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Performance and cost of wet and dry cooling systems for pulverized coal power plants with and without carbon capture and storage

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ABSTRACT

Thermoelectric power plants require significant quantities of water, primarily for the purpose of cooling. Water also is becoming critically important for low-carbon power generation. To reduce greenhouse gas emissions from pulverized coal (PC) power plants, post-combustion carbon capture and storage (CCS) systems are receiving considerable attention. However, current CO_2 capture systems require a significant amount of cooling. This paper evaluates and quantifies the plant-level performance and cost of different cooling technologies for PC power plants with and without CO_2 capture. Included are recirculating systems with wet cooling towers and air-cooled condensers (ACCs) for dry cooling. We examine a range of key factors affecting cooling system performance, cost and plant water use, including the plant steam cycle design, coal type, carbon capture system design, and local ambient conditions. Options for reducing power plant water consumption also are presented.

1. Introduction and objectives

Water is an integral element of electricity generation at thermoelectric power plants, primarily for the purpose of cooling. Thermoelectric power plants account for approximately 39% of freshwater withdrawals in the United States, ranking slightly behind agricultural irrigation as the largest source of freshwater use (Feeley et al., 2008). Future water demands for electricity generation will increase as thermoelectric generating capacity is projected to grow by approximately 18% by 2030 relative to 2005 (NETL, 2009). To minimize adverse environmental impacts, the Clean Water Act (CWA) requires the use of best available control technologies for new power plants, which has promoted the widespread use of closed-loop evaporative cooling systems employing wet cooling towers in place of once-through cooling systems (EPA, 2008).

If evaporative cooling towers continue to be utilized in new power plants, consumptive water use for electricity production in the U.S. could more than double by 2030 (DOE, 2006). In the meanwhile, to address growing concerns about greenhouse gas emissions from pulverized coal (PC) power plants, post-combustion carbon capture and storage (CCS) is receiving considerable attention. However, as will be seen in this paper, significant quantities of water are required to cool the post-combustion capture processes that are now commercially available for removing carbon dioxide (CO_2). This puts further pressure on the demand for water resources (IPCC, 2005; NETL, 2007a). Population and electricity demand growth, along with an increasing possibility of droughts in some areas, could induce water shortages that would further exacerbate this problem (Sovacool and Sovacool, 2009). In some regions of the U.S., limited water supplies already have led to deployment of alternative cooling technologies such as dry cooling systems in order to reduce power plants water use, albeit at a higher cost than conventional systems (EPRI, 2004). Given the growing importance of power plant water use, it is important to have a more complete picture of the performance and cost implications of alternative cooling technologies, particularly in the context of low-carbon power generation with CO_2 capture.

The major objectives of this paper, therefore, are to: (1) evaluate the plant-level performance and cost of current wet and dry cooling technologies for PC power plants, including systems with post-combustion CO_2 capture; (2) identify and display the effects of key factors affecting cooling system performance and cost for different plant designs; (3) compare the impacts of wet and dry systems on overall power plant water consumption, efficiency and cost for cases with and without CCS; and (4) draw out policy implications for integrating energy production and water resource management, especially in the context of climate change. The cooling technologies considered include recirculating evaporative towers for wet cooling and air-cooled condensers (ACC) for dry cooling. The performance evaluation emphasizes makeup water usage for wet systems and ACC sizing for dry systems. The cost assessment focuses on total capital cost and total levelized cost of electricity (COE) generation.

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