Technical and economic assessment of ammonia-based post-combustion CO₂ capture

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Abstract

The performance and cost of two ammonia-based post-combustion CO₂ capture systems operating at a new supercritical coal-fired power plant were modeled and compared to an amine-based CO₂ capture system operating at a similar plant. This assessment showed that for a fixed coal input, the plant derating of a CO₂ capture system operating with high ammonia concentrations (HighNH₃) was found to be 2 percentage points lower than a plant with the amine-based system. The plant derating of a CO₂ capture system operating with low ammonia concentrations (LowNH₃) was substantially higher. Preliminary estimates of the revenue requirement of the plants with HighNH₃ and LowNH₃ systems are U.S. 117/MWh and U.S. 148/MWh respectively, compared to U.S. 119/MWh for a plant with an amine-based system. The results from this performance assessment and preliminary cost analysis suggest that the LowNH₃ system will not be competitive and that the HighNH₃ system may have a slight energy and cost advantage over the amine system. Furthermore, a preliminary uncertainty analysis explores the critical factors that may affect the performance and cost estimates of these systems, including the potential for slow reaction kinetics to increase absorber costs, and these results are presented.

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1. Introduction

Policy makers face central questions about costs and effectiveness in assessing CO₂ emission mitigation options [1]. One such option is post-combustion CO₂ capture, which targets CO₂ emissions released from the burning of fossil fuels. Amine scrubbing is the leading post-combustion CO₂ capture technology, and is well understood and ready for large scale use [2]. Post-combustion CO₂ capture based on ammonia is less understood but is attractive because ammonia is inexpensive, the CO₂ can be regenerated at high pressure, and the steam requirements for the regeneration process may be lower than for amine-based technologies. This study presents a performance assessment and preliminary cost analysis of a power plant integrated with ammonia-based CO₂ capture, and compares the results to a plant with an amine-based system. Using tools that have already been developed, this paper is intended to be a starting point for estimating costs for this process, and will help policy makers be more informed about the costs of CO₂ emission mitigation options.

For comparing performance and costs between post-combustion CO₂ capture with ammonia and amine technologies, this paper uses the plant derating of CO₂ capture on the power plant and the levelized revenue required as two key parameters, as calculated in equation 1 and equation 2. The plant derating for CO₂ capture is expressed as the percentage reduction in net plant output for a constant energy input and is occasionally reported as an “energy penalty”.

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\text{Plant Derating} = \frac{\text{Plant Efficiency without Capture} - \text{Plant Efficiency with Capture}}{\text{Plant Efficiency without Capture}} \quad (1)
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\text{Revenue Required} = \frac{\text{Total Plant Costs + Fixed Charge Factor + O&M Costs}}{\text{8760} \times \text{Capacity Factor} \times \text{MWh Produced}} \quad (2)
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