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Cost and performance of fossil fuel power plants with CO_2 capture and storage

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Abstract

CO_2 capture and storage (CCS) is receiving considerable attention as a potential greenhouse gas (GHG) mitigation option for fossil fuel power plants. Cost and performance estimates for CCS are critical factors in energy and policy analysis. CCS cost studies necessarily employ a host of technical and economic assumptions that can dramatically affect results. Thus, particular studies often are of limited value to analysts, researchers, and industry personnel seeking results for alternative cases. In this paper, we use a generalized modeling tool to estimate and compare the emissions, efficiency, resource requirements and current costs of fossil fuel power plants with CCS on a systematic basis. This plant-level analysis explores a broader range of key assumptions than found in recent studies we reviewed for three major plant types: pulverized coal (PC) plants, natural gas combined cycle (NGCC) plants, and integrated gasification combined cycle (IGCC) systems using coal. In particular, we examine the effects of recent increases in capital costs and natural gas prices, as well as effects of differential plant utilization rates, IGCC financing and operating assumptions, variations in plant size, and differences in fuel quality, including bituminous, sub-bituminous and lignite coals. Our results show higher power plant and CCS costs than prior studies as a consequence of recent escalations in capital and operating costs. The broader range of cases also reveals differences not previously reported in the relative costs of PC, NGCC and IGCC plants with and without CCS. While CCS can significantly reduce power plant emissions of CO_2 (typically by 85–90%), the impacts of CCS energy requirements on plant-level resource requirements and multi-media environmental emissions also are found to be significant, with increases of approximately 15–30% for current CCS systems. To characterize such impacts, an alternative definition of the "energy penalty" is proposed in lieu of the prevailing use of this term.
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Keywords: CO_2 capture and storage cost; Comparative power plant economics; Carbon sequestration energy requirements

1. Introduction

CO_2 capture and storage (CCS) is receiving considerable attention as a potential greenhouse gas (GHG) mitigation option that could allow a smoother and less costly transition to a sustainable, low-carbon energy future over the next century (Riahi et al., 2003; IPCC, 2005). Although commercial technology exists to separate and capture the CO_2 generated in large-scale industrial processes, applications to date are found mainly in the petroleum and petrochemical industries (such as for natural gas processing and ammonia production). Capture of CO_2 from combustion-generated flue gases also has been demonstrated commercially at small scale for gas-fired and coal-fired boilers (Rao and Rubin, 2002). However, to date there have been no applications of CO_2 capture at an electric power plant at a large scale (e.g., 100 MW or more). Geological sequestration of captured CO_2 also has been demonstrated at three large-scale projects in Norway, Canada and Algeria (each storing over one million tons CO_2 per year), with other smaller-scale projects planned or underway worldwide (IPCC, 2005). Nevertheless, the legal and regulatory frameworks for a geological CO_2 sequestration program as a GHG abatement method largely remain to be developed.

The cost of CCS technology could pose another barrier to its widespread use as a GHG control strategy. The total cost of CCS includes the cost of CO_2 capture and compression; the cost of CO_2 transport (typically via a

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