Appendix A - Data Appendix

Unit-level compliance strategy choices

1. EPA Electronic Data Reporting for the Acid Rain Program/subpart H. The EPA collects hourly data from over 900 U.S. power plants who are required by law to install and operate Continuous Emissions Monitoring Systems (CEMS). All units that are affected by the Acid Rain Program, the NOx Budget Trading Program and/or the NOx SIP Call are subject to the monitoring and reporting provisions of Subpart H. Units must report what type of NOx controls they are operating, installation dates and hours of operation.
2. Energy Information Administration (EIA). Facilities must also report information about NOx controls annually to the EIA.
3. Institute for Clean Air Companies: Collects information about pollution control retrofits from press releases, annual reports, and other sources.
4. MJ Bradley & Associates: Maintains a comprehensive database containing unit-specific information regarding pollution control equipment.

Data required to estimate control costs at the unit level

1. U.S. EPA National Electric Energy System (NEEDS): (see above). Includes over 20 unit level variables, including capacity, heat rate, online year, firing and bottom types. Data are annual; most recent data are 2000.
2. EPA Electronic Data Reporting for the Acid Rain Program/subpart H: The EPA collects hourly data from over 900 U.S. power plants who are required by law to install and operate continuous emissions monitoring systems (CEMS). All the plants in my sample are subject to the monitoring and reporting provisions of subpart H. This database contains thousands of variables, most of which are measured hourly at the unit level. Data are available with approximately a six month lag.
3. U.S. EPA Emissions and Generation Integrated Database (EGRID): EGRID consolidates available plant level data for all U.S. power plants that are obliged to report data to the U.S. government. EGRID reports data on an annual level for hundreds of variables at the boiler, plant, company, parent company and state level. The most recent data are 2000.
4. Energy Information Administration (EIA) Form 767 : Power plants(non-nuclear) larger than 10MW are required to submit form EIA-767 annually. The forms collect data on plant operations and equipment design (including boilers, generators, cooling systems, flue gas desulfurizations, flue gas particulate collectors, and stacks). Most recent data are 2002.
5. Energy Information Administration (EIA) Form 860: Power plants(non-nuclear) larger than 10MW are required to submit form EIA-767 annually. The forms collect generator-specific information such as initial date of commercial operation, generating capacity, ownership and energy sources.
6. Platts BaseCase: A comprehensive database covering supply, electric demand, transmission interfaces, and Platts fuel price forecasts, as well as unit-level hourly data. Compiled from EIA, FERC, NERC, CEMS, RUS, utility reports, manufacturers' publications, and Platts sources.
7. Raftelis Financial Consultants Water and Wastewater Rate Survey.

8. Bureau of Labor Statistics: Regional estimates of boilermaker and construction wages.

9. Personal Correspondence: Representatives from the major coal-fired boiler manufacturers (Alstom Engineering, Babcock Power, Foster Wheeler, Riley Power Inc.) provided valuable information about the technical specifications of the boilers in the sample De-NOx Technologies LLC provided data on reagent and reagent transportation costs. Other technical assistance was provided by Cichanowicz Consulting Engineers LLP.

Permit Price/Transaction Data

1. Evolution Markets LLC

Estimates of anticipated post-retrofit NOx emissions rates (conditional on boiler characteristics) constructed using the following sources:

1. Biewald, B., J. Cavicchi, T. Woolf and D. Allen. 2000. "Use of Selective Catalytic Reduction for control of NOx Emissions from Power Plants in the U.S." *Synapse Energy Economics Inc.*

2. Cichanowicz, J.E. 2004. "Why are SCR costs still rising?". *Air Quality Control*, 148(3): 32.

3. Electric Policy Research Institute. 1999. "Application of Methodology for Identification of Least Cost NOx Control Combinations."

4. Electric Policy Research Institute. 1999. UMBRELLA: "Software for Assessing NOx Control Technology Combinations, Version 1.0."

5. Farzan, H. G.J. Maringo, D.W. Johnson, D.K. Wong . 1999."B&W's Advances on Cyclone NOx Control via Fuel and Air Staging Technologies", EPRI_DOE_EPA Combined Utility Air Pollutant Control Symposium, Atlanta GA.

6. Staudt, J. "Technologies and Cost Effectiveness of Post-Combustion NOx Controls." Andover Technology Partners, http://www.netl.doe.gov/publications/proceedings/99/99scr-sncr/staudt.pdf.

7. Steitz, T.H., R.W. Cole. 1999. "Field Experience in Over 30,000 MW of Wall Fired Low NOx Installations." Foster Wheeler Energy Corporation.

8. U.S. Department of Energy. 2002."Full-Scale Demonstration of Low-NOx Cell Burner Retrofit." http://www.netl.doe.gov/cctc/summaries/clbrn/cellburnerdemo.html.

9. U.S. Environmental Protection Agency. 2002. Documentation Supplement for EPA Modeling Applications (V.2.1) Using the Integrated Planning Model. Office of Air and Radiation. Washington D.C.

10. U.S. Environmental Protection Agency. 1999. Regulatory Impact Analysis for the Final Section 126 Petition Rule, Office of Air and Radiation, Washington DC.

11. U.S. Environmental Protection Agency. 1998. Regulatory Impact Analysis for the NOx SIP Call, Office of Air and Radiation, Washington DC.

12. U.S. Environmental Protection Agency. 1998, Feasibility of Installing NOx Control Technologies by May 2003, Office of Atmospheric Programs, Acid Rain Division, Research Triangle Park, NC.

13. U.S. Environmental Protection Agency. 1998. Regulatory Impact Analysis for the NOx SIP Call, FIP and Section 128 Petitions, Office of Air Quality Planning and Standards, Office of Atmospheric Programs, Washington D.C.

14. U.S. Environmental Protection Agency. 1998. Analyzing Electric Power Generation under the CAAA. Office of Air and Radiation. Washington D.C.

Table A-1: Generating Unit Characteristics

Variable	
# Units	632
# Facilities	221
Capacity [MW]	275
	(261)
Age [years in 2000]	35
	(13)
Pre-retrofit Emissions	0.50
[lbs NOx/kWh]	(0.22)

Notes: Standard deviations are in parentheses. The unit of analysis is a generating unit or boiler.

Appendix B - APEEP Simulations[1]

We use the AP2 model to estimate the effects of incremental changes in NOx emissions at power plants covered by the NBP and vehicles regulated by Tier 2 on the formation and transport of nitrates. The model, an updated version of the APEEP model, is comprised of six modules; emissions, air quality modeling, concentrations, exposures, physical effects, and monetary damages. The emissions data are provided by the USEPA's National Emission Inventory. The model attributes these data to both the appropriate source location and source type. Specifically, AP2 models emissions from individual point sources (mostly large electricity generating units). Emissions from the remaining point sources are decomposed according to height of emissions and the county in which the source is located. For ground-level emissions (these are produced by cars, residences, and small commercial facilities) the model attributes these discharges to the county in which they are reported (by US EPA) to occur.

The approach to air quality modeling uses a reduced form statistical model to capture the processes that connect emissions to concentrations. The predictions from the AP2 model have been tested against the predictions made by a more advanced air quality model (see Muller and Mendelsohn, 2007). The model then connects ambient concentrations to physical impacts using peer-reviewed dose-response functions. In order to value the risk of premature mortalities due to pollution exposure, the Value of a Statistical Life (VSL) method is used. In particular, a VSL of approximately $6 million is assumed. This value, which is used by USEPA, results from a meta-analysis of nearly 30 studies that compute VSLs. Further, each case of chronic bronchitis is valued at approximately $300 thousand which is also the value used by USEPA.

In each simulation, other components of the model are held fixed so that the resulting difference can be interpreted as the damage (measured in dollars) per pound of NOx emissions at the selected source. All damages are measured relative to those associated with observed 2002 emissions. Damages include adverse effects on human health, reduced yields of agricultural crops and timber, reductions in visibility, enhanced depreciation of man-made materials, and damages due to lost recreation services

Our comparison of these marginal damage estimates across source types should be interpreted with some care. Because the model uses a reduced form approximation of ozone photochemistry (versus photochemical air quality simulations), estimates of the effects of small changes in NOx emissions on ozone formation at different locations can be noisy. Specifically, the simulation model uses a linear regression model to estimate ozone concentrations as a function of ambient concentrations of precursors (i.e., NOx, VOCs, and CO), ambient air temperature, and geography variables. Because precursor concentrations are highly correlated, it is difficult to obtain a precise estimate of the isolated effect of a change in NOx emissions on ozone concentrations, or to simulate the conditions in power plant plumes versus auto exhaust. Moreover, the model does not include interactions between the precursors. Finally, formal hypothesis testing is outside the scope of this exercise as we obtained only point estimates of source-specific marginal damage measures..

[1]The authors are very grateful to Nicholas Muller for providing these marginal damage estimates and working with us to help us understand the underlying model.