

The Effect of EPA's Proposed NSPS on Carbon Capture and Storage Technology

Executive Summary Carbon capture and storage (CCS) is expected to require two generations of technology development to be commercially available and economically viable. **First generation** CCS is expensive but essential to demonstrating that CCS can be operated at commercial scale on coal-fueled power plants. Installing first generation CCS technology on a 600 megawatt (MW) coal plant can add up to \$1 billion in capital cost to the project.¹ A few first generation CCS projects are planned in the U.S., but only one is under construction. **Second generation** CCS is necessary to improve the cost and performance of CO₂ capture technology and will have to be demonstrated at new coal-fueled power plants because of the substantial challenges with retrofitting CCS to existing pulverized coal (PC) plants. However, new source performance standards (NSPS) that require CCS prematurely will effectively prevent any new coal-fueled plants from being constructed because these plants would have to rely on expensive first generation CCS. Consequently, second generation CCS will not be demonstrated, and CCS development will be stalled at a stage where the technology is not economically viable.

CCS Development: First and Second Generation Technology

According to the Administration's CCS task force, CCS development is intended to involve at least two generations of technology.² The first generation will demonstrate that CCS can be integrated at a coal-fueled power plant and operated at scale (200 MW - 580 MW) with existing CO₂ capture technologies.³ The second generation of CCS development is expected to include advancements that significantly improve the cost and performance of CCS, resulting in availability of CCS for wide spread commercial deployment.⁴

The first generation of CCS focuses primarily on current CO₂ capture technologies. Current CCS technology is adapted from gas separation processes already in use, for example, Rectisol. The Department of Energy (DOE) is currently supporting five first generation projects on coal-fueled power plants. The primary goal of these near-term projects is to integrate CCS at commercial scale on coal-fueled electric generating units. If successful, these projects will demonstrate “safe and reliable” CCS at commercial scale.⁵ However, these projects are not intended to resolve concerns about the cost of CCS, especially at commercial scale. Cost estimates for first generation CCS -- \$1,790/kW for a new PC plant, \$2,199/kW for an integrated gasification combined cycle (IGCC) plant, and \$1,999/kW for a PC retrofit -- are too high for the existing technology to be economically viable.⁶

DOE is actively pursuing research and development (R&D) on second generation CCS technologies. Over the past eight years, DOE has spent approximately \$6.9 billion on CCS technology development.⁷ These second generation CCS technologies are focused on improving the performance of CO₂ capture units that separate and compress CO₂. Specifically, the development of new solvents, sorbents, and membranes is focused on reducing the cost of CO₂ capture.⁸

Within the next 10 to 15 years, second generation CCS technologies will require the same type of demonstration projects that are ongoing for first generation CCS technologies.⁹ These second generation demonstration projects are a prerequisite to commercial availability and economic viability of CCS technologies. Without second generation CCS demonstration projects, the prospects for commercially available and economically viable CCS are significantly diminished.¹⁰

First Generation CCS: Status of Existing Demonstration Projects

Currently, DOE is supporting five CCS demonstration projects on coal-fueled power plants. These projects are supported through grants funded by the 2009 stimulus bill, as well as prior year appropriations. A majority

of the projects will use existing commercial gas separation processes adapted for CO₂ capture. Four of these projects are new facilities and one is a retrofit (see Appendix 1).

In 2010, *The Report of the Interagency Task Force on Carbon Capture and Storage* identified seven first-generation coal-fueled power plants integrated with CCS.¹¹ Of these seven, only the five listed in Appendix 1 are still ongoing and only one, Kemper County, is currently under construction. Three of the remaining four plants have pushed back their original operational dates by at least a year.¹²

In addition to these five active CCS demonstration projects, five first generation CCS demonstration projects on coal-fueled power plants in the U.S. have been abandoned, cancelled or withdrawn. Appendix 2 lists these projects.

The technological progress that could be achieved by these five remaining projects, while very important, will not assure that CCS is deployable across the power industry. For instance, only one of the projects, NRG Parish, is on an existing plant. In addition, the three IGCC projects will use the same existing acid gas removal technology, Rectisol. Should all five of these projects go forward successfully, second generation CCS technologies will still be necessary to demonstrate CCS at scale to lower CCS cost and improve performance.¹³ However, if the four projects that have not started construction are cancelled or withdrawn from the program, *only one* first-generation CCS project will exist in the U.S.

Demonstrating Second Generation CCS: The Need for New Plants
Second generation CCS has been the subject of nearly a decade of publicly funded R&D. Prior to commercial deployment, however, these new and novel approaches to CO₂ capture must be integrated at scale.¹⁴ The Congressional Budget Office (CBO) estimates that within the next 10 to 15 years, these technologies will be ready for deployment.¹⁵ Second generation CCS demonstrations are critical to the commercial acceptance of new technology in an industry dominated by long-lived capital assets. Second generation CO₂ capture technologies are listed in Appendix 3.

These second generation technologies must be scaled up and eventually demonstrated at commercial scale at new coal-fueled power plants. Second generation demonstration will, of necessity, be either new IGCC or PC application. Demonstrating second generation CCS technology that is applicable to an IGCC facility will require a new plant because of the extremely limited number of IGCC plants operating today. Additionally, demonstrating CCS at scale in a retrofit application on the existing fleet of PC units is challenging.¹⁶ The types of challenges that demonstrations face at existing PC plants fall in two categories: economic and physical.

Existing facilities retrofitting with CCS face substantial economic challenges associated with operating the CO₂ capture unit. Existing coal units tend to have lower efficiencies than new units.¹⁷ The installation of a CO₂ capture unit will result in a more pronounced efficiency impact on an existing unit than on a new plant.¹⁸ NETL has estimated that the installation of a CO₂ capture unit at an existing facility can lower the efficiency of the plant from 33 percent to 22 percent.¹⁹

Additionally, from an economic standpoint, retrofit CCS demonstrations pose a challenge because, even though second-generation technology is expected to be more cost-competitive, CCS retrofits are likely to cause a significant increase in the cost of electricity from the plant. In competitive markets, this means the plant may not be able to sell power competitively.²⁰ Similarly, for projects in regions where retail electricity rates are regulated, the approval of rate increases associated with a CCS demonstration by a public utility commission is uncertain and has already caused the cancellation of one demonstration project.²¹ Additionally, the planned remaining life of a power plant poses an economic challenge²² as it can limit the timeframe over which a plant owner can amortize the capital cost of the CO₂ capture unit.

Beyond these economic challenges, existing coal-fueled power plants attempting to retrofit with CCS face a series of physical limitations. A CO₂ capture unit at a power plant requires a significant amount of land at the plant site, which is not always available. NETL estimates that a 300 MW commercial CCS project may require 60 acres of land.²³ In addition

to limitations associated with space for the capture unit, if the captured CO₂ is to be used for enhanced oil recovery (EOR), the proximity of the nearest pipeline into which captured CO₂ can be pumped is a potential limitation.²⁴ Finally, in the event a pipeline is not available, existence of proper geology for underground CO₂ injection at or near the plant site is a physical limitation facing existing units.²⁵

In short, existing PC plants face significant challenges in demonstrating retrofit CCS. Without new IGCC and PC coal plants, the demonstration of second generation CCS is less likely to occur.

Global CCS Demand: The Case for Continued CCS Development in the U.S.

If CCS development in the United States stalls, the U.S. would cede its role as one of the global leaders in CCS R&D and lose the opportunity to sell CCS technology in the international marketplace.²⁶ The International Energy Agency (IEA) estimates the international demand for CCS deployment could be substantial. In order to meet international climate change goals, IEA projects that 968 gigawatts (GW) of CCS will be needed by 2035.²⁷ Of this 968 GW, IEA projects that 368 GW would be retrofit applications on existing power plants, 400 GW would be retrofit applications on future plants, and 200 GW would be new plants built with CCS.²⁸ Based on CCS capital cost estimates for new and retrofit applications from the Energy Information Administration (EIA) and the National Energy Technology Laboratory (NETL), the global CCS market could total nearly \$2 trillion by 2035.²⁹ If CCS development in the United States stalls, the potential for American companies to participate in this global market could be limited.

Conclusion

By requiring CCS prematurely, EPA's proposed NSPS will serve as a de facto ban on new coal plants. Without new coal plants, second generation CCS demonstration projects will not go forward. Without second generation CCS demonstration projects, CCS costs will remain high,

performance will remain uncertain, and commercial availability will be limited.

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1 Using an incremental capital cost of \$1,790/kW for a new 600 MW project results in an additional \$1.07 billion in incremental cost for CCS. Energy Information Administration, *Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants*, 6, (2013), http://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf

2 *Report of the Interagency Task Force on Carbon Capture and Storage*, 9 (2010).

3 *Ibid.*

4 *Ibid.*

5 *Ibid.*

6 Energy Information Administration, *Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants*, 6, (2013), http://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf; National Energy Technology Laboratory, *Assessment of Power Plants That Meet Proposed Greenhouse Gas Emissions Performance Standard*, 12 (2009).

7 Congressional Budget Office, *Federal Efforts to Reduce the Cost of Capturing and Storing Carbon Dioxide*, 5 (2012).

8 *Report of the Interagency Task Force on Carbon Capture and Storage*, 87 (2010).

9 Congressional Budget Office, *Federal Efforts to Reduce the Cost of Capturing and Storing Carbon Dioxide*, 6 (2012).

10 International Energy Agency, *Technology Roadmap: Carbon capture and storage*, 9 (2013).

11 *Report of the Interagency Task Force on Carbon Capture and Storage*, 35 (2010).

12 *Report of the Interagency Task Force on Carbon Capture and Storage*, 88-9 (2010); MIT, *Power Plant Carbon Dioxide Capture and Storage Projects*, http://sequestration.mit.edu/tools/projects/index_capture.html.

13 International Energy Agency, *Technology Roadmap: Carbon capture and storage*, 9 (2013).

14 Congressional Budget Office, *Federal Efforts to Reduce the Cost of Capturing and Storing Carbon Dioxide*, 6 (2012).

15 *Ibid.*

16 *Report of the Interagency Task Force on Carbon Capture and Storage*, 35 (2010).

17 Intergovernmental Panel on Climate Change, *Special Report on Carbon Capture and Storage*, 111 (2005).

18 *Ibid.*

19 National Energy Technology Laboratory, *Assessment of Power Plants That Meet Proposed Greenhouse Gas Emissions Performance Standard*, 261 (2009).

20 *Report of the Interagency Task Force on Carbon Capture and Storage*, 35 (2010).

21 Congressional Research Service, *Carbon Capture and Sequestration: Research, Development, and Demonstration at the U.S. Department of Energy*, 12 (2013).

22 International Energy Agency, *CCS Retrofit: Analysis of the Globally Installed Coal-Fired Power Plant Fleet*, 11 (2012).

23 National Energy Technology Laboratory, *Carbon Sequestration Program Environmental Reference Document*, 2-41-2 (2007), http://www.netl.doe.gov/technologies/carbon_seq/refshelf/nepa/AA%20-%20Assembled%20Document.pdf

24 *Report of the Interagency Task Force on Carbon Capture and Storage*, 35 (2010).

25 *Ibid.*

26 International Energy Agency, *Tracking Clean Energy Progress 2013*, 56 (2013), http://www.iea.org/publications/TCEP_web.pdf

27 International Energy Agency, *Redrawing the Energy-Climate Map*, 105 (2013), http://www.iea.org/publications/freepublications/publication/RedrawingEnergyClimateMap_2506.pdf

28 *Ibid.*

29 Using a capital cost of \$1,999/kW for retrofit applications of CCS applied to 768 GW and a capital cost of \$1,790/kW for new build CCS applied to 200 GW, the total estimated capital cost is \$1.89 trillion. These costs are reflective of the current cost to build CCS in the United States and could vary for the CCS capacity built elsewhere. International Energy Agency, *Redrawing the Energy-Climate Map*, 105 (2013), http://www.iea.org/publications/freepublications/publication/RedrawingEnergyClimateMap_2506.pdf; Energy Information Administration, *Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants*, 6, (2013) http://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf; National Energy Technology Laboratory, *Assessment of Power Plants That Meet Proposed Greenhouse Gas Emissions Performance Standards*, 12 (2009).

Appendix 1: First Generation CCS Projects

Kemper County.¹ Mississippi Power Company, a subsidiary of The Southern Company, is constructing a 582 MW IGCC power plant in Kemper County, Mississippi. Southern received \$270 million of DOE support through the Clean Coal Power Initiative to build an integrated gasification combined cycle (IGCC) power plant which captures and stores CO₂. The Kemper project will use an existing acid gas separation technology, Rectisol, and plans to capture over 65% of the CO₂ produced from the gasifier. The captured CO₂ will be used in an EOR operation.

Summit Texas Clean Energy Project (TCEP).² The Summit Power Group is planning to build a 400 MW IGCC power plant in Ector County, Texas. Summit received \$450 million of DOE support through the Clean Coal Power Initiative to build the IGCC which will capture approximately 90% of the CO₂ from the gasifier using a Rectisol system. Approximately 21% of the captured CO₂ will be used to produce fertilizer. The remaining 79% will be used for EOR, with several companies purchasing the CO₂ from Summit.

NRG Parish.³ Located at the existing W.A. Parish Plant in Houston, Texas, NRG plans to build a 240 MW post-combustion capture project. This project will operate as a slip stream from an existing 270 MW power plant and will use the Fluor Econoamine plus CO₂ capture technology. Having received \$167 million from DOE through the Clean Coal Power Initiative, NRG originally planned a 60 MW project. The project was scaled up to 240 MW to provide enough CO₂ for significant oil production in nearby EOR opportunities. Hillcorp Energy Co. will receive the CO₂ from the Parish plant to conduct EOR operations at their West Ranch Field.

Hydrogen Energy California (HECA).⁴ SCS Energy plans to build a 400 MW IGCC facility in Kern County, California. Supported by a \$408 million grant from the DOE Clean Coal Power Initiative, this facility will gasify a fuel mix composed of 75% coal and 25% petroleum coke, a solid fuel produced by the refining process. The project will utilize a Rectisol system to capture

approximately 90% of the CO₂ produced. Like the Summit TCEP, HECA will use the CO₂ to support both EOR and fertilizer production.

FutureGen.⁵ Located in Meredosia, Illinois, the FutureGen Alliance plans to repower a 200 MW unit at the Ameren Meredosia facility. This repowered unit will operate as a 200 MW oxy-combustion facility. The unit will capture CO₂ and inject it into a saline formation. This project received a \$1 billion grant from DOE.

1 MIT, *Kemper County IGCC Fact Sheet*, <http://sequestration.mit.edu/tools/projects/kemper.html>; National Energy Technology Laboratory, *Demonstration of a Coal-Based Transport Gasifier: Project Facts*, <http://www.netl.doe.gov/publications/factsheets/project/NT42391.pdf>.

2 MIT, *Texas Clean Energy Project (TCEP) Fact Sheet*, <http://sequestration.mit.edu/tools/projects/tcep.html>; National Energy Technology Laboratory, *Summit Texas Clean Energy, LLC: Texas Clean Energy Project: Pre-Combustion CO₂ Capture and Sequestration; Project Facts*, <http://www.netl.doe.gov/publications/factsheets/project/FE0002650.pdf>.

3 MIT, *W.A. Parish Fact Sheet*, http://sequestration.mit.edu/tools/projects/wa_parish.html; National Energy Technology Laboratory, *NRG Energy: W.A. Parish Post-Combustion CO₂ Capture and Sequestration Project: Project Facts*, <http://www.netl.doe.gov/publications/factsheets/project/FE0003311.pdf>

4 MIT, *Hydrogen Energy California Project (HECA) Fact Sheet*: <http://sequestration.mit.edu/tools/projects/heca.html>; National Energy Technology Laboratory, *Hydrogen Energy California Project: Project Facts*, <http://www.netl.doe.gov/publications/factsheets/project/FE0000663.pdf>.

5 MIT, *FutureGen Fact Sheet*, <http://sequestration.mit.edu/tools/projects/futuregen.html>; National Energy Technology Laboratory, *FutureGen 2.0: Project Facts*, <http://www.netl.doe.gov/publications/factsheets/project/FE0001882-FE0005054.pdf>.

Appendix 2: Cancelled, Abandoned or Withdrawn First Generation CCS Projects

AEP Mountaineer.¹ AEP planned to operate a 235 MW slip stream post-combustion capture project at their Mountaineer power plant in West Virginia. The project received a \$334 million grant from DOE but was cancelled due to uncertainty about the project's ability to recovery the additional costs through an increase in electricity rates.

Basin Electric Antelope Valley.² Basin Electric planned to conduct a 120 MW slip stream post-combustion capture project at their Antelope Valley Station in North Dakota. The project received a \$100 million grant from DOE and a \$300 million loan from USDA Rural Utility Service. The CO₂ was to be used in an EOR operation. The project withdrew from the DOE program due to regulatory uncertainty and high project cost.

Tenaska Trailblazer.³ Tenaska had planned to build a 600 MW pulverized coal (PC) plant in Sweetwater, Texas using Fluor Econoamine plus technology to capture 85-90% of the CO₂. The project planned to use the CO₂ for EOR. The project was cancelled because it was no longer "economically viable."⁴

Tenaska Taylorville.⁵ Tenaska had planned to build a 600 MW IGCC plant in Taylorville Illinois. Despite receiving a \$2.56 billion loan guarantee from DOE and \$412 million in tax credits, the project was cancelled due to the project being no longer "economically viable."⁶

Southern Company Plant Barry.⁷ Southern Company planned to capture CO₂ from a 160 MW unit at the existing Plant Barry in Alabama. The project withdrew from the DOE demonstration program after an announced \$295 million grant due to issues associated with cost and timing of the project.

1 MIT, *Mountaineer Fact Sheet*, http://sequestration.mit.edu/tools/projects/aep_alstom_mountaineer.html.

2 MIT, *Antelope Valley Fact Sheet*, http://sequestration.mit.edu/tools/projects/antelope_valley.html.

3 MIT, *Tenaska Fact Sheet*, <http://sequestration.mit.edu/tools/projects/tenaska.html>

4 PennEnergy, *Tenaska drops Taylorville, Trailblazer advanced coal power projects*, <http://www.pennenergy.com/articles/pennenergy/2013/06/tenaska-drops-taylorville-trailblazer-advanced-coal-power-projects.html>.

5 MIT, *Taylorville Fact Sheet*, <http://sequestration.mit.edu/tools/projects/taylorville.html>.

6 PennEnergy, *Tenaska drops Taylorville, Trailblazer advanced coal power projects*, <http://www.pennenergy.com/articles/pennenergy/2013/06/tenaska-drops-taylorville-trailblazer-advanced-coal-power-projects.html>.

7 Congressional Research Service, *Carbon Capture and Sequestration: Research, Development, and Demonstration at the U.S. Department of Energy*, 11 (2013).

Appendix 3: Second Generation CCS Technology

Below are only three examples of ongoing second generation CCS R&D. More detailed information on the ongoing second generation CCS R&D can be found in *DOE/NETL Advanced Carbon Dioxide Capture R&D Program: Technology Update* published in May 2013.

Pre-Combustion Capture. Through ongoing work at universities, industry and national labs, pre-combustion CO₂ capture R&D focuses on membranes, solvents, solid sorbents and hybrid technologies that combine the three. Broadly, these efforts research methods to lower the cost of separating CO₂ from the fuel gas; research goals include increasing CO₂ selectivity of membranes, reducing CO₂ solvent corrosivity, and improving CO₂ sorbent durability.

Post-Combustion Capture. Like the work in pre-combustion capture, national labs, universities and industry are working to lower the overall cost of separating CO₂ from power plant flue gas. The research is focused on solvents, sorbents and membranes. Research goals include increasing the reaction kinetics of CO₂ solvents, improving CO₂ sorbent heat management, and optimizing membrane process design.

Oxy-Combustion. A mix of private, academic and public institutions are undertaking R&D efforts to reduce the overall cost associated with oxy-combustion systems. With a focus on both improving oxygen separation systems and combustion systems, the goals include developing advanced compact boiler designs, minimizing air leakage in boiler retrofits, and developing low cost oxygen separation membrane systems.