Analysis of Dynamic, Flexible NO_x and SO_2 Abatement from Power Plants in the Eastern U.S. and Texas

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Electricity Generation and U.S. Air Quality

- National Ambient Air Quality Standards (NAAQS) for ozone and fine particulate matter have undergone significant changes in averaging time, level, and form over the past several decades and have increasingly required states to consider both local and regional emissions control measures.

- Emissions from **electric generating units** (EGUs), primarily coal-fired facilities, contribute to the **regional** nature of **ozone** and **fine particulate matte**r formation and acidic deposition.

- During 2008, 66% of national SO_2 emissions and 18% of national NO_x emissions were attributed by the EPA to the U.S. electricity sector emitted.

Common Technologies for Controlling EGU Emissions

- **NO_x Control**
  - ❖ Combustion control: low NO_x burners; boiler tuning and optimization
  - ❖ Post-combustion control: Selective Catalytic Reduction (SCR); Selective Non-Catalytic Reduction (SNCR)

- **SO_2 Control**
  - ❖ Post-combustion control: Flue Gas Desulfurization (FGD)

http://www.lcra.org/energy/power/facilities/scrubber.html

Emissions Cap and Trade Programs

- **Preferred federal policy** for control of SO_2 and NO_x emissions from EGUs since the early 1990s.

- Typically facilities provide or purchase emissions allowances; facilities that reduce their emissions below their allowances can trade or sell allowances in a market; total emissions are reduced by lowering number of allowances (cap) over time.

- Extensive studies have documented **successes and challenges**.

- Prominent examples:
  - U.S Acid Rain Program
  - NO_x SIP Call and, its predecessor, OTAG's NO_x Budget Trading Program
  - Cross-State Air Pollution Rule (CSAPR) would allow both intra- and inter-state emissions trading, ensuring states achieve pollution reductions.

Time Differentiated NO_x Regulation of EGUs

- Market-based cap and trade programs have historically treated emissions as equivalent regardless of where and when they occur.
  - Ozone and fine particulate matter formation depend on quantity, timing and location of precursor emissions.
  - Analyses of use of NO_x emissions allocation in the northeastern U.S. by Martin (2008) suggested disproportionate reductions across summer ozone season.

- Sun et al. (2012) examined **dynamic air quality management strategies** for **NO_x emissions** from EGUs that provided pricing incentives for maximizing reductions when ozone concentrations were highest in the Pennsylvania-New Jersey-Maryland (PJM) electrical grid.

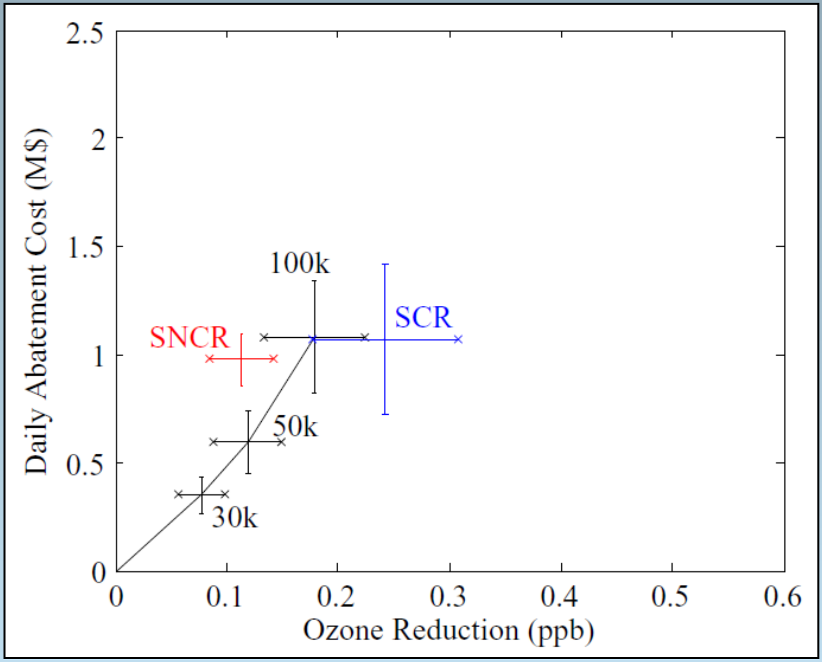
Key Findings of Sun et al. (2012)

- Sufficient **flexibility exists** to allow power production to be switched from high to low NO_x emitting facilities.

- **Emissions pricing** required to induce changing strategies for power generation are **competitive** with control costs for **SCR and SNCR**.

- Dispatching strategies can lead to **ozone** concentrations **reductions** comparable to conventional control technologies.

- Air quality forecasting is sufficiently accurate to allow EGUs to adapt their power generation strategies.



Average daily costs of time-differentiated NOx pricing, SNCR, and SCR versus average reductions in daily 8-h maximum ozone concentrations over 37 monitoring sites in the Philadelphia/Baltimore area with high ozone days defined for a threshold of 75 ppb.

Project Objective and Hypotheses

- Objective is to develop methods for evaluating the **air quality impacts and cost-effectiveness of time-differentiated trading of NO_x and SO_2** from EGUs considering two markets: PJM and the Electric Reliability Council of Texas (ERCOT).

- Hypotheses:
  1. Time-differentiated dispatching strategies lead to reductions in ozone and fine particulate matter concentrations and exposure that are comparable to technologies such as SCR and SNCR.
  2. Hybrid scenarios that combine time-differentiated trading and other technologies within a single electric grid provide more cost-effective control and greater air quality benefits than a single approach.
  3. The effectiveness of emissions trading strategies is sensitive to the selection of an air quality impact metric.
  4. An emissions pricing strategy can be developed that optimizes the joint abatement of multiple pollutants by considering the integrated impact.

Elements of Integrated Modeling Approach

1. Simulation of generation dispatching
   - Optimal Power Flow Approach using PowerWorld v.14
   - Minimization of total operating cost subject to transmission constraints and security contingencies

2. Development of regional air quality model applications
   - Comprehensive Air Quality Model with Extensions (CAMx)
   - EPA's Transport Rule/CSAPR 2005 episode

3. Simulation of time-differentiated and prescriptive emissions reductions scenarios
   - Pricing scenarios for time-differentiated trading to achieve region-wide EGU emissions reductions for each pollutant
   - Power dispatching based on individual or combined threshold concentrations for ozone and fine particulate matter
   - Control technology scenarios with SNCR, SCR, FGD across all days

Elements of Integrated Modeling Approach

4. CAMx application and evaluation of air quality metrics
   - Interpretation of success could be influenced by choice of metric
   - Consider wide range of metrics (e.g., location, population)

5. Hybrid emissions control scenarios
   - Decision analysis module to allow heterogeneous responses across EGUs within same scenario, i.e., use dispatching decisions to adapt to varying emissions prices or opt for control technology

6. Multi-pollutant emissions trading scenarios
   - Explore potential for a strategy that considers an integrated impact of multiple pollutants to optimize joint abatement of EGU emissions
   - For example, a weighted sum value that aggregates impacts of multiple pollutants into a single commodity to be traded in a single market

Status of Current Work

- Capital costs, O&M costs, and heat rate penalties for SCR and SNCR technologies
  - EPA 2010 Integrated Planning Model (IPM) Base Case v4.10 estimates
  - Fully endogenous modeling capability

- Analysis and comparison of CEMS and eGRID data
  - eGRID annual rates used in previous PowerWorld by Sun et al. (2012)
  - Hourly emissions rates from CEMS could not be associated with generation; strong variations in heat and sulfur content of coal.
  - Generally good agreement between CEMS and eGRID data; large differences at a small subset of facilities (represent <1 % of generation and emissions)
  - Initial PowerWorld scenarios are using 2005 CEMS data

- Worked with EPA to transfer 2005 base year CAMx episode used for Transport Rule/ CSAPR analyses

Preliminary Analysis of Multipollutant Emissions

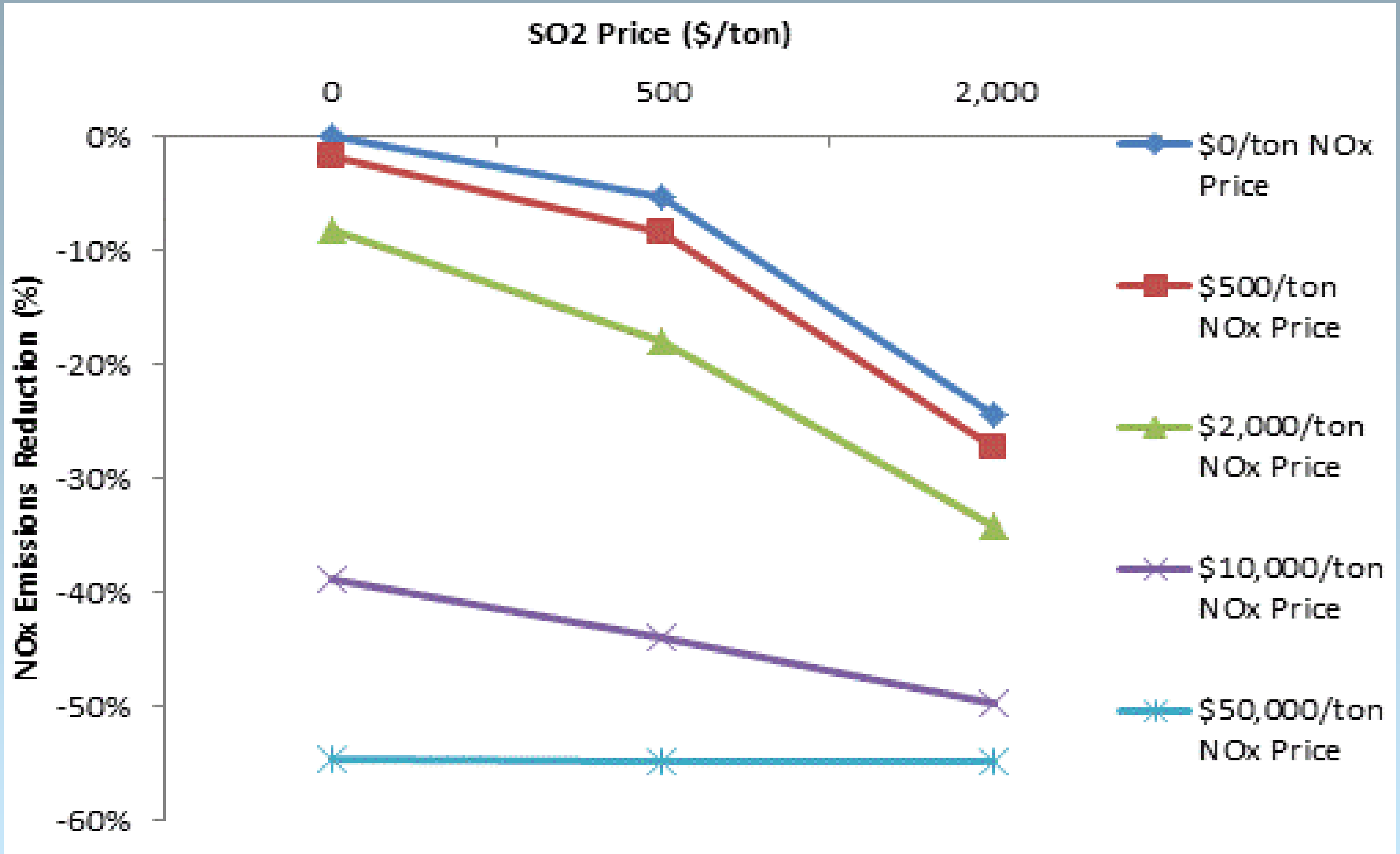
- Experimental Design:
  - NO_x Prices: $0, $500, $2000, $10000, $50000/ton NO_x
  - SO_2 Prices: $0, $500, $2000/ton SO_2

- Applied in ERCOT for representative:
  - Low demand day (Hourly peak demand 39,000 MWh)
  - Average demand day (Hourly peak demand 54,000 MWh)
  - High demand day (Hourly peak demand 64,000 MWh)

- PowerWorld v.14 to determine dispatch

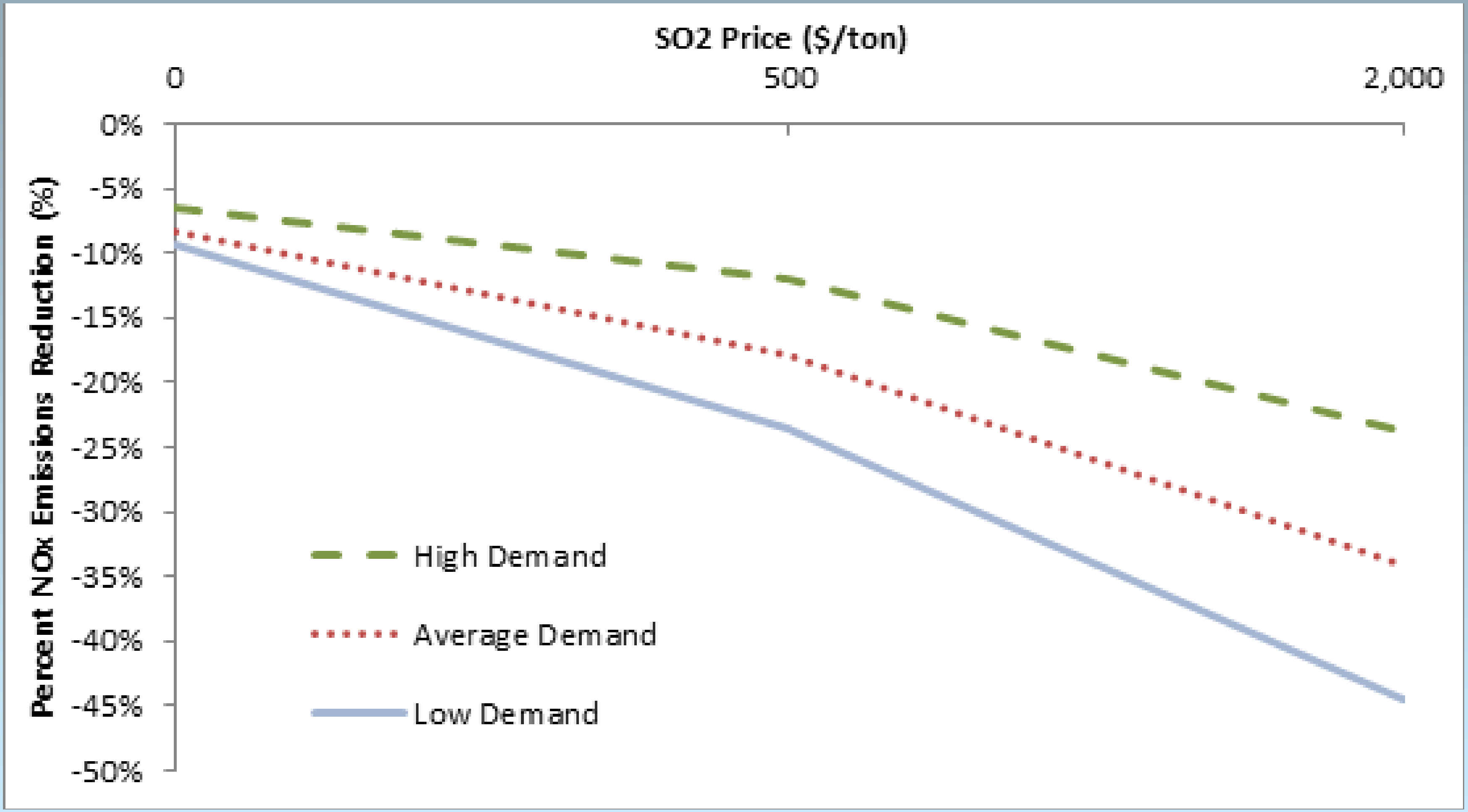
- Impacts on
  - NO_x Emissions
  - SO_2 Emissions

SO_2 and NO_x Pricing Effects on 24-Hour Aggregate NO_x Reductions for an Average Demand Day



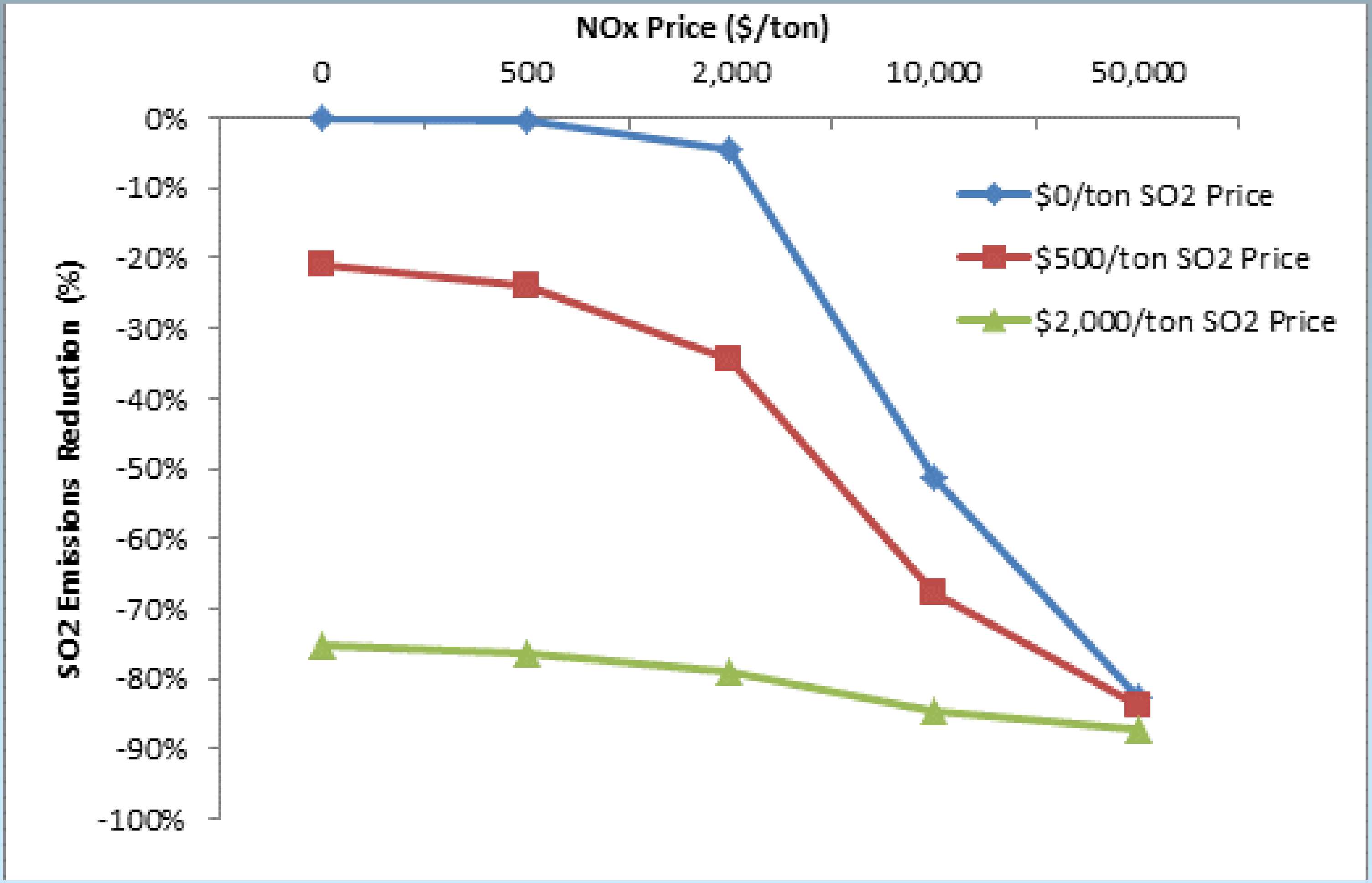
- Either NO_x or SO_2 emissions pricing induces a shift from coal to gas-fired generation, lowering NO_x emissions.
- Pricing reaches a threshold where further increases result in more limited emission reduction benefits.

Electricity Demand and SO_2 Pricing Effects on 24-Hour Aggregate NO_x Reductions (NO_x Price of $2000/ton)



- Electricity demand influences gains from emissions pricing.

SO_2 and NO_x Pricing Effects on 24-Hour Aggregate SO_2 Reductions for an Average Demand Day



- Either NO_x or SO_2 emissions pricing lowers BOTH SO_2 and NO_x (slide 12) emissions.

Next Steps

- Air quality model development:
  - Replication of EPA SMOKE emissions processing and CAMx base case
  - Performance evaluation
  - Base case modifications and updates

- PowerWorld and CAMx simulation of dispatching and technology scenarios
  - Pricing scenarios for time-differentiated trading to achieve region-wide EGU emissions reductions of 15%, 30%, 50% for each pollutant and region
  - Power dispatching based on individual or combined threshold concentrations for ozone and fine particulate matter
  - Control technology scenarios with SNCR, SCR, or FGD across all days to achieve equivalent reduction levels

- Development of metrics