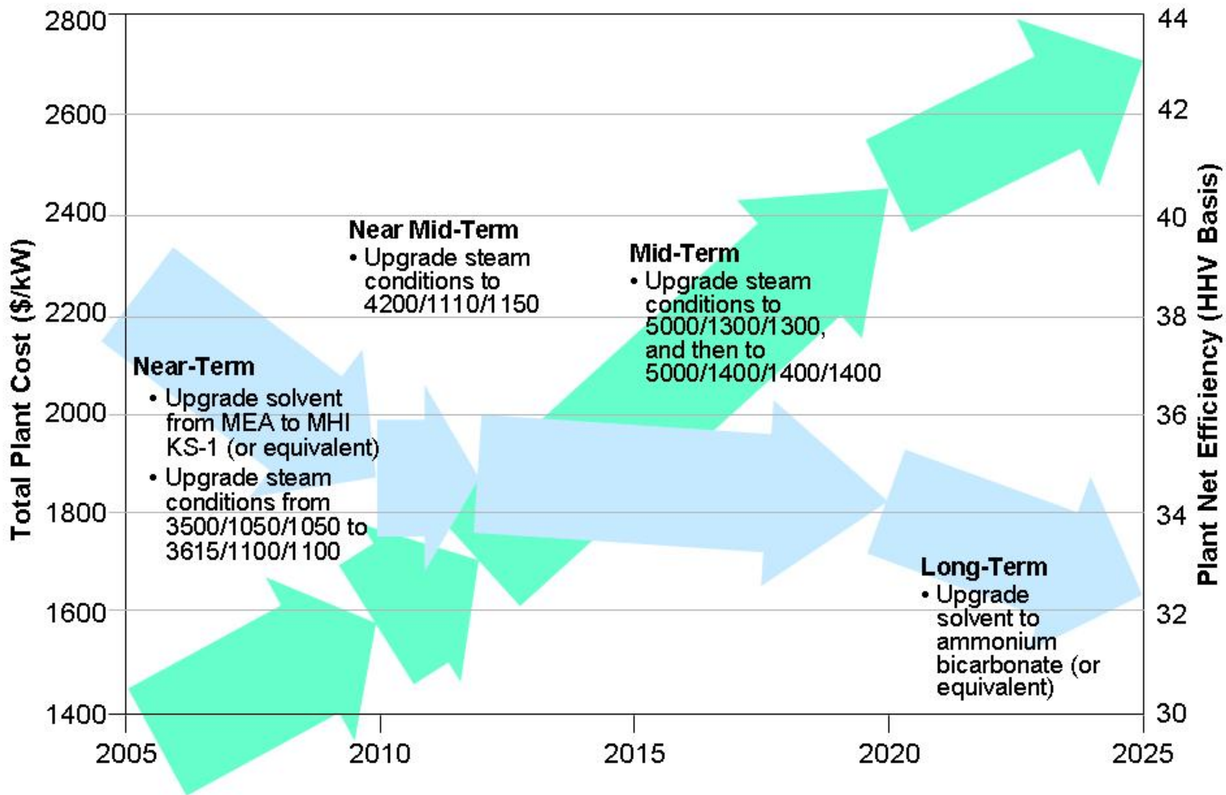
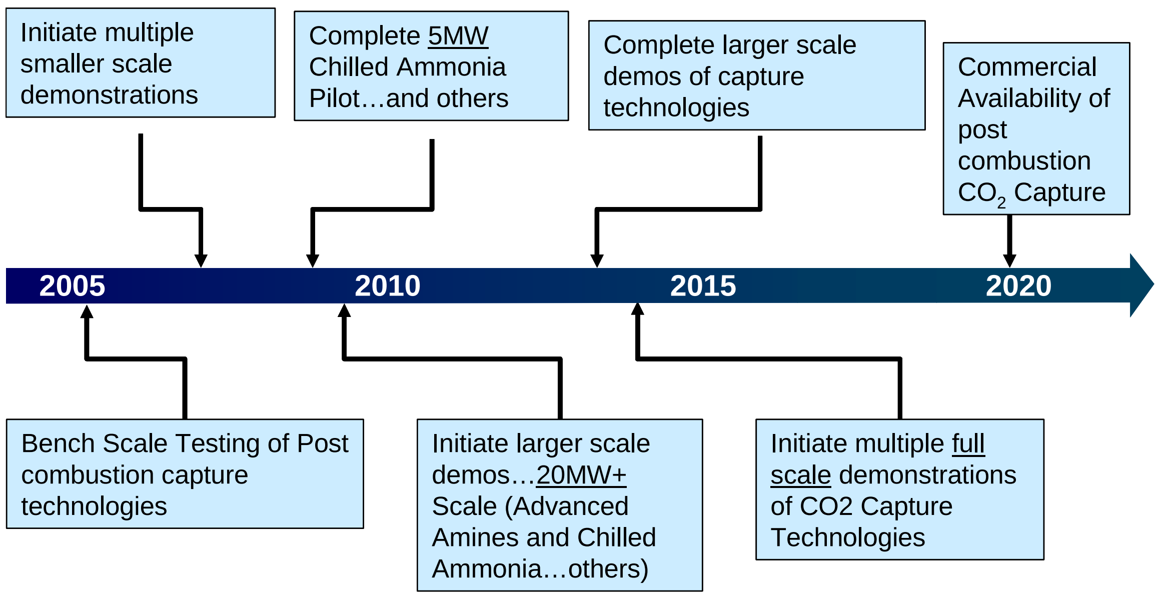


Figure 2: Forecast Reduction in Capital Cost and Improvement in Efficiency through Implementation of the CoalFleet USC PC RD&D Augmentation Plan[4]
(Pittsburgh #8 coal, 90% availability, 90% CO_2 capture,
as-reported data from various studies [not standardized])

For PC plants, the progression to advanced ultra-supercritical steam conditions will steadily increase plant efficiency and reduce CO_2 production. Improved solvents are expected to greatly reduce post-combustion CO_2 capture process. EPRI is working to

4 Ibid.

accelerate the introduction of novel, alternative CO_2 separation solvents with much lower energy requirements for regeneration. Such solvents—for example, chilled ammonium carbonate—could reduce the loss in power output imposed by the CO_2 capture process from about 30% to about 10%. A small pilot plant (5 MW-thermal) is being designed for installation at a power plant in Wisconsin later this year; success there would warrant a scale-up to a larger pilot or pre-commercial plant. An EPRI timeline (compatible with DOE's timeframe) for the possible commercial introduction of post-combustion CO_2 capture follows.



The introduction of oxy-fuel combustion may allow further reductions in CO_2 capture costs by allowing the flue gas to be compressed directly, without any CO_2 separation process and reducing the size of the supercritical steam generator. Boiler suppliers and major European and Canadian power generators are actively working on pilot-scale testing and scale-up of this technology.

Assuring timely, cost-effective coal power technology with CO_2 capture entails simultaneous and substantial progress in RD&D efforts on improving capture processes and fundamental plant systems. EPRI sees the need for government and industry to pursue these and other pertinent RD&D efforts aggressively through significant public policy and funding support. Early commercial viability will likely come only through firm commitments to the necessary R&D and demonstrations and through collaborative arrangements that share initial risks and disseminate results.

CO_2 TRANSPORTATION & STORAGE

Geologic sequestration of CO_2 has been proven effective by nature, as evidenced by the numerous natural underground CO_2 reservoirs in Colorado, Utah, and other western states. CO_2 is also found in natural gas reservoirs, where it has resided for millions of years. Thus, evidence suggests that depleting or depleted oil and gas reservoirs, and similar “capped” sandstone formations containing saltwater that cannot be made potable, are capable of storing CO_2 for millennia or longer.

Geologic sequestration as a strategy for reducing CO_2 emissions is being demonstrated in numerous projects around the world. Three relatively large projects—the Sleipner Saline Aquifer CO_2 Storage (SACS) project in the North Sea off of Norway;[5] the Weyburn Project in Saskatchewan, Canada,[6] and the In Salah Project in Algeria[7]—together sequester about 3 to 4 million metric tonnes per year, which approaches the output of a typical 500 megawatt coal-fired power plant. With 17 collective years of operating

[5] http://www.iku.sintef.no/projects/IK23430000/
[6] http://www.co2captureandstorage.info/project_specific.php?project_id=70
[7] http://www.co2captureandstorage.info/project_specific.php?project_id=71

experience, these projects suggest that CO_2 storage in deep geologic formations can be carried out safely and reliably.

In the United States, DOE has an active R&D program (the "Regional Carbon Sequestration Partnerships") that is mapping geologic formations suitable for CO_2 storage and conducting pilot-scale CO_2 injection validation tests across the country. These tests, as well as most commercial applications for long-term storage, will compress CO_2 to a liquid-like "supercritical" state to maximize the amount stored per unit volume underground. As a result, virtually all CO_2 storage applications will be at least a half-mile deep, helping reduce the likelihood of any leakage to the surface.

CO_2 injection technology and subsurface behavior modeling have been proven in the oil industry, where CO_2 has been injected for 30 years for enhanced oil recovery (EOR) in the Permian Basin fields of west Texas and Oklahoma. Regulatory oversight and community acceptance of injection operations are well established.

The DOE Regional Carbon Sequestration Partnerships represent broad collaborative teaming of public agencies, private companies, and non-profits; they would be an excellent vehicle for conducting larger "near-deployment scale" CO_2 injection tests to prove specific U.S. geologic formations, which EPRI believes to be one of the keys to commercializing CCS for coal-based power plants.

Evaluations by the DOE Regional Carbon Sequestration Partnerships and others suggest that enough geologic storage capacity exists in the United States to hold several centuries' worth of CO_2 emissions from coal-based power plants and other stationary sources. However, the distribution of suitable storage formations across the country is not uniform. Some areas have ample storage capacity whereas others appear to have little or none. Thus, CO_2 captured at some power plants would be expected to require pipeline transportation for several hundred miles to suitable injection locations, which may be in other states. While this adds cost, it doesn't represent a technical hurdle because CO_2 pipeline technology has been proven in oil field EOR applications. As CCS is applied commercially, EPRI expects that early projects would take place at coal-based power plants near sequestration sites or an existing CO_2 pipeline. As the number of projects increases, regional CO_2 pipeline networks connecting multiple sources and storage sites (often called "sinks") would be needed.

There is still much work to be done before CCS can implemented on a scale large enough to significantly reduce CO_2 emissions into the atmosphere. In addition to large-scale demonstrations at U.S. geologic formations, many legal and institutional uncertainties need to be resolved. Uncertainty about long term monitoring requirements, liability, and insurance is an example. State-by-state variation in regulatory approaches is another. Some geologic formations suitable for CO_2 storage underlie multiple states. For private companies considering CCS, these various uncertainties translate into increased risk.

SUMMARY AND RECOMMENDATIONS

CO_2 capture technologies can be feasibly integrated into virtually all types of new coal-fired power plants, including IGCC, PC, CFB, and oxy-fuel boilers. Current costs and energy use are significant for all plant types, although not uniformly. Among these plant types, there is no economically preferred technology for generating electricity with CCS.

All have relative competitive advantages under various scenarios of available coal types, plant capacity, location, opportunities for by-product sales, etc. EPRI strongly recommends that R&D investments and climate policies reflect a portfolio approach that enables commercial incorporation of CCS into multiple advanced coal power technologies.

Sites for long-term geologic storage of captured CO_2 are regionally available throughout the United States (although some areas appear to have no nearby options).

There are major challenges to be overcome—both technically and in terms of public policy—before widespread commercial-scale carbon capture and storage can be achieved.

For geologic storage of CO_2 to become commercially viable, multiple large-scale (>1 million tons) demonstrations need to commence as soon as possible, and legal and regulatory frameworks need to be established to guide these demonstrations. EPRI believes that programs like the DOE Regional Carbon Sequestration Partnerships are excellent vehicles for conducting large-scale demonstrations. Regarding legal issues, work with our members and the FutureGen partners has shown that resolution of long-term liability, indemnification, and insurance unknowns is a crucial area where federal policy is needed.

R&D pathways for generating electricity from coal through 2030 have been established collaboratively by EPRI, DOE, and industry groups, such as the Coal Utilization Research Council. Plans for both IGCC and PC technologies show that—with adequate investment and resolution of policy issues—advanced coal-based power plants that capture more than 90% of the CO_2 that would otherwise be emitted could produce electricity at a cost competitive with other low-carbon generation technologies.

The funding needed to execute these R&D plans is a significant step up from current levels of investment, but is within historical percentages of energy R&D for government agencies and private industry. Given the long technology development and deployment lead times inherent in capital intensive industries like energy, investment and policy decisions must be made now or we risk foreclosing windows of opportunity for technology options that we expect will prove tremendously valuable in a carbon-constrained future.

Summary of Testimony to the Carbon Capture and Sequestration Subcommittee on Energy and Air Quality of the U.S. House of Representatives

Stu Dalton, Electric Power Research Institute
March 6, 2007

EPRI's new "Electricity Technology in a Carbon-Constrained Future" study suggests that with aggressive R&D, demonstration, and deployment of a portfolio of advanced technologies, it is technically feasible to slow down and stop the increase in U.S. electric sector CO_2 emissions, and then eventually reduce them over the next 25 years while meeting the increased demand for electricity. The study indicates that the largest single contributor to eventually reducing CO_2 emissions comes from applying carbon capture and storage (CCS) technologies to new coal-based power plants after 2020.

Carbon capture technologies can be feasibly integrated into virtually all types of new coal-fired power plants, including integrated gasification combined cycle (IGCC), pulverized coal (PC), circulating fluidized-bed (CFB), and variants such as oxy-fuel combustion. Among these plant types, there is no economically preferred technology for adopting CCS. All have relative competitive advantages under various scenarios of available coal types, plant capacity, location, opportunities for by-product sales, etc. EPRI strongly recommends that policies reflect a portfolio approach that enables commercial incorporation of CCS into multiple advanced coal power technologies.

Sites for long-term geologic storage of CO_2 (also called carbon sequestration) are regionally available throughout the United States (although some areas appear to have no options). Even where sites are available, there are major challenges to be overcome—both technically and in terms of public policy—before widespread commercial-scale carbon capture and storage can be achieved. Specifically, multiple large-scale (>1 million tons) demonstrations need to commence as soon as possible, and legal and regulatory frameworks need to be established.

Post combustion CO_2 separation processes (placed after the power plant) are currently used commercially but at a scale much smaller than that needed for coal-fired power plants. These processes themselves are also huge energy consumers, and without investment in their improvement, they could reduce plant electrical output by as much as 30% (creating the need for more new plants). Application of CO_2 separation processes to IGCC necessitates development of new plant equipment, including additional chemical process steps and gas turbines that can burn nearly pure hydrogen.

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