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Potential emissions reductions from grandfathered coal power plants in the United States

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ABSTRACT

A two-tiered approach to environmental regulation in the United States has long allowed existing coal-fired power plants to emit air pollutants at far higher rates than new facilities. The potential for reducing the emissions of existing coal-fired facilities is quantified via two hypothetical scenarios: the installation of available retrofit control technologies, or the imposition of New Source Performance Standards (NSPS). Available control technologies could have reduced year 2005 emissions by 56% for NO_x and 72% for SO_2 for a cost of $11.3 billion/year (2004$), likely yielding far larger benefits to human health. Slightly more emission reductions would be achieved by upgrading or replacing existing facilities to achieve the NSPS emissions limits required of all new facilities. Potential CO_2 reductions are more speculative due to the emerging nature of carbon capture and efficiency retrofit technologies. Recent policies such as the Cross-State Air Pollution Rule would likely achieve most of the NO_x and SO_2 reduction potential identified by the scenario analyses for grandfathered facilities. However, escalating obstacles to new generation capacity may perpetuate the reliance on an aging fleet of power plants, resulting in higher rates of coal consumption and CO_2 emissions than could be achieved by new or retrofit units.

1. Introduction

The United States historically has followed a two-tiered approach in regulating the emissions from coal-fired power plants, the nation's largest industrial emitters of nitrogen oxides (NO_x), sulfur dioxide (SO_2), and carbon dioxide (CO_2) (US-EPA, 2007c; US-DOE, 2010). New or modified facilities must achieve New Source Performance Standards (NSPS) for air pollutant emissions (US-EPA, 2007a). Those standards are periodically reviewed and strengthened based on the performance of available technologies, and may soon be extended to greenhouse gas emissions (US-EPA, 2009b).

By contrast, existing power plants avoid the regulatory hurdles of new construction and are exempted from NSPS emissions limits under "grandfathering" provisions of the Clean Air Act (Nash and Revesz, 2007). Cap-and-trade policies such as the Acid Rain Program (US-EPA, 2000), NO_x State Implementation Plan (SIP) Call (US-EPA, 2003), and Clean Air Interstate Rule (US-EPA, 2005) have prompted many existing power plants to reduce their emissions, primarily via the installation of retrofit control technologies. In addition, States impose facility-specific emissions limits on existing sources to help attain ambient air quality standards. However, those limits are often far more lax than the NSPS required of new sources, and many coal-fired power plants continue to operate with less stringent controls than could be achieved (US-EPA, 2009c, 2010d).

Ackerman et al. (1999) showed that requiring grandfathered power plants in 1996 to on average achieve NSPS limits would have reduced their NO_x and SO_2 emissions by 3.3 and 7.3 million tons/year, respectively, at an annual cost of $9.2 billion. Since then, air pollutant emissions at existing facilities have declined substantially under more stringent permit requirements and cap-and-trade limits (Kim et al., 2006; US-EPA, 2007b). Meanwhile, NSPS for new electric generating units (EGUs) have been strengthened (US-EPA, 2007a), and control technologies for NO_x and SO_2 have continued to develop, enabling control efficiencies of 80–96% (Srivastava and Jozewicz, 2001; Srivastava et al., 2005). Retrofitting power plants for carbon capture and storage (CCS), while still not in widespread practice, is now a plausible option to consider (Rao and Rubin, 2002; Patino-Echeverri et al., 2007).

This manuscript reassesses the potential for curtailing emissions at existing US coal-fired power plants by applying two hypothetical scenarios to the year 2005 fleet. Scenario A quantifies the emission reductions and associated costs of applying the most stringent available retrofit technologies to existing boilers, while Scenario B computes the emission reduction that would be

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necessary if all grandfathered boilers were required to meet current NSPS emissions limits.

2. Data

A comprehensive database of existing US coal steam power plants was assembled by merging the most recent available data at the time of this analysis from two sources: year 2005 boiler-level emissions and operating statistics from the Emissions and Generation Resource Integrated Database (eGRID2007 v. 1.1) (US-EPA, 2008), and boiler-level capacity and heat rate data from the National Electric Energy Data System 2006 (NEEDS) (US-EPA, 2006). The one-year mismatch in the data sources is not problematic because the NEEDS data represent time invariant boiler characteristics. Of the 1491 coal steam boilers in eGRID, we restrict our analysis to the 1218 boilers that could be matched with NEEDS data, corresponding to 97.1% of the eGRID fleet on a year 2005 heat input basis. Annual electricity generation (GWh/year) from each boiler is estimated by dividing year 2005 eGRID heat input data (MMBtu/year) by NEEDS heat rate data (Btu/kWh).

3. Results

3.1. Characterization of existing coal EGU fleet

The distribution of year 2005 coal-fired electricity generation by boiler vintage (Fig. 1) reflects a fleet in which very few new boilers have come online since 1990, yet hundreds of grandfathered boilers have outlasted the 30-year useful lifetime often assumed for such devices. The largest share of boilers came online in the 1970s, when electricity demand grew more than twice as fast as today (US-DOE, 2009) and rising oil prices prompted a shift toward coal. Less than 5% of US coal-fired electricity generation in 2005 came from boilers built since 1990, while 51% came from boilers that were more than 30 years old (Fig. 1).

Older boilers on average emit SO_2 and NO_x at far higher rates than their more recent counterparts, while CO_2 emission rates are roughly constant for vintages since the 1950s (Fig. 2). The most pronounced trend is for SO_2, with 1950s vintage boilers emitting 5 times more on an output-weighted average basis than the newest boilers. NO_x emission rates decline by more than a factor of 2 across these vintages. The trends primarily reflect the greater prevalence of emission control technologies such as flue gas desulfurization ("scrubbers") for SO_2 (Srivastava and Jozewicz, 2001) and selective catalytic reduction (SCR) for NO_x among the newer boilers (Srivastava et al., 2005), while CO_2 emissions have gone uncontrolled. Thus, boilers older than 30 years old represented 70% and 56% of SO_2 and NO_x emissions, respectively, despite supplying only 51% of coal-fired electricity in 2005.

Within the vintages, there were order of magnitude variations in the NO_x and SO_2 emissions rates of individual boilers, driven largely by the extent of control technologies that have been deployed. For example, among coal-fired boilers that came online in the 1970s, year 2005 NO_x emission rates ranged from 0.4 to 10.5 lb/MWh (weighted average: 3.3; standard deviation: 1.7), and SO_2 emission rates ranged from 0.3 to 40.7 lb/MWh (weighted average: 9.5; std. dev.: 8.2) (Fig. 3). Carbon dioxide emission rates were much more consistent; for example, they ranged from 1866 to 2975 lb/MWh (weighted average: 2121; std. dev.: 174) among the 1970s boilers. The narrower range occurs because traditional control technologies do not reduce CO_2

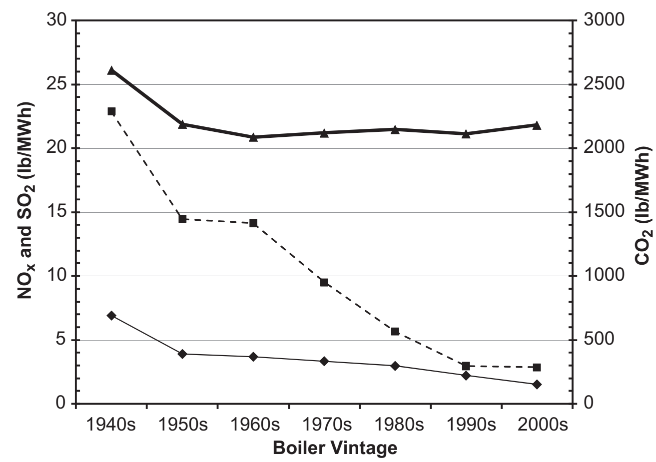

Fig. 2. Output-weighted emission rates of CO_2 (thick line), SO_2 (dashed), and NO_x (thin) from coal-fired boilers in the year 2005 merged database.

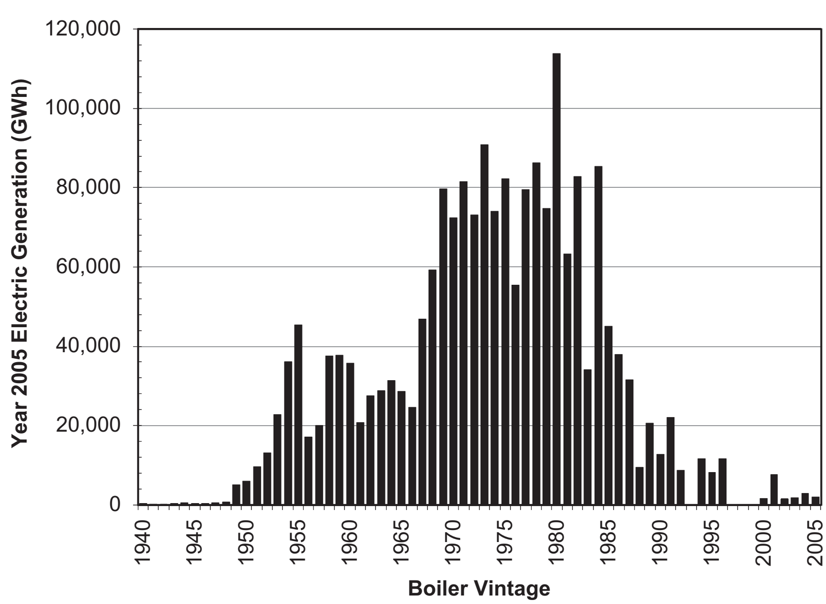

Fig. 1. Coal-fired electricity generation in the 2005 merged database, by boiler vintage.