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Testimony on

Technological Requirements for Meeting New Source Performance Standards (NSPS) for Emissions of Carbon Dioxide from Electric Generating Units (EGU)

Presented by
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Members of the Subcommittees on Environment and Energy:

Thank you for the opportunity to offer testimony on the New Source Performance Standards (NSPS) being considered by the U. S. Environmental Protection Agency (EPA) under Section 111 of the Clean Air Act of 1970.

EPA identified the following key factors in their criteria for the proposed rulemaking:

- Feasibility – whether the system of emissions reduction is technically feasible
- Costs - whether the costs of the system are reasonable
- Size of the Emissions Reductions – amount of CO2 emissions reduction resulting from the system
- Technology Development – whether the system promotes implementation and further development of technology

My testimony will focus on coal-fired electricity generation. Topics discussed are lessons learned about technology development, the stage of development of CCS (carbon capture and storage) technologies, technology development in other nations, and the need for federal support for research and demonstration projects.

Lessons Learned in Technology Development

Coal Plant Deployments and Performance

Thomas Sarkus of the National Energy Technology Laboratory (NETL) provided an overview of the U. S. Government's program in developing Clean Coal Technologies in a presentation at the 2013 Pittsburgh International Coal Conference. [1]

He noted that pulverized coal boilers were commercialized in the 1920s and 1930s, and that there are about 5,000 units operating world-wide with approximately 1,100 operating in the U. S. Fluidized bed coal combustion boilers were commercialized in the 1970s-1980s, and there are around 500 units operating world-wide with about 150, mostly small, units in the U.S. However, for Integrated Gasification Combined-Cycle (IGCC) coal power plants, there are only nine units operating world-wide and only four in the U. S.

He also shared his experience as a project manager for demonstration projects. He observed that technology performance often degrades with scale-up. In other words, a technology that looks promising in a small laboratory setting may not achieve the predicted operating performance at commercial scales. We often discover that new factors arise in larger systems that were not apparent in laboratory experiments. Also, project financing, cost of a system, and meeting construction schedules are all important considerations in determining if a technology is ready for commercial deployment.

First and Nth of a Kind Plants

In studying the development of technology for full scale systems that are deployed in large numbers such as the 5,000 pulverized coal plants referenced above, engineers have been able to quantify concepts that are called technology learning curves. Typically the highest cost for a full scale unit is the first of a kind (FOAK). As more copies of the same design are built and debugged, the performance of the design will generally improve and the cost for construction and operation will decrease. EPA is counting on the learning curve effect in making its projections for future performance and cost of CCS-based coal plants in establishing the proposed emissions limits on coal systems.

Care is needed, however, in in defining FOAK units and NOAK (Nth of a kind) units. Large scale units are usually based on a particular manufacturer's technology. Observations in the DOE/NETL-34/042211 report [2] illustrate the example that although gasification technologies are similar, it is unlikely that one vendor will share its experience with rivals. They comment that the E-Gas IGCC system (Conoco-Phillips technology) proposed for the Excelsior project is only a second of a kind

[1] Thomas Sarkus, Lessons Learned from U. S. Government Support of Clean Coal Technologies, International Pittsburgh Coal Conference, 2013, Beijing
[2] Quality Guidelines for Energy System Studies – Technology Learning Curve (FOAK and NOAK), DOE/NETL-341-042211, January, 2012 National Energy Technology Laboratory

IGCC based on the Wabash project experience. Little or no benefit will accrue to the E-Gas designers from the Pinion Pines (KRW technology) plant that failed, the Polk (GEE technology) in Florida, or the Buggenum and Puertollano (Shell) projects. Since the Excelsior project did not go forward to construction, of the nine IGCC plants cited by Sarkus above, it is possible they could all be FOAK plants. In this case, we would have only one, high-cost demonstration of each type that still has many major design parameters to be worked out to bring costs down and performance up to the values for an N^{th} of a kind plant.

We must also recognize that, unlike natural gas that is readily available nationally as a uniform commodity, coal varies from region to region in its characteristics. Coal power plants must be designed to accommodate the particular characteristics of the coal supplied. Hence, a large number of plants must be tested over a range of coals to bring a technology to a state of commercial readiness whereby a financial backer is willing to provide financing and a technology vendor is willing to guarantee system performance under penalty of paying the costs for operation of underperforming units.

Traditional pulverized coal plants have achieved demonstrated technology status. New designs such as ultra-supercritical systems or oxygen fired (oxyfuel) systems have not achieved that level of performance attainment given their relatively new introduction as a next-generation technology. Some of EPA's criteria in the NSPS proposal are based on only a FOAK system rather than a NOAK system. Experience has shown that FOAK systems are not commercially available and additional iterations on the technology are required to achieve commercial status.

Technology Integration

Technology learning curve theory also includes the proposition that some plants may have components of a technology that can be considered as N^{th} of a kind, but have critical components that are new and first of a kind. Hence, a pulverized coal technology plant that uses a new technology for carbon capture, such as a membrane, could be considered as a FOAK kind of a plant for the following reason. Control and operational problems usually have to be overcome due to the difficulties of integrating the new component with an older component that was not originally designed to be a good interface with advanced technology systems.

Integrating CCS with a power generation plant introduces complexities. The full system must be designed to handle contingencies that may occur. What if access to the carbon storage reservoir becomes unavailable - what happens to the CO2 captured? Alternatively, if the plant goes off line and the reservoir performance is based on continuous injection of CO2 to avoid damage to the long term performance of the reservoir, where does the plant or reservoir operator get the CO2 needed?

CO2 injection studies into geologic reservoirs have only been carried out at scales of tens of thousands of tons of CO2 per site. Larger scale studies are underway. For a full scale operating plant, a million tons of CO2 per year may be generated and would need to be injected to handle the plant's output. We need to validate geologic storage at this scale to prove out an integrated system with a CO2 capture plant. FutureGen, which is scheduled to be on line in 2017, will integrate the operation of the Meredosia plant with the storage reservoir operations. Integration of all components will be a challenge. This experiment will be a FOAK kind of plant in the context of the present discussion. Since this plant is still not in operation, we have not yet achieved a FOAK status with regard to developing a lessons learned notebook on demonstrating the technology.

Status of Carbon Capture Technologies

Many of the currently discussed post-combustion carbon capture technologies are based on the use of amines or chilled ammonia (recent technology developed by Alstom). The amine technology was originally developed for the chemical industry. In a chemicals plant, it is often necessary to remove CO2 from the process stream. Amine systems have high operating costs. Energy is required to disassociate the captured CO2 from the amine in order to use it again in the process stream. Chemical plants producing high value products can afford the extra expense since costs are recovered in the price of the product.

The price of the electricity is one of the lowest "value-added" components of a multi-product plant – i.e, for a polygeneration plant. Here fertilizer could be made, the captured CO2 sold for enhanced oil recovery (EOR) and process steam sold for district heating. Electricity is a smaller component of the overall outputs of the plant. The Summit and HECA plants referenced in the EPA proposal are plants of this type.

The cost of operating an amine technology for carbon capture in a stand-alone power plant is relatively more than in a chemicals plant. In a plant dedicated solely to generating electricity, the cost of using the traditional amine technology is generally summarized as:

- 45-70% increase in the cost of electricity
- 35-110% increase in capital costs
- 15-21% decrease in the plant's electricity output compared to operations before carbon capture equipment was added

While it has been demonstrated that carbon capture using amines will work technologically, this type of technology is not cost competitive for a stand-alone power generation plant as compared to a chemical refinery or a polygeneration plant. Using newer advanced technologies such as membranes or ionic liquids, or revised power cycles that minimize the steps required to separate and capture CO2 are ways to reduce costs. However, these are newer technologies that have not been demonstrated at commercial scales.

Legal and Social Issues

The large number of legal and social issues associated with developing a carbon sequestration site can delay construction and must be factored into the assessment of a technology's readiness for deployment. Data from many sources show that the cost of electricity from new natural gas plants would be low compared to new coal fired plants. Around 22% of the total cost of electricity for a natural gas combined-cycle plant is the capital cost, whereas capital costs could be as much as 50% of the total cost of electricity for a coal IGCC plant. Given the large fraction of a coal plant's cost that is tied up in debt service for financing and the long operating time over which payback may occur (typically 30-40 yeas), it is important that project construction occur on a timely basis. Otherwise, the increased cost of capital over the delay period would raise the cost of electricity even higher for the coal plant.

Practice has shown, however, that the following factors often add to cost increases that affect financing, technology development, and timeliness for the construction of coal plants:

- Regulatory Issues - permitting, treatment of CO2, …

- Infrastructure Development – pipeline construction and permitting, …
- Human Capital – need for developing a new workforce skilled in building and managing the equipment inside the plant boundary and handling the transport and storage of CO_2 in the field, …..
- Legal Framework – liability for the CO_2 once it is injected, ownership of the pore space under ground, ownership of the CO_2 once injected, legal hassles between states over cross-boundary transport of CO_2 underground, ….
- Public Acceptance – NIMBY → NUMBY perception by the general public
- Uncertainty – uncertainty about future legislation on CO_2 emissions, ….

Carbon storage in geologic reservoirs must also overcome the concerns about injecting fluid into a space that is already crowded as compared to EOR injections. Using CO_2 injection for enhanced oil recovery has been ongoing for a long time. In EOR, the injection of CO_2 can be likened to re-pressurizing the reservoir to an original condition and thereby counterbalances the subsidence that could occur from removing the oil. For geologic storage in saline aquifers, the injection amounts to over-pressurizing the formation, promoting migration of fluids to other areas. This result generates more concerns than for EOR processes. These factors lead to delays in permitting and construction, and hence must be considered as a part of the cost and technical readiness of a technology. These issues have not been adequately resolved to attract power plant financers to invest money in projects with CCS.

Demonstration Status of CCS Technologies

The following comments address the theme of the present hearing, namely, has the commercial deployment of CCS technologies been "adequately demonstrated" to meet the key criteria of EPA cited above.

Feasibility

As noted above, the feasibility of using amine solutions for capturing CO_2 has long been demonstrated in the chemicals industry. While technically feasible, the cost of the amine solution process is very expensive for power generation. The use of these amine solutions over extended duty cycles in coal gas atmospheres needs further development.

System integration issues are also a concern with regard to the operation of amine towers. The process works by trickling the solution down a wall that is exposed to the CO_2 gas. Most chemical plants operate with one tower where instabilities in the falling film of amine caused by the upward rush of the CO_2-laden air can be managed based on operating experience. For a large scale power plant, multiple amine towers will be required. Fluid flow instabilities in one tower can affect the operation of adjacent towers due to switching air flows in reaction to the tower upsets. This situation is one example of integration studies that need to be performed on large scale demonstration units before the technology can be said to be adequately demonstrated at commercial scale.

Coal-based IGCC systems have not been demonstrated in sufficient numbers as noted above, especially in carbon capture applications. Many of the examples cited in the EPA proposal have been for polygeneration systems. Additional research and demonstration is needed for stand-alone IGCC power generation systems.

Long-term storage of CO_2 in geological reservoirs has not been demonstrated for large volumes of injected fluid on a continuous basis.

Cost

As noted above, costs associated with amine capture are high compared to costs that are expected to be realized when advanced carbon capture technologies come to fruition.

Additional costs are incurred due to the social and legal aspects of permitting a CCS power plant – storage field operation. These factors must be considered in assessing the cost of compliance with the 1,100 pounds of CO_2 per megawatt hour standard proposed by EPA.

The latest pulverized coal plant that is an indication of the state of pulverized coal technology is the Turk plant, which is estimated to operate at a rate of 1,800 pounds of CO_2 per megawatt hour. A significant cost and performance penalty will apply to reduce the emissions to 1,100 pounds per megawatt hour. Large scale operations of a coupled plant and storage system have not been operated sufficiently long to develop cost estimates of a combined operation.

The cost of using currently available carbon capture technologies is considered to be too expensive to be competitive for coal based systems.

Size of Emissions Reductions

Given the uncertainties associated with questions of feasibility and costs as noted above, it is likely that few if any coal plants will be deployed in the time frame proposed by EPA. Hence, the present proposal will not lead to significant reductions as stated by EPA.

However, if the proposal could be modified to delay the lower CO_2 emissions requirement, there may be opportunities to propose new plants based on technologies that could be developed in the near future. Therefore, emissions reductions could result from a delay in implementing the standard.

Technology Development

As above, if no new plants would be built, there is no driver for developing technology for CO_2 capture and storage. It is desirable to maintain a diverse portfolio of fuels to meet our energy needs. Programs that would encourage technology development are essential. Phasing in the standards over a longer time would provide a window for developing advanced technologies that could be demonstrated on a timely basis to achieve the goals of the EPA proposal.

Comments on Global Technology Development

The use of coal for power generation and chemicals production (liquid fuels, fertilizer, chemical products, ….) in China has passed the U. S. usages and the gap between the U. S. and China will continue to widen with respect to coal technologies.

Chinese planners have been willing to make investments in new technologies through support of fundamental and engineering scale research, and development of coal-based systems from large pilot plant operations to full scale development. These investments have been made by the government or by government-owned industries.

As a result, China has taken a leadership role in coal-to-chemicals and coal-to-liquid fuels production technologies, and is rapidly developing technologies for advanced power generation with coal systems and carbon storage. Their next Five Year plan will include a focus on government supported CCS activities, with active involvement in geological storage research and demonstrations.

Federal Support for Research and Demonstration Projects

The U. S. research and development program for coal-based technologies has made progress in developing advanced pulverized coal and gasification systems that include higher efficiency processes and carbon capture and storage applications. However, more progress needs to be made to achieve the goals proposed by EPA. A robust federal research, development and demonstration program is needed.

Advances in fundamental research in developing new materials, new control and integration technologies, and advanced cycles offer promise for higher efficiency in terms of power generation and in carbon capture and storage. Demonstration programs are more-or-less at the first of a kind status in developing ideas to the scale where their commercial viability and performance can be evaluated. In both of these areas, we need continued and strong support from Congress to ensure continued development of coal as a viable fuel for our nation.

Efficient coal technologies will ensure our energy and economic security by maintaining diversity in our portfolio of fuels. As a nation, we can show global leadership by developing and exporting technologies that address mounting concerns about carbon emissions. A risk we take by not acting in a strong leadership manner is that we will be buying our technology from other nations who are more aggressive in developing their technology base.

Closing Comments

Without the building of new plants, no technology advancement would occur to demonstrate the commercial readiness of new carbon capture and storage plants. Investments in a strong research, development and demonstration program, coupled with a delayed phase-in of the standards proposed by EPA would provide improved opportunities for technologists to meet the challenges proposed to us by EPA to improve our environment and economic competitiveness through advanced coal technologies. I recommend your consideration for both of these approaches.