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Cleaning Air for Less: Exploiting Tradeoffs Between Different Air Pollutants

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ARTICLES

CLEAN AIR FOR LESS: EXPLOITING TRADEOFFS BETWEEN DIFFERENT AIR POLLUTANTS

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INTRODUCTION

President Bush has announced his Administration's Clear Skies Initiative to regulate power plant emissions, including nitrogen oxides ("NO_x") and sulfur dioxide ("SO_2").[1] This initiative was introduced in the 107th Congress in a bill sponsored by Senator Bob Smith (R-NH).[2] A competing bill proposed by Senator James Jeffords (I-VT) narrowly passed the Senate Environment and Public Works Committee in June 2002.[3] Both the Clear Skies Initiative

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1. *See* White House Clear Skies Initiative Fact Sheet, President Bush Announces Clear Skies & Global Climate Change Initiatives (February 14, 2002) (announcing President George W. Bush's plan to reduce nitrogen oxides ("NO_x") and sulfur dioxide ("SO_2") by 70%), *available at* http://www.epa.gov/clearskies/clear_skies_factsheet.pdf (last visited Dec. 20, 2002).

2. S. 2815, 107th Cong. (2002). Companion legislation was introduced in the House of Representatives as H.R. 5266, 107th Cong. (2002) by Rep. Joe Barton (R-TX).

3. *See* Press Release, Senate Environment and Public Works, Majority Office, Jeffords Moves Clean Power Act Out of Committee (June 27, 2002) (announcing the passage of the Clean Power Act through the Senate Environment and Public Works Committee), *available at* http://epw.senate.gov/maj_pr_062702b.htm (last visited Dec. 20, 2002). Jefford's Proposal differs from the Clear Skies Initiative in that it calls for mandatory

and the Jeffords' Proposal take a "cap and trade" approach[4] to achieve dramatic emission reductions by limiting emissions on a pollutant-by-pollutant basis.[5] These approaches, however, both miss an opportunity to simultaneously reduce compliance costs and environmental damages because they do not allow trading between pollutant limitations. In particular, the legislative proposals prohibit tradeoffs between two pollutants that cause similar environmental problems, NO_x and SO_2.[6]

We recommend enabling trading between pollutants. Market forces would not only act to affect the supply of NO_x and SO_2 permits but also the relative stringency of controls for each pollutant. Trading between pollutants could both reduce compliance costs and increase expected environmental benefits.[7] Cost savings from integrating NO_x and SO_2 markets could exceed $1.1 billion per year without a reduction in expected environmental benefits.[8]

Trading between NO_x and SO_2 emissions makes sense for three reasons. First, these pollutants have similar environmental effects. For example, the biggest reason, by far, for stringent new emissions limits is that both NO_x and SO_2 raise concentrations of fine particulate matter (PM),[9] which in turn boosts mortality risk[10] and restricts

carbon emission cuts. *See* Senator James Jeffords, Statement on Clear Skies Proposal for the Senate Comm. On Env't and Pub. Works (July 29, 2002), *at* http://jeffords.senate.gov/~jeffords/press/02/06/07292002clear_skies.html (last visited Dec. 20, 2002).

4. The cap and trade program establishes federally enforceable emissions limits for each pollutant and allows sources to transfer these among themselves to achieve the required reductions at the lowest cost. *See* EPA, Fact Sheet on Clear Skies Initiative (2002) (describing Clear Skies Initiative mandatory emissions reduction plan based on a cap and trade program), *available at* http://www.epa.gov/clearskes/clearskiesfactsheet_3_26.pdf (last visited Dec. 20, 2002); *see also* Clean Power Act of 2001, S. 556, 107th Cong. § 132(b) (2001) (providing the objectives, guidelines, and authority for EPA activity in this area).

5. S. 2815, 107th Cong. § 403 (2002); Press Release, Senate Environment and Public Works, Majority Office, Jeffords Moves Clean Power Act Out of Committee (June 27, 2002), *available at* http://epw.senate.gov/maj_pr_062702b.htm (last visited Dec. 20, 2002).

6. *See, eg.*, S. 2815, 107th Cong. § 403 (2002) (omitting trading between NO_x and SO_2).

7. *See infra* Environmental Damages section.

8. *See id.*

9. NAT'L CTR. FOR ENVTL. ASSESSMENT-RTP OFFICE, OFFICE OF RESEARCH AND DEV., EPA, EPA/600/P-99/002AC, THIRD EXTERNAL REVIEW DRAFT OF AIR QUALITY CRITERIA FOR PARTICULATE MATTER Vol.1, page E-5 (APRIL, 2002), *available at*

visibility.[11] Both pollutants also contribute to high levels of acidity in lakes and forests.[12] And while it is true that nitrogen, but not sulfur, contributes to eutrophication of water bodies,[13] controlling this eutrophication through better farm practices is likely to be much cheaper than regulations on power plants.[14] Furthermore, while NO_x, but not SO_2, raises ozone concentrations,[15] the public health implications of ozone are quite small compared with the public health effects of elevated PM.[16]

Second, increasing one pollutant in exchange for reductions in the other would affect only a fraction of total anthropogenic emissions because utilities are only one of many sources of NO_x and SO_2.[17] To

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http://www.epa.gov/ncea/pdfs/partmatt/VOL_I_AQCD_PM_3rd_Review_Draft.pdf (last visited Dec. 20, 2002).

10. *Id.* at E-23.

11. *Id.* at E-32.

12. *Id.* at E-28.

13. Eutrophication is an increase in the rate of supply of organic matter to a water body, and usually refers to an increase in the rate of algal production. *See* Chris Clement, S. B. Bricker & D.E. Pirhalla, *Eutrophic Conditions in Estuarine Waters,* NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION. STATE OF THE COAST REPORT (2001), *at* http://state-of-coast.noaa.gov/bulletins/html/eut_18/intro.html (last visited Dec. 20, 2002); Nitrogen but not sulfur is a plant nutrient. *See* FLORIDA COOPERATIVE EXTENSION SERVICE, INSTITUTE OF FOOD AND AGRICULTURAL SCIENCES, UNIVERSITY OF FLORIDA, A BEGINNER'S GUIDE TO WATER MANAGEMENT – NUTRIENTS n.2 (2002), *available at* http://edis.ifas.ufl.edu/BODY_FA079#FOOTNOTE_2 (last visited Dec. 20, 2002). N.B.: this reference does not explicitly state that sulfur is not a nutrient.

14. A variety of studies substantiate this point, although they all poorly address the costs of implementing and enforcing control measures. *See, e.g.*, COASTAL OCEAN PROGRAM, NAT'L OCEANIC AND ATMOSPHERIC ADMINISTRATION, U.S. DEP'T OF COMMERCE, DECISION ANALYSIS SERIES NO. 20, EVALUATION OF THE ECONOMIC COSTS AND BENEFITS OF METHODS FOR REDUCING NUTRIENT LOADS TO THE GULF OF MEXICO, Tables B.1, B.3 (1999), *available at* http://www.nos.noaa.gov/pdflibrary/hpox_t6final.pdf (last visited Dec. 20, 2002).

15. *See* EPA National Ambient Air Quality Standards for Ozone: Final Rule, 62 Fed. Reg. 38,858 (July 18, 1997); 40 C.F.R. §§50.1-50.12.

16. Office of Air Quality Planning and Standards, EPA, Regulatory Impact Analyses for the Particulate Matter and Ozone National Ambient Air Quality Standards and Proposed Regional Haze Rule 16-17 (1997) (Executive Summary), *available at* http://www.epa.gov/ttn/oarpg/naaqsfin/ria.html (last visited Dec. 20, 2002).

17. *See* WHITE HOUSE CLEAR SKIES INITIATIVE POLICY BOOK 3 (February 14, 2002) (stating that power plants emit 67% of all SO_2 emissions and 25% of all NO_x emissions), *available at* http://www.epa.gov/clearskies/ro_clear_skies_book.pdf (last visited Dec. 20, 2002). The proposed new legislation would reduce power

the extent that legislative proposals reduce NO_x and SO_2 emissions from power plants, they make these emissions sources increasingly unimportant relative to other sources.[18]

Third, the Clean Air Act still requires states to implement federally approved plans to attain health-based air quality standards by reducing emissions in those areas where air quality does not adequately protect public health.[19] Continued enforcement of the Clean Air Act implies that, even under a trading regime, states still enforce limits that attain health-based air quality standards.

Market prices for NO_x and SO_2 emissions permits do not correspond with available information on environmental damages. In 2001, SO_2 allowances traded for between $152 and $211,[20] while NO_x permits in the northeast regional market traded at around $2,000.[21] Yet a ton of SO_2 causes environmental damages 3 to 5

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plant emissions by 75%. *See infra* Legislative Proposal section. The share of SO2 and NO_x emissions from power plants after reductions would fall to about 34% and 8%, respectively, assuming that emissions from other sources do not change. A hypothetical increase in emissions of 20% of these values would be less than 5% for SO_2 and less than 2% for NO_x.

18. *See* Press Release, *supra* note 5.

19. *See* Clean Air Act § 110(a)(1); 42 U.S.C. § 7410 (2002).

20. *See* EPA Clean Air Market Programs, Cumulative SO_2 Trading Activity Table, *at* http://www.epa.gov/airmarkt/trading/ so2market/cumchart.html (last visited Dec. 20, 2002) (charting estimates of year 2000 SO_2 allowance trading volume); EPA Clean Air Market Programs, Monthly Average Price of Sulfur Dioxide Allowances, *at* http://www.epa.gov/airmarkt/trading/so2market/ pricetbl.html (last visited Dec. 20, 2002) (noting that price information originated with the brokerage firm Cantor Fitgerald and Fieldston Publications market survey).

21. No centralized source exists for market price information. This is a conservative estimate reflecting discussions with staff at trading firms, government economists, and some independent reports. *See generally* EPA Clean Air Market Programs, No_x Allowance Market Analysis (April, 2001), *at* http://www.epa.gov/airmarket/trading/noxmarket/pricetransfer.html (last visited Dec. 20, 2002) (showing estimates of market information). N.B.: NO_x emissions allowance trading currently pertains to a five-month seasonal program, rather than the annual restrictions included in legislative proposals. Allowance prices are greater under a seasonal program because capital costs must be recovered over a smaller amount of emission reductions. *See* Dallas Burtraw *et al.*, *Cost-Effective Reduction of NO_X Emissions from Electricity Generation*, 51 J. AIR & WASTE MANAGEMENT 1482-84 (2001); *see also* DALLAS BURTRAW, RANJIT BHARVIRKAR & MEGAN MCGUINNESS, UNCERTAINTY AND THE COST-EFFECTIVENESS OF REGIONAL NO_X EMISSIONS REDUCTIONS FROM ELECTRICITY GENERATION 29-31 (Resources for the Future Discussion, 2002), *available at* http://www.rff.org/disc_papers/PDF_files/0201.pdf (last visited Dec. 20, 2002).

times larger than a ton of NO_x, according to government estimates.[22] Thus, it is economically nonsensical for the more damaging pollutant to be subject to less costly controls. Allowing tradeoffs between NO_x and SO_2 is one way to avoid such outcomes.

The idea that NO_x and SO_2 emissions permits can be traded for one another is not new. Amendments to the Clean Air Act provide: "Not later than January 1, 1994, the Administrator shall furnish to the Congress a study evaluating the environmental and economic consequences of amending this subchapter to permit trading sulfur dioxide allowances for nitrogen oxides allowances."[23] Unfortunately, the Environmental Protection Agency ("EPA") has not implemented this directive.[24] Independent researchers have studied economic gains from inter-pollutant trading but have been unable to persuade policymakers to adopt this type of trading.[25]

The rest of the paper is organized as follows. Section I shows that current legislative proposals to limit power plant emissions do not allow trading between pollutants or any integration of the markets for both pollutants. In Section II we argue that trading of NO_x and SO_2 emissions can create economic and environmental benefits. Section III presents a quantitative analysis showing that the integration of NO_x and SO_2 markets could save more that $1 billion annually. Before concluding, we show, in Section IV, that integrating markets could also increase environmental protection.

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22. *See* U.S. OFFICE OF MGMT. AND BUDGET, REPORT TO CONGRESS ON THE COSTS AND BENEFITS OF FEDERAL REGULATIONS 46 (June 2000), *available at* http://www.whitehouse.gov/ omb/inforeg/2000fedreg-report.pdf (last visited Dec. 20, 2002). (presenting ranges of monetary benefits for reducing emissions of NO_x, SO_2, particulate matter, and hydrocarbons).

23. Clean Air Amendments of 1990 § 403c, 42 U.S.C. § 7651(b) (1990), *available at* http://www.epa.gov/oar/caa/caaa.text (last visited Dec. 20, 2002).

24. Phone conversation with EPA staff member, EPA Clean Air Markets, Office of Air and Radiation, October 18, 2001.

25. *See generally, e.g.,* ALAN KRUPNICK, ET AL., COST-EFFECTIVE NO_x CONTROL IN THE EASTERN UNITED STATES 21 (Resource for the Future, 2000), *available at* http://www.rff.org/CFDOCS/disc_papers /PDF_files/0018.pdf (last visited Dec. 20, 2002)(suggesting that the EPA should consider altering its trading policy to achieve greater economic efficiency).

I. LEGISLATIVE PROPOSALS TO LIMIT POWER PLANT EMISSIONS DO NOT ALLOW TRADING BETWEEN POLLUTANTS.

Current law allows for trading of SO_2 emissions from fossil-fired power plants, subject to an aggregate emission cap established under Title IV of the 1990 Clean Air Amendments.[26] Affected facilities may trade and bank SO_2 allowances, but the aggregate cap is fixed without regard to how much of an NO_x emission reduction the particular facility might be willing to offer in exchange for an increase in SO_2. Emissions of NO_x from fossil-fired plants are also regulated under Title IV, but according to an emission rate standard rather than an emission cap.[27] Emission trading is allowed for NO_x under regulations that are specified by the Environmental Protection Agency.[28]

Most current bills addressing air pollution of power plants apply a cap-and-trade approach to emissions of NO_x and SO_2 individually[29] and none allow tradeoffs in the aggregate levels of emissions between different pollutants. The Senate Environment and Public Works Committee passed Senator Jeffords' S.556 to reduce power plant emissions of each pollutant by roughly 75% and to allow for trading of emissions allowances.[30] The Bush Administration's Clear Skies Initiative proposes final caps on SO_2, NO_x, and mercury emission allowances similar to those of the Jeffords' bill,[31] but allows a

26. Clean Air Act Amendments of 1990, 42 U.S.C. §§ 7401-7700 (1994). The annual cap pertains to the allocation of emission allowances. Annual emissions may be greater than actual annual allocations because of the opportunity to bank allowances from previous year allocations.

27. Clean Air Act Amendments of 1990, 42 U.S.C. §§ 7401-7700 (1994).

28. Finding of Significant Contribution and Rulemaking for Certain States in the Ozone Transport Assessment Group Region for Purposes of Reducing Regional Transport of Ozone, 40 C.F.R. pts. 51, 72, 75, 96 (2001).

29. *See, e.g.*, Clean Power Act of 2001, S. 556, 107th Cong. § 132(b) (2001); Clean Smokestacks Act of 2001, H.R. 1256, 107th Cong. § 2 (2001); Acid Rain Control Act of 2001, S. 588, 107th Cong. § 4(a) (2001); EPA Fact Sheet on Clear Skies Initiative .2-3, *available at* http://www.epa.gov/clearskies/final_clearskiesfactsheetjul.pdf (last visited Dec. 20, 2002) (noting that existing SO_2 cap and trade provisions served as a model for the Clean Skies Initiative). For a point-by-point comparison of the major proposals to regulate multiple pollutants from the electricity sector, *see* Resources for the Future, Making Sense of Multipollutant Legislation, *at* http://www.rff.org/multipollutants/ (last visited Dec. 20, 2002).

30. *See* Clean Power Act of 2001, S. 556, 107th Cong. § 132(b) (2001).

31. Compare the President's Clear Skies Initiative's aims to cap SO_2 emission allowances at 3 million tons, NO_x at 1.7 million tons, and mercury ("Hg") at 15 tons with Jefford's proposal.

longer timeline over which to achieve them.[32] Whereas the Jeffords' bill would accomplish complete reductions by 2008, the Bush Clear Skies approach would not mandate final reductions till 2018.[33] Both Clear Skies and the Jeffords' Bill provide for limits that can be achieved by trading among sources within a particular pollutant but not between different pollutants.[34] Figure 1 summarizes the caps on NO_x and SO_2 emissions that these bills would put in place alongside estimates of the emissions that would occur in 2007 without new legislation.[35]

Late in the 107th Congress Senator Tom Carper (D-DE) introduced S.3135 as an intended compromise proposal.[36] The bill would establish caps for SO_2 of 2.25 million tons, equivalent to S. 556, but not

32. *See* EPA Fact Sheet on Clear Skies Initiative 2-3, *available at* http://www.epa.gov/clearskies/final_clearskiesfactsheetjul.pdf (last visited Dec. 20, 2002); *see also* White House Clear Skies Initiative Fact Sheet, President Bush Announces Clear Skies & Global Climate Change Initiatives (February 14, 2002), *available at* http://www.epa.gov/clearskies/clear_skies_factsheet.pdf (last visited Dec. 20, 2002).

33. *See* White House Clear Skies Initiative Fact Sheet, President Bush Announces Clear Skies & Global Climate Change Initiatives (February 14, 2002), *available at* http://www.epa.gov/clearskies/clear_skies_factsheet.pdf (last visited Dec. 20, 2002). Senator Jeffords' bill, S.556, limits the three pollutants to 2.24 million, 1.51 million, and 4.8 tons, respectively, in 2007. *See* OFFICE OF ATMOSPHERIC PROGRAMS, OFFICE OF AIR AND RADIATION, U.S. ENVTL. PROT. AGENCY, ECONOMIC ANALYSIS OF A MULTI-EMISSIONS STRATEGY Table 1 (prepared for Senators James M. Jeffords and Joseph I. Lieberman, October 31, 2001), *available at* http://www.epa.gov/air/jeffordslieberm.pdf (last visited Dec. 20, 2002). Both proposals allow banking so annual emissions may remain above annual allocations of emission allowances until the bank is exhausted.

34. *See* EPA, Fact Sheet on Clear Skies Initiative (2002), *available at* http://www.epa.gov/clearskes/clearskiesfactsheet_3_26.pdf (last visited Dec. 20, 2002) (describing Clear Skies Initiative mandatory emissions reduction plan based on a cap and trade program). The cap and trade program establishes federally enforceable emissions limits for each pollutant and allows sources to transfer these among themselves to achieve the required reductions at the lowest cost. *See also* Clean Power Act of 2001, S. 556, 107th Cong. § 132(b) (2001) (providing the objectives, guidelines, and authority for EPA activity in this area).

35. *See generally* ENERGY INFO. AGENCY, OFFICE OF INTEGRATED ANALYSIS AND FORECASTING, U.S. DEP'T OF ENERGY, SR/OIAF-2001-04, REDUCING EMISSIONS OF SULFUR DIOXIDE, NITROGEN OXIDES, AND MERCURY FROM ELECTRIC POWER PLANTS Table ES-1 (2001), *available at* http://www.eia.doe.gov/oiaf/servicerpt/ mepp/pdf/sroiaf(2001)04.pdf (last visited Dec. 20, 2002) (analyzing the impact of three scenarios for reducing power sector emissions of NO_x, SO_2 and Hg).

36. Clean Air Planning Act of 2002, S. 3135, 107th Cong. (2002).

fully phased in until 2015. It would establish a cap of 1.7 million tons for NO_x, the same as the Clear Skies Initiative, but this would be achieved by 2012. The bill includes mercury limits that are midway between the other bills caps for carbon dioxide ("CO_2"), a greenhouse gas, more moderate than S. 556. Like S. 556 and S. 2815, the bill would treat NO_x and SO_2 as two separate pollution problems and prohibit tradeoffs in aggregate emissions of these two pollutants.

Policymakers' neglect of trading between NO_x and SO_2 is surprising because trading between two pollutants seems a textbook example of a cost-effective regulatory strategy that can create economic and environmental benefits.

II. INTEGRATING TRADING OF NO_X AND SO_2 ALLOWANCE MARKETS CAN CREATE ECONOMIC AND ENVIRONMENTAL BENEFITS.

A. *Integrating Trading Of No_x And So_2 Allowance Markets Can Avoid Unnecessary Costs Imposed By Fixed Statutory Limits.*

Standard conditions for cost-effective environmental protection are that the incremental control cost relative to the incremental damages avoided must be the same for each pollutant.[37] In order to be cost-effective, emissions controls must reflect the incremental effects of NO_x and SO_2 on both environmental damages and emissions control costs. Congressional proposals that specify caps on NO_x and SO_2 without (apparent) regard to *relative* incremental costs and damages are therefore very likely to be unnecessarily costly.

To demonstrate this point, suppose emissions of NO_x and SO_2 were capped at N_c and S_c respectively, i.e., point K on Figure 2. The rate that SO_2 emissions can substitute for NO_x emissions (and NO_x emissions cuts for SO_2 emissions cuts) without increasing environmental damages is given by the slope of the iso-damage curve reflecting all the combinations of emissions that give damages D_2. The rate that SO_2 emissions can substitute for NO_x emissions (and NO_x *cuts* for SO_2 *cuts*), without increasing compliance costs is the slope of the iso-cost curve reflecting control costs C_2. Any shift in emissions that decreases NO_x and increases SO_2 while keeping emissions within the lens-shaped area formed by D_2 and C_2 would improve

37. *See* WILLIAM J. BAUOMOL & WALLACE E. OATES, THE THEORY OF ENVIRONMENTAL POLICY 47 (1988).

environmental protection while reducing compliance costs. In Figure 2, both environmental damages and compliance costs could be reduced by an emissions control strategy that reduced NO_x emissions and increased SO_2 emissions. Cost-effective NO_x and SO_2 emissions caps occur only at points of tangency of iso-damage and iso-cost curves, like point J, which is at the point of tangency of C_1 and D_1.[38] Thus, the relative costs and the relative effects of the two pollutants on environmental damages are crucial to ensuring that emissions control policies avoid unnecessary costs. Legislative proposals that arbitrarily fix the ratio of emissions forego opportunities simultaneously to lower costs and improve the environment.

Estimating the potential gains from integrating NO_x and SO_2 markets requires information about how the costs and relative environmental benefits change with changes in the mix of emissions.[39] We address these below.

B. *Estimating Benefits Of Integrating No_x And So_2 Markets Requires Information On Relative Control Costs.*

We review existing estimates of relative control costs and then present some of our own. Developing estimates of the potential gains from integrating NO_x and SO_2 markets requires information about more than the relative incremental controls cost at emissions levels likely to result from legislative proposals. As we have just shown, it also requires information about how control costs change as the mix of emissions shifts. Government agencies have not yet estimated total incremental control costs for NO_x and SO_2 for different mixes of these two pollutants, so we develop our own estimates of control costs after reviewing some estimates that government agencies have already completed.

1. Recent Government Estimates.

The EPA and the Energy Information Agency ("EIA") have prepared studies of permit pricing of NO_x and SO_2 under various emission control scenarios. None of these reports are directly comparable, however, since they are based on different assumptions.

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38. *See id.* at 45-47, 169-72.

39. *See id.* at 160-168 (highlighting the importance of considering complex factors in analyzing the marginal net damage of polluting activity).

In its analysis of the Clear Skies Initiative, EPA estimated relative permit prices for NO_x and SO_2 emissions that vary significantly by region and by stage of implementation.[40] Because the Bush Administration's proposal would separate the NO_x permit market into an eastern and western region, the relative costs of controlling the two pollutants differ by region.[41] EPA's estimates show that the permit price of SO_2 relative to the permit price of NO_x, given the Clear Skies Initiative emissions reductions of 67% for NO_x and 73% for SO_2 by 2018, would be around 68% for the East and 266% for the West.[42] Table 1 presents EPA's estimates of relative permit prices for the Clear Skies Initiative, illustrating that they vary by region and over time.

Table 1

Marginal Costs of Controlling SO_2 Emissions Relative to Marginal Costs of Controlling NO_x Emissions (In Percent) Bush Administration Clear Skies Initiative[43]		
NO_x Region	2008-2012	2018-2022
East	50	68
West	75	266

The Energy Information Administration ("EIA") recently estimated SO_2 and NO_x permit prices implicit in various emission control scenarios and showed the price of NO_x emissions permits would

40. *See* EPA, IPM SYSTEM SUMMARY REPORT: IPM2000S153D_C.DOC, ENVIRONMENTAL MEASURES REPORT OF CLEAR SKIES INITIATIVE 10.1, 10.29, 10.30, *available at* http://www.epa.gov/airmarkets/epa-ipm/results.html (last visited Dec. 20, 2002) (offering tables of emissions at certain plants of SO_2, NO_x East, and NO_x West).

41. *See* EPA Regional Differentiation in the Clear Skies Initiative, *available at* http://www.epa.gov/clearskies/geo-scope4_11.pdf (last visited Dec. 20, 2002); *see also* Clear Skies Act of 2002, S. 2815, 107th Cong. § 451-3 (2002).

42. *See* EPA, *supra* note 40, at 10.1, 10.29, 10.30.

43. *See* EPA, *supra* note 40, at 10.1, 10.29, 10.30 (providing tables of emissions at certain plants of SO_2, NO_x East, and NO_x West).

be less than the price of SO_2 emissions permits.[44] These estimates provide information about the relative marginal control costs, since permit prices reflect marginal control costs.[45] The report analyzes three scenarios: 50%, 65% and 75% cuts in both NO_x and SO_2 emissions. The estimated marginal cost of reducing SO_2 emissions would be 17%, 29% and 14% in 2010, respectively, of the marginal cost of reducing NO_x emissions. [46] In 2020 the report estimated the marginal cost of reducing SO_2 emissions would be 65%, 95%, and 62%, respectively, of the marginal cost of reducing NOx emissions. [47]

EPA also estimated permit prices for pollutant emissions cuts of interest to different Senators, and found that SO2 permit prices relative to Nox permit prices varied with different scenarios for emissions reductions.[48] Since the President remains opposed to mandatory carbon emissions cuts,[49] we focus here on the scenarios without them.

Relative marginal control costs for SO_2 and NO_x for different emissions reduction scenarios are reported in Table 2. EPA attrib-

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44. *See* ENERGY INFO. AGENCY, *supra* note 35, at Table B14, C14, D14.

45. *See* ENERGY INFO. AGENCY, *supra* note 35, at Table B14, C14, D14. These numbers were used in calculating marginal control costs for this article.

46. *See* ENERGY INFO. AGENCY, *supra* note 35, at Table B14, C14, D14. The EIA also assumed in these scenarios that mercury emissions would be cut by 50 %, 65 %, and 75 %, respectively. *See id.* at vii.

47. *See* ENERGY INFO. AGENCY, *supra* note 35, at Tables B14, C14, and D14.

48. *See* EPA, ANALYSIS OF MULTI-EMISSIONS PROPOSALS FOR THE U.S. ELECTRICITY SECTOR REQUESTED BY SENATORS SMITH, VOINOVICH, AND BROWNBACK 9-10 (2001), *available at* http://www.epa.gov/air/meproposalsanalysis.pdf (last visited Dec. 20, 2002) (reporting in reponse to request by the senators for analyses of reductions of SO_2, NO_x, and Hg emissions). In a separate report, the EPA estimated compliance costs and permit prices for emissions cuts of 75% for both NO_x and SO_2 in response to a request from Senators Jeffords and Lieberman. *See* Office of Atmospheric Programs, Office of Air and Radiation, EPA, Economic analysis of a Multi-Emissions Strategy Table 3 (prepared for Senators James Jeffords and Joseph Lieberman; October 31, 2001), *available at* http://www.epa.gov/air/jeffordslieberm.pdf (last visited Dec. 20, 2002) (showing incremental policy costs). The estimates in response to Senators Jeffords and Lieberman, however, are not directly comparable to those in the Clear Skies Initiative, the EIA's, or the Smith/Voinovich/Brownback report because the EPA considered scenarios that included mandatory cuts in carbon dioxide emissions. *See id.*

49. *See* Letter from George W. Bush to Senators Hagel, Helms, Craig, and Roberts (May 13, 2001), *available at* http://www.whitehouse.gov/news/releases/2001/03/20010314.html. (last visited Dec. 20, 2002).

utes the differences between its estimates and EIA's estimates to a variety of factors.[50]

Table 2

Emissions Control Scenarios: Percent cut in emissions, NO_x and SO_2	Marginal Costs of Controlling SO_2 Emissions Relative to Marginal Costs of Controlling NO_x (In Percent)		
	EIA Analysis[51] (2020)	EPA: Smith/ Voinovich/Brownback Request[52]	EPA: Jeffords/Liebermann Including Carbon Cuts.[53]
50	65	212	NA
65	95	134	NA
75	62	110	17 to 20

50. *See* EPA, Office of Air and Radiation, Comparison of Jeffords-Lieberman and Smith-Voinovich-Brownback 6-9 (2001), *available at* http://www.epa.gov/air/finalanalyses.pdf (last visited Dec. 20, 2002). N.B.: None of the factors distinguishing the EPA and EIA analysis are directly relevant to an analysis of inter-pollutant trading.

51. *See* ENERGY INFO. AGENCY *supra* note 35, at tables B14, C14, and D14.

52. See ENERGY INFO. AGENCY *supra* note 35, at 10.

53. *See* Office of Atmospheric Programs, Office of Air and Radiation, EPA, Economic analysis of a Multi-Emissions Strategy 14 (Prepared for Senators James Jeffords and Joseph Lieberman; Oct. 31, 2001), *available at* http://www.epa.gov/air/jeffordslieberm.pdf (last visited Dec. 20, 2002) (showing incremental policy costs).

2. Modeling Predicts Relative Incremental Control Costs.

As the recent government analyses offer inadequate information to estimate the efficiency gains from integrating NO_x and SO_2 markets, we also use Haiku, a model of electricity markets developed by researchers at Resources for the Future, to generate estimates of permit prices and compliance costs.[54] The model has been compared with other simulation models in two series of meetings of Stanford University's Energy Modeling Forum.[55] The Haiku electricity model simulates equilibrium in regional electricity markets and inter-regional electricity trade with an integrated algorithm for SO_2 and NO_X emission control technology choice.[56] The model calculates

54. *See generally* ANTHONY PAUL & DALLAS BURTRAW, THE RFF HAIKU ELECTRICITY MARKET MODEL 1 (Resources for the Future, 2002), *available at* http://www.rff.org/reports/PDF_Files/haiku.pdf (last visited Dec. 20, 2002). The model has been used extensively in journal articles published in the peer-reviewed economics literature. *See, e.g.,* Dallas Burtraw *et al.*, UNCERTAINTY AND THE COST-ECONOMICS OF REGIONAL NO_X EMISSIONS REDUCTIONS FROM ELECTRICITY GENERATION (Resources for the Future, 2002), *available at* http://www.rff.org/disc_papers/PDF_files/0201.pdf (last visited Dec. 20, 2002); *see also* Dallas Burtraw, et al., Ancillary Benefits of Reduced Air Pollution in the United States from Moderate Greenhouse Gas Mitigation Policies in the Electricity Sector (Resources for the Future, 2002) *available at* http://www.rff.org/disc_papers/PDF_files/0161.pdf (last visited Dec. 20, 2002); *see also* Dallas Burtraw *et al., Cost-Effective Reduction of NO_x Emissions from Electricity Generation*, 51 JOURNAL OF AIR & WASTE MANAGEMENT 1476-89 (2001). The model was also used for a study sponsored by the State of Maryland Department of Natural Resources. *See* Karen Palmer *et al.*, Electricity Restructuring, Environmental Policy, and Emissions, (Resources for the Future 2002), *available at*, http://www.rff.org/reports/2002.htm (last visited Dec. 20, 2002). Further information on the model is available from the authors. *See also* SPENCER BANZHAF *ET AL.*, EFFICIENT EMISSION FEES IN THE U.S. ELECTRICITY SECTOR 2, 11-12 (Resources for the Future, 2002); *see also*, Karen Palmer *et al.*, *Capping Emissions: How Low Should We Go?*, PUBLIC UTILITIES FORTNIGHTLY, at 28-36 (Dec. 2002).

55. *See* ENERGY MODELING FORUM, FINAL REPORT OF EMF WORKING GROUP 15, A COMPETITIVE ELECTRICITY INDUSTRY 22 (Stanford Univ. 1998), *available at* http://www.stanford.edu/group/EMF/home/index.html (last visited Dec. 20, 2002) (summarizing a comparison of simulation models); *see also* ENERGY MODELING FORUM, FINAL REPORT OF EMF WORKING GROUP 17, PRICES AND EMISSIONS IN A RESTRUCTURED ELECTRICITY MARKET 1-6, 31 (Stanford Univ. 2001), *available at* http://www.stanford.edu/group/EMF/home/index.html (last visited Dec. 20, 2002).

56. *See* ANTHONY PAUL & DALLAS BURTRAW, THE RFF HAIKU ELECTRICITY MARKET MODEL 1 (Resources for the Future Report, June 2002), *available at*

electricity demand, electricity prices, the composition of electricity supply, inter-regional electricity trading activity among 13 regions of the United States, and emissions of NO_X, SO_2, and carbon dioxide from electricity generation.[57] Three customer classes are represented: residential, industrial, and commercial.[58] Detail about demand functions is provided and supply curves are calculated for four time periods (super-peak, peak, shoulder, and baseload hours) in each of three seasons (summer, winter, and spring/fall).[59] The model determines investment in new generation capacity and retirement of existing facilities, based on capacity-related costs of providing service in the future ("going forward costs").[60] Generator dispatch in the model is based on minimization of short run variable costs of generation.[61] The variable costs of emission controls plus the opportunity cost of emission allowances under cap-and-trade programs are added to the variable cost of generation in establishing the operation of generation capacity.[62]

The algorithm for compliance with NO_X emissions caps in Haiku solves for the least cost set of post-combustion investments from among three control options: selective catalytic reduction (SCR), selective noncatalytic reduction (SNCR) and reburn.[63] For control of SO_2, the model distinguishes coal-burning model plants by the presence or absence of flue gas desulfurization (scrubbers). Unscrubbed coal plants have only one potential SO_2 post-combustion abatement technology, a retrofit scrubber, but firms also may select from a series of coal types that vary by sulfur content and price as a strategy to reduce SO_2 emissions.[64]

For simplicity, we model only one scenario, picking emissions caps that approximate those we believe the 108th Congress might adopt. Estimates derived from the Haiku model for a scenario that is

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http://www.rff.org/reports/PDF_Files/ haiku.pdf, at 1 (last visited Dec. 20, 2002) (providing model documentation).

57. *See id.* at 5.

58. *See id.* at 7, 15, 16.

59. *See id.* at 15-18.

60. *See id.* at 18-22, 32.

61. *See* ANTHONY PAUL & DALLAS BURTRAW, THE RFF HAIKU ELECTRICITY MARKET MODEL 16-18 (Resources for the Future, June 2002), *available at* http://www.rff.org/reports/PDF_Files/haiku.pdf (last visited Dec. 20, 2002) (providing model documentation).

62. *See id.* at 25-26.

63. *See id.* at 38-42.

64. *See id.* at 36, 43-46.

close to the Administration's Clear Skies Initiative suggest similar relative incremental control costs similar to EPA's estimates.[65] For simplicity we model only one scenario, picking emissions caps that approximate those we believe the 108[th] Congress might adopt. For the year 2015, we assume caps for NO_x and SO_2 of 1.5 million and 2.5 million tons, respectively, but exclude caps for carbon and mercury emissions from our baseline analysis.[66] In this case, the price of SO_2 allowance relative to the price of NO_x allowances, that is the relative incremental control cost, is 1.4.[67] Compared with the relative incremental control cost estimates for the Clear Skies Initiative presented in Table 1, this estimate is greater than the figure for the East and less than the figure for the West.

C. *Estimating Unnecessary Costs Requires Information On Relative Incremental Environmental Damages From NO_x And SO_2.*

Existing estimates of the marginal damages of NO_x and SO_2 are at best approximations, but they indicate that the benefits of reducing SO_2 are greater than the benefits of reducing NO_x. The government has provided recent estimates of the relative incremental damages from NO_x and SO_2. The federal Office of Management and Budget ("OMB") reported estimates of the benefits of reducing NO_x, that were arguably methodologically superior to estimates that ignored

65. Unlike the Clear Skies Initiative, our scenario does not include an emissions cap for mercury. *See* White House Clear Skies Initiative Fact Sheet, President Bush Announces Clear Skies & Global Climate Change Initiatives (2002), *available at* http://www.epa.gov/clearskies/clear skies factsheet.pdf (last visited Dec. 20, 2002) (predicting that implementation of the President's Clear Skies Initiatives would reduce NO_x emissions to 1.7 million tons and SO_2 emissions to a cap of 3 million tons in 2018).

66. The Clear Skies Initiative has an SO_2 cap of 3.0 million tons and a NO_x cap of 1.7 million tons. *See* S. 2815, 107[th] Cong (2002). The Jeffords Proposal has an NO_x cap of 1.51 million tons and a SO_2 cap of 2.25 million tons. *See* S. 556, 107[th] Cong. (2002). The timing of the two proposals varies, with Jeffords Proposal achieving its ultimate reduction targets nearly a decade earlier. *See* BILLY PRIZER & DALLAS BURTRAW, A SIDE-BY-SIDE COMPARISON OF S. 556 AND S. 2815 (Resources for the Future, 2002), *at* http://www.rff.org/Jeffords-Clear%20Skies%20table%209-25-02.pdf (last visited Dec. 20, 2002). Also, both proposals include the opportunity for banking, which means that annual emissions would not approximate annual allowance allocations until after the bank reaches equilibrium. *Id.*

67. The numbers that we present are the arithmetic averages of the relevant values for the 11 year period from 2010 to 2020.

the effects of NO_x on particulates, and ranged from \$960 to \$2500 per ton for the emissions reductions from one rule (the OTAG NO_x SIP call), and from \$1,350 to \$2,100 per ton for the emissions reductions from another rule (issued under Section 126) in 2007.[68] We disagree with OMB estimates that depend on an assumption that NO_x reductions have no particulate matter concentrations, because we believe that this assumption is indefensible. The federal Office of Management and Budget recently reported that the monetary benefits of reducing emissions of SO_2 were \$3,768 to \$11,539 per ton.[69] Taking the ratio of lower bounds and upper bounds respectively suggests that SO_2 damages are between 2.8 and 5.5 times greater than NO_x damages.[70]

An analysis by EPA also supports the conclusion that reducing SO_2 emissions is more valuable than reducing NO_x emissions.[71] It suggests that mortality-related benefits per ton of NO_x reduced are around \$1,300 and the benefits per ton of SO_2 reduced are around \$7,300 for electricity generating units.[72] These estimates, which were intended to provide an "order of magnitude approximation rather than a precise estimate,"[73] reflect only the mortality-related benefits because the author believes these accounted "for over 90 percent of monetary benefits in previous analyses."[74] This EPA analysis suggests that the environmental damages from a ton of SO_2 emissions are about 5.6 times greater than damages from a ton of NO_x emissions.[75]

Academic research confirms these government estimates. Economists report that reductions in sulfates, or more generally reductions in emissions of SO_2, yield about 3.2 times more benefits per ton than

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68. U.S. OFFICE OF MGMT. AND BUDGET, REPORT TO CONGRESS ON THE COSTS AND BENEFITS OF FEDERAL REGULATIONS 46 (2000), *available at* http://www.whitehouse.gov/omb/inforeg/2000fedreg-report.pdf (last visited Dec. 20, 2002).

69. *See id.*

70. *See generally id.* (presenting information from which damage estimates can be calculated).

71. *See* Memorandum from Bryan Hubbell of the EPA's Innovative Strategies and Economics Group entitled Benefits Associated with Electricity Generating Emissions Reductions Realized Under the NSR Program 1 (2002) (on file with the *Fordham Environmental Law Journal*).

72. *See id.*

73. *See id.*

74. *See id.*

75. *See generally id.* (providing information from which damage estimates were calculated).

reductions in nitrates, or more generally reductions in emissions of NO_x.[76] An integrated assessment model, the Tracking and Analysis Framework (TAF), is used to explore a wide range of SO_2 and NO_x emission levels and locations.[77] Estimates of the marginal benefits of emission reductions generally vary widely with geography and with the modeler's choice of parameters to describe atmospheric transport of pollutants, epidemiology, and economic valuation of health effects.[78] Yet, a robust relationship between the potency of sulfates and nitrates with respect to marginal benefits is reported.[79] Interestingly, their estimate may be relatively insensitive to new scientific information about the health risks or economic valuations of changes in health status. New information that affects the incremental benefits of SO_2 and NO_x by the same proportion will leave the relative incremental benefits unchanged.[80]

The true uncertainty is greater than implied by the range of existing estimates because the biological mechanism by which fine particles might cause mortality at the relevant concentration (for exam-

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76. *See* SPENCER BANZHAF *ET AL.*, EFFICIENT EMISSION FEES IN THE U.S. ELECTRICITY SECTOR 2, 11-12 (Resources for the Future, 2002) (noting that differences in geographic location of emission cause large differences in marginal benefits), *available at* http://www.rff.org/disc_papers/PDF_files/0245.pdf (last visited Dec. 20, 2002).

77. Tracking and Analysis Framework ("TAF") was developed in support of the National Acid Precipitation Assessment Program ("NAPAP") and is work of a team of more than 30 modelers and scientists from institutions around the country. *See* NATIONAL SCIENCE AND TECHNOLOGY COUNCIL, NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM BIENNIAL REPORT TO CONGRESS: AN INTEGRATED ASSESSMENT A-2, A-4 (1998), *available at* http://www.nnic.noaa.gov/CENR/NAPAP/ (last visited Dec. 20, 2002); *see also id.* at A-7. Each module of TAF was constructed and refined by a group of experts in that field. As the framework in which these literatures are integrated, TAF itself was subject to an extensive peer review in December 1995, which concluded that "TAF represent[s] a major advancement in our ability to perform integrated assessments" and that the model was ready for use by NAPAP. *See* OAK RIDGE NATIONAL LABORATORY, PEER REVIEW OF THE TRACKING AND ANALYSIS FRAMEWORK (TAF) FOR USE IN THE 1996 NAPAP INTEGRATED ASSESSMENT 3 (ORNL/M-4994, 1995). N.B.: The entire model is available at http://www.lumina.com/taflist (last visited Dec. 20, 2002). *See generally,* Cary Bloyd, ANL/DIS/TM-36, Tracking and Analysis Framework (TAF) Model Documentation and User's Guide (Argonne National Laboratory, 1996).

78. *See* BANZHAF *ET AL.*, *supra* note 75, at 13-15. *See also* Dallas Burtraw & Erin Mansur, *Environmental Effects of SO_2 Trading and Banking*, 33 ENVIRONMENTAL SCIENCE & TECHNOLOGY 3489-94 (1999).

79. *See* BANZHAF *ET AL.*, *supra* note 75, at 11-12, Figures 2a, 2b.

80. *See* BANZHAF *ET AL.*, *supra* note 75, at 14.

ple, 15 micrograms per cubic meter of particulate matter with a diameter of less than 2.5 microns) has not yet been identified.[81]

III. QUANTITATIVE ANALYSIS SHOWS REDUCED COMPLIANCE COSTS FROM INTEGRATING NO_X AND SO_2 PERMIT MARKETS.

Integrating NO_x-SO_2 permit markets can generate significant cost savings. The government cannot provide these savings simply by legislating an emissions cap because relative control costs will change over time, and such changes will alter the most cost-effective combination of emissions controls.[82] Integrating the two markets with an appropriate trading ratio will allow for the greatest possible cost savings irrespective of how developing control technologies may affect the relative cost of reducing NO_x and SO_2.

A. *Baseline Assumptions.*

For simplicity, we focus on one scenario, picking emissions caps that approximate those we believe the 108th Congress might adopt. In our judgment, however, our quantitative estimates would change only slightly with small variations in NO_x and SO_2 caps, although they might vary significantly if carbon emissions were also subject to a stringent cap. For the year 2015, we assume caps for NO_x and SO_2 of 1.5 million and 2.5 million tons, respectively, but exclude caps for carbon and mercury emissions from our baseline analysis.[83]

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81. *See* NAT'L CTR. FOR ENVTL. ASSESSMENT-RTP OFFICE, OFFICE OF RESEARCH AND DEV., U.S. ENVTL. PROT. AGENCY, EPA/600/P-99/002BB, SECOND EXTERNAL REVIEW DRAFT OF AIR QUALITY CRITERIA FOR PARTICULATE MATTER Vol.II, pages 8-10 (March, 2001), *available at* http://www.epa.gov/ncea/pdfs/partmatt/VOL_II_AQCD PM_2nd_Review_Draft.pdf (last visited Dec. 20, 2002) (discussing limited available data to discern mortality rates).

82. *See* BAUOMOL & OATES, *supra* note 37, at 41.

83. The Clear Skies Initiative has an SO_2 cap of 3.0 million tons and a NO_x cap of 1.7 million tons. *See* S. 2815, 107th Congress (2002). The Jeffords Proposal has an NO_x cap of 1.51 million tons and a SO_2 cap of 2.25 million tons. *See* S. 556 107th Congress (2002). The timing of the two proposals varies, with Jeffords Proposal achieving its ultimate reduction targets nearly a decade earlier. *See* BILLY PIZER & DALLAS BURTRAW, A SIDE-BY-SIDE COMPARISON OF S. 556 AND S. 2815 (2002), *at* http://www.rff.org/Jeffords-Clear%20Skies%20table%209-25-02.pdf. (last visited Dec. 20, 2002) Also, both proposals include the opportunity for banking, which

In this case, the price of SO_2 allowance relative to the price of NO_x allowances, that is the relative incremental control cost, is 1.4.[84] Under such an approach, the market is willing to reduce SO_2 emissions by one ton in exchange for increasing NO_x emissions by 1.4 tons.[85] We also presume that the relative incremental environmental damage from SO_2 is 3 times as great as from NO_x,[86] although we address in a later section the implications of uncertainty in this estimate.

B. *Calculating Savings From Integrating NO_x And SO_2 Markets.*

The level of NO_x and SO_2 emissions as they may be capped by the 108th Congress is shown as point B – the baseline scenario – in Figure 3. Points on a line with a slope of –3 that goes through the baseline scenario at point B thus have emissions levels that offer environmental protections equivalent to point B. Allowing firms to acquire one SO_2 permit in exchange for three NO_x permits, or vice versa, would shift emissions along the line. Such shifts would continue until the relative incremental cost of controlling emissions equals the exchange rate of three NO_x to one SO_2. At any other level of emissions firms could make money by buying the relatively inexpensive permit from the market, exchanging it for the relatively more expensive one, and then selling it for cash. We identify two points (J and K) on this trading line that have a ratio of marginal costs illustrated by the nonlinear isocost curves that have slopes somewhat less than and somewhat greater than –3. The lowest cost point on this line lies between these two points J and K in Figure 3, where an isocost curve with a slope of –3 is just tangent to the trading line.

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means that annual emissions would not approximate annual allowance allocations until after the bank reaches equilibrium.

84. The numbers that we present are the arithmetic averages of the relevant values for the eleven year period from 2010 to 2020.

85. *See supra* note 65 and accompanying text (discussing relative permit prices). The relative permit price is 1.4, which means that the incremental cost of controlling one ton of SO_2 is 1.4 times the incremental cost of controlling one ton of NO_x. Thus, increasing NO_x emissions by 1.4 tons will lower control costs by the same amounts as a reduction in SO_x emissions of one ton. Since such a change in emissions sources would not raise control costs, we assume that emissions sources would be willing to undertake such a change.

86. *See* BANZHAF *ET AL.*, *supra* note 75, at 2, 11-12; *see, e.g.*, OMB, *supra* note 22, at 46.

This analysis suggests that integrating markets for NO_x and SO_2 permits could reduce compliance costs by at least $1.1 billion annually, from $11.8 billion to $10.6 billion.[87] The $1.1 billion excludes changes in the consumer surplus from higher electricity prices, which are typically smaller than compliance costs.[88] From a baseline scenario that resembles Clear Skies, market integration (shown by points J and K) would increase NO_x emissions between 1.5 million and 2 million tons per year, while lowering SO_2 emissions by 0.5 million to 0.67 million per year according to analysis using the Haiku model. Given the evidence that the benefits of reducing SO_2 are about three times as large as the benefits of reducing NO_x, this change in the mix of emissions would not reduce expected environmental protection.

C. *Dealing With Uncertainty*

Montero analyzes in detail the merit of integrating related pollutant markets when regulators face uncertainty about the marginal benefits of different pollutants.[89] He shows that even with uncertainty about the benefits, as long as the marginal cost curve is steeper than the marginal benefits curve - that is, the absolute value of marginal costs are greater than marginal benefits in the vicinity of emissions targets - the economically optimal policy is to integrate the pollutant control markets.[90] The rationale is that interpollutant trading provides flexibility to firms to avoid high control costs by shifting control efforts to a pollutant that is relatively inexpensive to control. If the marginal cost curves are steeper than the marginal benefit curves, the regulatory should pay more attention to the cost of control rather

87. These estimates reflect the average of the annual cost savings over the years 2010 to 2020. During this period the Clear Skies Initiative involves increasingly stringent caps. *See* EPA, Clear Skies Initiative Summary 6,12 (2002), *available at* http://www.epa.gov/clearskies/clearskiessummary04-11.pdf (last visited Dec. 20, 2002) (graphing the cost of SO_2 and NO_x reductions for 2010-2020). N.B.: Cost savings in a particular year are not necessarily representative.

88. *See* Karen Palmer *et al.*, Restructuring and the Cost of Reducing NO_x Emissions in Electricity Generation (Resources for the Future, 2001), *available at* http://www.rff.org/disc_papers/PDF_files/ 0110REV.pdf (last visited Dec. 20, 2002).

89. *See* Juan Pablo Montero, *Multipollutant Markets*, 32 RAND J. ECON. 762-74 (2002).

90. *See id.* at 762.

than the amount of control, and therefore, markets should be integrated.[91]

There are several reasons to believe that marginal cost curves are steeper than the marginal benefit curves. The marginal benefit curves are essentially flat, because the values of the risk reduction from exposure to fine particles, which are the vast majority of all benefits, appear to vary linearly with concentration.[92] In addition, NO_x and SO_2 from power utilities are only a relatively small share of total emissions, so the change in emissions from these sources will have a diluted impact on aggregate emissions and air quality.[93]

IV. ADVERSE ENVIRONMENTAL AND HEALTH EFFECTS OF TRADING CAN BE CONTROLLED.

Integrating NO_x and SO_2 markets is only a small departure from current policy. All major legislative proposals allow NO_x and SO_2 emissions from any given plant to depend in large part on market conditions, while setting national emissions rates by statute.[94] However, current programs do not fix national NO_x levels. For example, plants with dissimilar access to low-sulfur coal or with different incremental control costs would emit different mixtures of NO_x and SO_2 for any given set of emission permit market prices. In this sense, an exchange of SO_2 permits for NO_x permits is not qualitatively different in its effects on environmental protection than the type of trading already in place. Trading NO_x for SO_2 is unlikely to weaken environmental protection relative to existing and likely programs.

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91. *See id.* at 763. In the other case, where the marginal benefit curves are steeper, the regulator should pay more attention to the amount of control in each market, and therefore the markets should be separated. *Id.*

92. *See* OFFICE OF POLICY, OFFICE OF AIR AND RADIATION, U.S. ENVTL. PROT. AGENCY, EPA-410-R-99-001, BENEFITS AND COSTS OF THE CLEAN AIR ACT: 1990-2010, EPA REPORT TO CONGRESS, p. 57, D-8, D-9 (1999), *available at* http://www.epa.gov/air/sect812/1990-2010/frullrept.pdf. (last visited Dec. 20, 2002).

93. *See* POLICY BOOK, *supra* note 17.

94. *See* S. 556, 107th Cong. § 706 (2002); S. 588, 107th Cong. §§ 4(b), 7 (2002); S. 2815, 107th Cong. § 403 (2002); H.R. 5277, 107th Cong. § 403 (2002); H.R. 1256, 107th Cong. § 2(b)(B) (2002) (providing for trading); *see also* S. 556, 107th Cong. § 704 (2002); S. 588, 107th Cong. § 2 (2002); S. 2815, 107th Cong. §§ 413-4, 441 (2002); H.R. 5266, 107th Cong. §§ 413-4, 441 (2002); H.R. 1256, 107th Cong. § 2 (2002) (limiting emissions).

A. *Managing Risks*

Deriving an unbiased estimate of relative damages is difficult. For this reason, it may be worth considering approaches that reduce the risk that integrating NO_x and SO_2 markets actually damages the environment. The simplest approach would be for a government office simply to exchange permits in a way that reduces expected environmental damages. For example, a government office could sell 30 NO_x permits in exchange for 11 SO_2 permits (or sell 10 SO_2 permits for 33 NO_x permits). Either trade would provide a tax "for the environment" of ten percent given that expected environmental damages from SO_2 are three times as great as from NO_x. As long as the tax is not excessive, trades at these distinct exchange rates would reduce expected environmental damages.[95]

To illustrate the potential magnitude of environmental benefits from this approach, we consider a case where the government grants permits to emit two tons of NO_x in exchange for a permit to emit a ton of SO_2. As noted earlier, two tons of NO_x cause less expected environmental damage than a ton of SO_2. In this case, from the baseline of 1.5 million tons of NO_x and 2.5 million tons of SO_2, firms would willingly exchange permits for a half million tons of SO_2 in order to obtain permits to emit an additional million tons of NO_x. To see this, note that they could profit by such trades because our analysis with the Haiku model indicates that in the baseline scenario a permit to emit a ton of SO_2 is about 1.4 times as expensive as a permit to emit a ton of NO_x. Firms that give up permits to emit 10 tons of SO_2 in exchange for permits to emit 20 tons of NO_x would profit by the value of permits to emit 6 tons of NO_x. Such profitable exchanges would continue until the cost of reducing SO_2 emissions rose to equal twice the cost of reducing NO_x emissions.[96] Our analysis with the Haiku model implies that this condition would occur with annual NO_x emissions of 2.5 million tons and annual SO_2 emissions of 2 million tons. The Haiku model indicates that the costs of

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95. Offset programs in areas that do not attain national ambient air quality standards already require such emission reduction ratios. Many analysts believe, however, that these ratios have significantly impeded trading. *See* Bob Hahn & Gordon L. Hester, *Where did all the Markets Go? An Analysis of EPA's Emissions Trading Program*, 6 YALE J. ON REG. 109, 146 (1989) (analyzing the EPA's emissions trading program).

96. At this point the government would be offering to exchange SO_2 permits for NO_x permits of equal value.

achieving these emissions limits are $800 million per year less than in the baseline scenario, but net environmental damages have also fallen by the equivalent of a half million tons of NO_x. The reductions in SO_2 emissions of a half million tons per year from the baseline scenario have environmental benefits equivalent to 1.5 million tons of NO_x, given the evidence summarized above that the incremental environmental damages of a ton of NO_x emissions are about a third of the incremental damages of a ton of SO_2. These benefits outweigh by an amount equivalent to about a half million tons of NO_x the environmental damages from increased NO_x emissions relative to the baseline scenario.

A refinement of this approach would allow different exchange rates for different ratios of NO_x and SO_2 emissions. It may make sense to allow further increases in NO_x emissions only in exchange for progressively larger reductions in SO_2 emissions. For example, as NO_x emissions from power plants increase, municipalities may find it harder to meet EPA's ozone air quality standard because NO_x, but not SO_2, contributes to ozone.[97] Regulators could allow firms to get 30 NO_x permits for every 10 SO_2 permits, but only up to a given level, beyond which the rate might change to 30 to 11.

B. *State And Local Health-Based Regulations Will Buttress Federal Trading Approaches.*

Some public health advocates may oppose NO_x-SO_2 trading because increases in emissions of NO_x emissions - but not SO_2 emissions - can result in elevated ozone concentrations. Although ozone is a less significant health risk than particulates formed from sulfates and nitrates, ozone is associated with childhood asthma attacks.[98] There may be concerns that families should not bear increased risks of asthma attacks in children in exchange for reduced mortality from particulates that would primarily affect elderly parents.

There are several flaws with this argument. Although NO_x may contribute to more frequent asthma attacks among children, NO_x emissions from utilities under either S.556 or the Clear Skies Initiative would be around 8 % to10 % of total NO_x emissions, so a given percentage increase in utilities' NO_x emissions is a much smaller

97. *See* EPA Air Quality Standard For Ozone, 40 C.F.R. §§ 53.1-53.21, 58.1-58.32 (1997).

98. *See id.*

percentage increase in the total.[99] Further, the philosophy and strategy of Title I of the Clean Air Act is to allow states to choose how, but not whether, to meet federally mandated health-based ozone standards.[100] The multi-pollutant bills will be buttressed by additional local emissions reductions in locales where air quality is poor.[101]

To further reduce the risk of adverse environmental effects from NO_x-SO_2 exchanges, Congress, after authorizing trades between NO_x and SO_2, could change EPA with reviewing new scientific evidence to assess whether exchange rates reflect unbiased estimates of relative incremental environmental damages. Congress could authorize EPA to change the exchange rates through rulemaking if it concluded that the exchange rate lowered air quality.

CONCLUSION

Congress should encourage changes in the mix of NO_x and SO_2 emissions, in particular, emission reductions of the pollutant for which the bang for the buck is greater. Existing legislative proposals to control multiple pollutants from power plants do not take advantage of opportunities to reduce both environmental damages and

99. We calculate 8% as a ratio between the S.556 proposal of 1,550,000 tons of NO_x emissions and total NO_x emissions from all anthropogenic sources in 2007 as projected in the regulatory analysis for EPA's 2000 Heavy Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements, or 20.6 million tons. *See* OFFICE OF AIR AND RADIATION, U.S. ENVTL. PROT. AGENCY, EPA420-R-00-026, REGULATORY IMPACT ANALYSIS: HEAVY DUTY ENGINE AND VEHICLE STANDARDS AND HIGHWAY DIESEL FUEL SULFUR CONTROL REQUIREMENTS 145, Table II.B-27 (2000), *available at* http://www.epa.gov/otaq/regs/hd2007/frm/ria-ii.pdf (last visited Dec. 20, 2002) (listing total NO_x emissions in 2007 along with components due to vehicles and other sources). Ten percent is the Clear Skies Initiative's emissions cap of 1.7 million tons of NO_x emissions in 2018 relative to the total emissions of NO_x from anthropogenic sources in 2020 as projected in the same analysis, or 17.9 million tons. *See* S. 556 107th Cong. § 704 (Jeffords Proposal NO_x emissions levels); EPA Fact Sheet on Clear Skies Initiative 2 (2002), *available at* http://www.epa.gov/clearskies/clearskiesfactsheet_3_26.pdf (last visited Dec. 20, 2002) (Clear Skies Initiative NO_x emissions levels).

100. *See* Clean Air Act § 110(a)(1), 42 U.S.C. § 7410.

101. The purposes of the bills do not include a goal to eliminate the need for additional local emissions reductions. *See, e.g.*, S. 556, 107th Cong. (2001) and H.R. 5266, 107th Cong. (2002).

compliance costs because they adopt a pollutant-by-pollutant approach, and prohibit shifts in the mix of NO_x and SO_2 emissions.

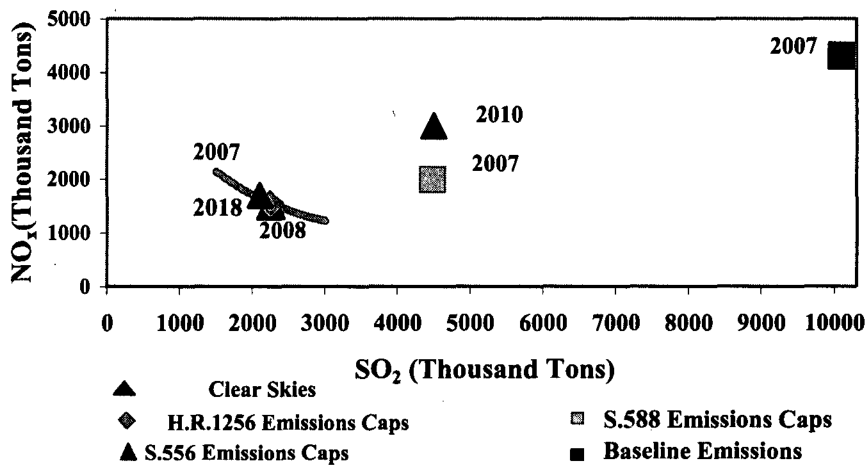
While choosing the right NO_x-SO_2 exchange rate may be difficult, there is no doubt that an outright prohibition of such transactions is excessively prescriptive and burdensome. It makes sense only given the irrational assumption that a reduction in national emissions of NO_x (or SO_2), regardless of its size, could never compensate for a one-ton increase in emissions of SO_2 (NO_x). Yet, all multi-pollutant proposals offered to date embody this approach.

To further reduce the risk of adverse environmental effects from NO_x-SO_2 exchanges, Congress could charge EPA with reviewing new scientific evidence to assess whether exchange rates reflect unbiased estimates of relative incremental environmental damages. Congress could authorize EPA to change the exchange rate through rulemaking if it concluded that the exchange rate lowered air quality.

Congress should abandon the pollutant-by-pollutant approach that it has used to develop new emissions legislation because it is incompatible with cost-effective environmental protection. The mix of emissions should vary with control costs and not be set at absolute and unchanging statutory levels. Allowing markets to choose the lowest cost set of NO_x and SO_2 emissions from among ones with equivalent environmental effects will lower the costs of emissions controls. Economic modeling suggests that cost savings from integrating NO_x and SO_2 markets can exceed $1.1 billion per year without reductions in environmental benefits. This no-lose solution should interest both those environmentalists and industry representatives who promote cost-effective clean air policy.

Figure 1

NO_x and SO_2 Utility Emissions



Note: The curve that goes through the H.R.1256 emissions cap represents the set of NO_x and SO_2 emissions where compliance costs are approximately constant, based on EIA's estimates of SO_2 and NO_x permit prices for the emissions reductions in an earlier version of S.556, which was identical to H.R. 1256.

Effective dates for the bills differ slightly. Emissions allowance caps for S.556, which are very similar to those in H.R. 1256, would be effective in 2008; the NO_x cap in S.588 would begin in 2004 and grow until 2007; H.R. 1256 would be effective in 2007, while the Administration's Clear Skies proposal would take effect in 2008 and specify increasingly stringent caps for 2010 and 2018. Banking enables emissions to remain above allowance caps until the bank is exhausted.

Figure 2

Improved Air Quality and Reduced Compliance Costs with NO_x-SO_2 Trading

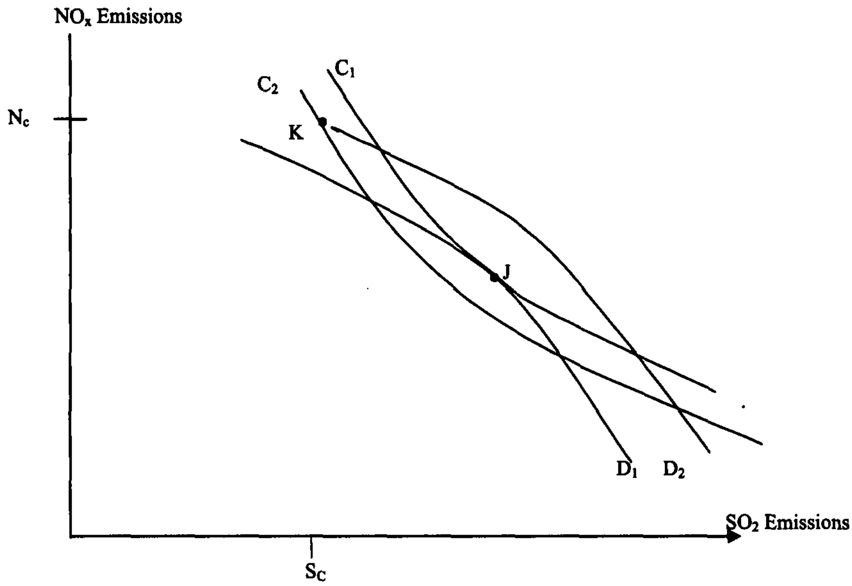
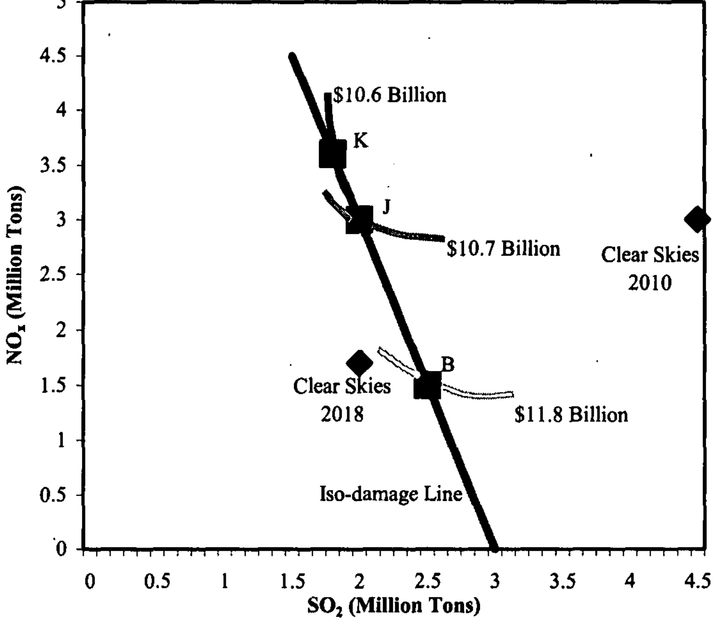


Figure 3

NOx-SO2 Permit Trading Saves More than $1 Billion Annually



Note: The diamonds labeled Clear Skies, "♦", represent emissions under the Bush administration's proposal in 2010 and 2018. The squares representing points B, J and K refer to annual levels of NO_x and SO_2 emissions averaged over the years 2010 to 2020. The iso-cost curves going through these three points are the sets of NO_x and SO_2 emissions where annual control costs are constant at $11.8 billion, $10.7 billion and $10.6 billion respectively. The slopes of the various iso-cost curves at the points B, J and K represent the incremental costs of controlling SO_2 relative to the incremental costs of controlling NO_x. The iso-damage line represents the combination of NO_x and SO_2emissions expected to offer the same protection to health and the environment as point B. It assumes that one ton of SO_2, is as damaging as 3 tons of NO_x.. Since points B, J and K all offer the same level of protection, but differ by at least $1 billion annually in control costs, by allowing firms collectively to increase NO_x emissions in exchange for additional SO_2 reductions, should save at least $1 billion annually without lowering environmental protection.