Status of CO_2 Capture Technologies

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ABSTRACT

EPRI has an on-going effort to understand the landscape of postcombustion CO_2 capture technologies globally, and accelerate their development. Several central issues facing CO_2 capture involving scale, energy, and overall status of development will be discussed. We show that the scale of CO_2 emissions is sufficiently large to place inherent limits on the types of capture processes that could be deployed broadly. We also discuss the minimum energy usage in terms of a parasitic load on a power plant and we present summary findings of the landscape of capture technologies using an index of technology readiness levels.

Keywords: Post-Combustion, CO_2 Capture

1 INTRODUCTION

Many governmental agencies at the state, federal, and international level are discussing and pursuing placing limits on CO_2 emissions as part of a drive to reduce overall anthropogentic greenhouse gas (GHG) emissions. The the electric generation industry is among the first group of emission sources being targeted for these reductions, as exemplified by the recent US Environmental Protection Agency (EPA) proposed rules for new source performance standards for greenhouse gas emissions from electric utility generating units.[1] The electric utility industry in the US and other countries that rely substantially on combusing fossil fuels to generate electricity are therefore keen to find ways to reducing GHG emissions. For the US, in 2008, CO2 emissions from electricity generation in accounted for about 40% of US CO2 emissions and 34% of the US total GHG emissions.**Error! Bookmark not defined.**,[2] Globally, approximately 31.2 Gt CO2 was emitted in 2008, dropping by 1.3% in 2009.[2]

One option for controlling post-combustion CO2 emissions is carbon capture and storage (CCS), where CO2 is separated from the rest of the flue gas and permanently stored in subsurface geologic reservoirs. In part, due to the absence of regulation today, no utility-scale (500+ MWe) post-combustion CO2 capture systems have been tested, and most testing to date has been on scales less than 20-25 MWe. But these first-generation capture technologies are energy intensive and are projected increase the cost of electricity (COE) for the host power plant by 60-100% and reduce net electrical output by 30-35%. [3,4,5]

While the US Department of Energy has not set a performance target for energy consumption for post-combustion carbon capture processes, it has set a cost target of less than 35% increase in COE with CO2 capture, compression, transportation, injection, and storage with measurement, monitoring, and verification.[6] Among the costs for each CCS component, CO2 capture is the most expensive at approximately 60-70% of the total cost, and is the primary focus for CCS cost reduction opportunities.[4,5]

To enable such cost reductions, EPRI has a multi-year on-going effort to identify, vet, and appropriately accelerate promising post-combustion CO_2 capture technologies. We have evaluted over 120 technologies thus far. From this activity, several broad-based insights have been garnered and are presented in this paper.

2 TWO CHALLENGES

CO_2 capture is challenging for two reasons: energy for capture and scale of emissions.[7] The energy required for capture is the dominant cost in CO_2 capture,[5] and in as in any separation of a mixture, a thermodynamically minimum amount of energy is required to conduct the separation. Flue gas from a coal-fired power plant contains about 13% CO_2, and separating 90% of it from the rest of the flue gas (predominantly N_2) requires a thermodynamic minimum energy of 0.1611 GJ/t CO_2 if the gas temperature is 40°C.[7] The average emissions of coal-fired power plants is 25.17 t CO_2/MWe-day of generation or generates 3.43 GJ of net electricity for each tonne of CO_2 it emits.[7,8] Hence, if the only energy source for energy to drive the capture comes from the net electrical output of a power plant, then any capture process would impose a minimum parasitic load of 4.22% on the net output of a power plant. A capture process more load to a less efficient power plant and less load to a more efficient power plant. Most near-term capture processes, excluding compression, however, impose a load of 20-25%, or about 5-6 times this minimum value. Indeed, many large-scale commercial separation processes operate at several multiples of their own thermodynamic minimum energy. Yet, it is not yet clear if there is a practical, economic lower limit to the energy required for carbon capture, and this gives the hope that potentially lower energy carbon processes could be developed.

The second reason carbon capture is challenging is scale of emissions. The US utility sector emits about 2.4 Gt CO_2/year, while the US as a nation emits about 6 Gt CO_2/year.[9,10] To put this in perspective, the top 50 chemicals produced in the US have a total combined mass of only 0.4 Gt/year. Indeed, it is fairly straightforward to show,[7] that reagents used to capture CO_2 just from the US utility sector will exhaust both US and global supplies by many multiples unless the reagent can be regenerated. Likewise, chemicals made from CO_2 just from the US utility sector will saturate US and global markets of these chemicals by many multiples. Therefore, CO_2 capture technologies that rely on using reagents in a once-through manner or those that rely on making saleable products from CO_2 will be inherently limited to niche applications relative to the scale of anthropogenic CO_2 emissions. Likewise, the enitre current US usage of CO_2 for enhanced oil recovery can be supplied by just four of the largest power plants in the US.[7] These arguments, therefore, place inherent limits on the beneficial use of CO_2 realtive to the scale of anthropogenic emissions.

3 STATUS

In our work, we actively sought process developers, both in early-stage research to actively pursuing pilot testing. We analyzed solvents, adsorbents, membranes, mineralization, and other processes. Our approach was to understand the basic principles of the process, focusing expressily on the mass and energy balances, and attempting to determine whether the technology could be deployed broadly across the utlity industry. In addition, we used a sscale of technology readiness level (TRL) to determine the readiness of a technology for power plant application. First developed by NASA to determine readiness of given technologies for space applications,[11] TRL is a useful metric that can provide an easy means to determine overall state of development. TRL is metric that relies only on technical and developmental attributes, not economic attributes.

Of the 120 technologies we've considered thus far, we were able to assign a TRL ranking to approximately 95 of them. As expected, technologies closer to commercial deployment reflected higher energy consumption, higher costs, and lower risk, whereas technologies fruther from commercial deployment reflect potentially lower energy consumption, lower costs, but with significant uncertainty and technical risk. Moreover, we noted that the time needed to move from early-stage technologies to late-stage technologies is at least 10-15 years on a very well-funded, very aggressive schedule.

4 CONCLUSIONS

Based on this on-going work, EPRI has gained significant insights on capture processes, trends, and techncial gaps in CO_2 capture. During this work, we observed that virtually all existing approaches for new material development are serially driven from synthesis chemistry to process engineering to power plant testing. This serial development is slow and frequently leads to capture processes that actually increase energy consumption, increase COE, or are simply impractical. Therefore, we firmly believe that CO_2 capture development must be done in close coordination with synthesis chemists to develop CO_2 capture materials, separation engineers to wrap processes around the materials, and personnel at power plants who will ultimately use the technology.[7] EPRI has several projects and programs focused on this approach, both internally and in partnership with other organizations.

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