

MARKETS AND GEOGRAPHY: DESIGNING MARKETABLE PERMIT SCHEMES TO CONTROL LOCAL AND REGIONAL POLLUTANTS

Jonathan Remy Nash and Richard L. Revesz***

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* Harry A. Bigelow Fellow and Lecturer in Law, University of Chicago Law School.

** Lawrence King Professor of Law, New York University School of Law; Visiting Professor of Law, Yale Law School, Spring 2001. We are grateful to Bruce Ackerman, Donald Dewees, Richard Epstein, Raymond Jasen, Douglas Lichtman, and James Salzman for comments on a prior draft; to Kal Raustiala for discussions concerning the RAINS model; to Orin Tempkin for insights on the chemistry of ozone formation; and to Donna Goggin, Shorge Sato, and Elena Zlatnik for their excellent research assistance. Prior versions of this article were presented at the 2001 annual meeting of the American Law and Economics Association; at the 2000 annual meeting of the Canadian Law and Economics Association; at a Science, Technology, and Environmental Policy workshop at the Woodrow Wilson School of Public and International Affairs, Princeton University; at a faculty workshop at the University of Virginia Law School; and at a workshop of the Environmental Law Society at the University of Chicago Law School. The Filomen D'Agostino and Max E. Greenberg Research Fund at the New York University School of Law provided financial assistance.

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INTRODUCTION

The idea of establishing markets in pollution rights is not new.¹ J.H. Dales strongly advocated this regulatory technique in the late 1960s.² Thereafter, tradable permit regimes became popular among academic economists.³ In a 1985 article that had considerable influence on the legal literature, Bruce Ackerman and Richard Stewart strongly advocated tradable permits as an alternative to command-and-control regulation.⁴ In recent years, there has been a steady rise in the use of tradable permits in the regulatory process.⁵ They have been employed as tools to control both air and water pollution,⁶ and have been implemented on local, regional, and national scales.⁷ While trading regimes have to date been used mostly in the United States, they are attracting increasing attention abroad,⁸ and there is now considerable interest in emissions trading on a global scale to address the problem of anthropogenic greenhouse gases.⁹

The design of the trading regime most commonly advocated in the academic literature – based upon a single market in

1. For discussions of the various environmental regulatory tools from which policymakers may choose, see Jonathan Baert Wiener, *Global Environmental Regulation: Instrument Choice in Legal Context*, 108 YALE L.J. 677, 679 n.4 (1999); Robert N. Stavins, *Policy Instruments for Climate Change: How Can National Governments Address a Global Problem?*, 1997 U. CHI. LEGAL F. 293, 294-99.

2. See J.H. DALES, *POLLUTION, PROPERTY & PRICES* (1968).

3. See Wallace E. Oates, *From Research to Policy: The Case of Environmental Economics*, 2000 U. ILL. L. REV. 135, 136-37; see also Wiener, *supra* note 1, at 679 n.4 (citing sources).

4. Bruce A. Ackerman & Richard B. Stewart, *Reforming Environmental Law*, 37 STAN. L. REV. 1333 (1985).

5. See Nathaniel O. Keohane, Richard L. Revesz & Robert N. Stavins, *The Choice of Regulatory Instruments in Environmental Policy*, 22 HARV. ENVTL. L. REV. 313, 317-18, 365 (1998).

6. See, e.g., *infra* Part II (discussing air pollution trading programs); Robert C. Anderson et al., *Cost Savings from the Use of Market Incentives for Pollution Control*, in MARKET-BASED APPROACHES TO ENVIRONMENTAL POLICY: REGULATORY INNOVATIONS TO THE FORE 15, 30-31 (Richard F. Kosobud & Jennifer M. Zimmerman eds., 1997) [hereinafter MARKET-BASED APPROACHES] (discussing water pollution trading programs).

7. See *infra* Part II (describing national sulfur dioxide program, regional ozone transport program, and local RECLAIM program).

8. See NEW INSTRUMENTS FOR ENVIRONMENTAL POLICY IN THE EU 4-8 (Jonathan Golub ed., 1998).

9. See Wiener, *supra* note 1, at 712-13.

emission permits – is relatively straightforward. A policymaker determines the total number of emission permits that will be allocated to a region. These permits are then distributed among polluters, generally either by means of an initial auction or through grandfathering.¹⁰ Subsequently, permits are traded in an open market.¹¹ Assuming that a robust market for permits arises, a tradable emission permit regime reduces aggregate emissions to the chosen aggregate level for the least cost.¹²

Such a trading regime, however, does not control the distribution of those emissions throughout the region. As a result, it does not ensure that an ambient standard – specifying a maximum permissible concentration of the pollutant – is met throughout the region.¹³ To the extent that trades result in a disproportionate concentration of the pollutant in some portion of the region, ambient standards could be violated. More generally, a tradable emission permit regime does not prevent the formation of “hot spots” of pollution – that is, locations at which the damage caused by pollutants is particularly severe.¹⁴ Ackerman and Stewart acknowledge this shortcoming: “[T]he market system we have described could allow the creation of relatively high concentrations of particular pollutants in small areas within the larger pollution control region.”¹⁵ They note that “[t]he extensive literature on marketable permits . . . points to a variety of feasible means for dealing with the hot spot problem,”¹⁶ and recommend that “a long-run strategy for institutional reform should strive to take advantage of these more sophisticated market solutions to the problem of intraregional variation.”¹⁷

Over the years, commentators have advocated several alternative design structures to deal with the problem of ambient standard violations and hot spots. Each of these alternatives, however, has significant drawbacks, either providing only an incomplete solution to the problem or introducing complexity that could stand in the way of the efficient functioning of the market.

In this Article, we propose an alternative that would avoid the violation of ambient standards and formation of hot spots

10. See *infra* text accompanying note 27-30 .

11. See, e.g., Ackerman & Stewart, *supra* note 4, at 1347.

12. See *id.* at 1341-42 & n.19.

13. See *infra* Section I.B.

14. See *infra* text accompanying notes 46-51.

15. Ackerman & Stewart, *supra* note 4, at 1350.

16. *Id.* at 1351 (footnote omitted).

17. *Id.*

without greatly increasing administrative complexity or introducing excessively high transaction costs. Our idea is to construct a market in tradable emission permits under which trading would be entirely unfettered, with the sole exception that a prospective buyer and seller would have to receive approval before they could consummate their trade. This approval could be accomplished with a database, accessed through a website¹⁸ administered by the government,¹⁹ which would contain emissions data for all sources in the region.²⁰ When a proposed trade is submitted for approval, the website would temporarily update its saved data to reflect the change in the geographic distribution of emissions that would result from the proposed trade. The website then would use an atmospheric dispersion model to predict the impact of the emissions from all the sources in the region – as modified by the proposed trade – on ambient pollution levels at various receptor points. The website would reject any trade resulting in the violation of an applicable ambient standard and would approve all other trades.

Part I of this Article describes the functioning of the typical regime of tradable emission permits and examines how such a regime can lead to the violation of ambient standards and the formation of hot spots. Part II describes the structure of three recent and prominent regulatory programs involving tradable emission permits: the national sulfur dioxide trading program, regional trading in ozone precursors in the northeast, and local trading in sulfur and nitrogen oxides emissions in the Los Angeles metropolitan area. It explains why these programs are poorly suited to ensure either the attainment of ambient standards or the prevention of hot spots. It also discusses the unsuccessful efforts to correct these shortcomings.

18. For ease of exposition, we hereinafter refer to the combination of the database and website simply as a "website".

19. The government could decide to engage a private contractor to perform administrative functions. See *infra* text accompanying note 320.

20. For a discussion of the growing use of the internet in the administration of the EPA's sulfur dioxide trading program, see Joseph A. Kruger et al., *A Tale of Two Revolutions: Administration of the SO₂ Trading Program*, in EMISSIONS TRADING: ENVIRONMENTAL LAW'S NEW APPROACH 115 (Richard F. Kosobud et al. eds., 2000) [hereinafter EMISSIONS TRADING]. In particular, EPA collects, and posts on its website, both emissions data and allowance transfer data. See *id.* at 123-25. In addition, brokers and traders of sulfur dioxide emission allowances have also relied upon internet technology "to disseminate price information and to help match buyers with sellers." *Id.* at 128; see Daniel J. Dudek et al., *Emissions Trading in Nonattainment Areas: Potential Requirements, and Existing Programs*, in MARKET-BASED APPROACHES, *supra* note 6, at 151, 154 ("[E]lectronic bulletin boards and computerized tracking systems have been developed to facilitate trading.").

Part III evaluates three proposals advanced by commentators as alternatives to the typical emission trading regime. We first examine a system in which the emissions market is divided into zones and interzonal trades are prohibited. Next, we analyze a system of markets in units of environmental degradation, under which permits do not entitle a holder to emit a fixed amount of pollutant, but rather to cause a fixed amount of environmental damage at a certain receptor point. Last, we discuss pollution offset markets, under which trading in emission permits does not occur on a one-to-one ratio.

In Part IV, we present a proposal for a tradable emission permit regime designed to solve the problem of ambient standard violations. First, we explain its major elements. Second, we compare its relevant features to those of the three alternatives examined in Part III. We demonstrate that our proposal protects against ambient standard violations as well as or better than other systems that guard against ambient standard violations and does not introduce as much complexity for the government or the market participants. Third, we highlight our proposal's impacts on the structure of the permit markets. Fourth, we present a numerical simulation that illustrates the design and implementation of our proposal.

Part V then discusses how our proposal would deal with a number of important issues. In particular, we analyze purchases of permits by sources that locate in the area after the establishment of the market; uses of permits by sources that relocate or change fundamental characteristics (such as smokestack height); variable – as opposed to uniform – ambient standards throughout the region; auctions of permits, either at the time of the initial distribution or subsequently; and purchases of permits with the intent to bank them for use at a future time, retire them in order to improve environmental quality, or hold them as an investment with the goal of reselling them in the future.

I

TRADABLE EMISSION PERMITS AND THE VIOLATION OF AMBIENT STANDARDS AND FORMATION OF HOT SPOTS

We first examine the structure of the most common tradable pollution permit regime, in which trades take place in a single market, in units of emissions, and on the basis of a one-to-one trading ratio. Next, we explain how this regime can lead to the violation of ambient standards and the formation of hot spots.

A. Elements of a Market System

The design and implementation of a tradable emission permit regime proceeds in several steps.²¹ First, the policymaker identifies the pollutant to be regulated²² and the region over which the regulation will extend.²³ Next, the policymaker determines what aggregate level of emissions in a given year (or other time period) will be deemed acceptable²⁴ and then subdivides this amount into a number of discrete emission permits, each of which authorizes the holder to emit a fixed amount of the regulated pollutant. The policymaker also defines the bundle of rights that accompanies each permit, including permit longevity, whether the government can eliminate permits before their expiration,²⁵ and whether unused permits can be retained for future use.²⁶

The policymaker then adopts a mechanism for allocating these permits among prospective polluters. For example, it can distribute the permits to existing polluters according to their prior emission history.²⁷ If it chooses this grandfathering option for the initial allocation of permits, the policymaker can distribute the permits at no charge²⁸ or can charge some pre-determined amount.²⁹ Alternatively, it can distribute all or some

21. See Jonathan Remy Nash, *Too Much Market? Conflict Between Tradable Pollution Allowances and the "Polluter Pays" Principle*, 24 HARV. ENVTL. L. REV. 465, 483-84 (2000).

22. The policymaker also might consider the possibility of interpollutant trading. See Clean Air Act § 403(c), 42 U.S.C. § 7651b(c) (1994) (contemplating the possibility of limited interpollutant trading).

23. In the paradigmatic regime, the entire region constitutes a single trading zone.

24. Although the government's process in determining what level of emissions is acceptable is beyond the scope of this Article, generally the government might consider public health and efficiency concerns.

25. See Richard F. Kosobud & Jennifer M. Zimmerman, *Introduction to Part 2: From Journal Articles to Actual Markets: The Path Taken*, in MARKET-BASED APPROACHES, *supra* note 6, at 49, 53.

26. See Nash, *supra* note 21, at 484; Kosobud & Zimmerman, *supra* note 25, at 53.

27. See Nash, *supra* note 21, at 484; Stavins, *supra* note 1, at 306. For example, the national sulfur dioxide trading program and the Los Angeles metropolitan area smog precursor trading program follow such an approach. See *infra* text accompanying notes 78-80, 260-261.

28. See Nash, *supra* note 21, at 484; J.M. Tomkins & J. Twomey, *International Pollution Control: A Review of Marketable Permits*, 41 J. ENVTL. MGMT. 39, 46 (1994). For example, the national sulfur dioxide trading program and Los Angeles metropolitan area smog precursor trading program generally allocate allowances at no cost to recipients. See *infra* text accompanying notes 78-80, 84-85, 260-261.

29. See Stavins, *supra* note 1, at 306; Nash, *supra* note 21, at 484.

of the permits through an auction.³⁰ The policymaker must also devise rules for the subsequent trading of the permits in an open market. For example, should non-polluters be free to buy and hold emission permits, either for investment purposes or in order to retire them as a means of improving environmental quality?³¹

B. Impact of Trading on Environmental Quality

In discussing the impact of a particular pattern of emissions on environmental quality, it is important to distinguish among three different types of pollutants. For "global" pollutants, this impact is independent of the location of the various sources; only the aggregate amount of emissions matters.³² Greenhouse gases are a prominent example of a global pollutant.³³ The adverse impact of a ton of carbon dioxide is the same regardless of whether it is discharged in the United States or China.³⁴

Most pollutants, however, do not have this feature. Instead, their harm depends on the location at which they are emitted.³⁵ For "local" pollutants, the location of the emissions and the place where the harm occurs are relatively coextensive.³⁶ "Regional" pollutants, on the other hand, travel further – in the case of sulfur dioxide, for example, hundreds of miles, and across state and national boundaries – but the affected region is defined by reference to where the emissions come from.³⁷ Thus, for both

30. See Nash, *supra* note 21, at 484; Tomkins & Twomey, *supra* note 28, at 46. For example, the national sulfur dioxide program distributes some allowances by means of an auction. See *infra* text accompanying notes 86-88.

31. See Kosobud & Zimmerman, *supra* note 25, at 53.

32. See Nash, *supra* note 21, at 499-500; Richard L. Revesz, Note, *Technology-Based Emission and Effluent Standards and the Achievement of Ambient Environmental Objectives*, 91 YALE L.J. 792, 792 n.5 (1982).

33. See Richard B. Stewart, *Environmental Quality as a National Good in a Federal State*, 1997 U. CHI. LEGAL F. 199, 223; Nancy Kete, *The U.S. Acid Rain Control Allowance Trading System*, in CLIMATE CHANGE: DESIGNING A TRADEABLE PERMIT SYSTEM 78, 83 (Organisation for Economic Co-operation and Development, 1992). But see Richard B. Stewart & Jonathan B. Wiener, *The Comprehensive Approach to Global Climate Policy: Issues of Design and Practicality*, 9 ARIZ. J. INT'L & COMP. L. 83, 104 n.73 (1992) (explaining that certain greenhouse gases are also local pollutants).

34. See Laura H. Kosloff & Mark C. Trexler, *Global Warming, Climate-Change Mitigation, and the Birth of a Regulatory Regime*, 27 ENVTL. L. REP. (BNA) 10012 (1997).

35. See Maureen L. Cropper & Wallace E. Oates, *Environmental Economics: A Survey*, 30 J. ECON. LIT. 675, 688 (1992).

36. See Thomas H. Tietenberg, *Transferable Discharge Permits and the Control of Stationary Source Air Pollution: A Survey and Synthesis* 56 LAND ECON. 391, 395-96 (1980).

37. See Lily N. Chinn, Comment, *Can the Market Be Fair and Efficient? An Environmental Justice Critique of Emissions Trading*, 26 ECOLOGY L.Q. 80, 107 (1999);

local and regional pollutants, the location of the emissions determines the location and magnitude of the adverse environmental consequences.³⁸ In the vocabulary of environmental economics, the emission of one unit of pollution at different locations results in "spatially differentiated" externalities.³⁹

For local and regional pollutants, the environmental impacts of trading are a function of two important sets of variables. First, the costs of pollution control faced by the various participants in the market determine the distribution of emissions among these sources. A polluter will reduce its emissions up to the point at which a further unit of reduction is more costly than the market price of a permit. A polluter that can reduce its emissions for less than the market price of a permit will invest additional resources in pollution control technology and sell permits. In contrast, a polluter with comparatively high costs of pollution control will save money by increasing its emissions and buying additional permits. Trading continues until each source's marginal cost of pollution reduction – the cost of an additional unit of emission reduction – is equal to the market price of the permit.⁴⁰

Second, emissions at different locations throughout a region have different effects on environmental quality. For example, in

M.L. Livingston et al., *The Determinants of International Pollution: Empirical Evidence from CO₂ Emissions*, 28 TULSA L.J. 723, 737 (1993); Kete, *supra* note 33, at 82.

38. See S.E. Atkinson & T.H. Tietenberg, *Economic Implications of Emissions Trading Rules for Local and Regional Pollutants*, 20 CANADIAN J. ECON. 370, 371 (1987). Although the discussion in the text speaks specifically of air pollution, the location of water pollutant emissions also can affect the extent and location of the damage caused by the emissions, as Joseph Sax recognized over a quarter century ago. See JOSEPH L. SAX, *WATER LAW, PLANNING & POLICY: CASES AND MATERIALS* 403 (1968) ("[O]ne's location on the stream may have something to do with the extent to which he is contributing to infringement of desired downstream uses. For example, a plant far upstream from a swimming area will benefit more from the assimilative capacity of the stream than one located just upstream of the swimming area."). See also Ann Powers, *Reducing Nitrogen Pollution on Long Island Sound: Is There a Place for Pollutant Trading?*, 23 COLUM. J. ENVTL. L. 137, 196-98 (1998) (describing how, because of Long Island Sound's geography, emissions from different locations cause different harms).

39. See Ronald C. Griffin, *Environmental Policy for Spatial and Persistent Pollutants*, 14 J. ENVTL. ECON. & MGMT. 41, 41 (1987). Cf. Carol M. Rose, *The Several Futures of Property: Of Cyberspace and Folk Tales, Emission Trades and Ecosystems*, 83 MINN. L. REV. 129, 171-73 (1998) (discussing problem of "partial proprietization"); James Salzman & J.B. Ruhl, *Currencies and the Commodification of Environmental Law*, 53 STAN. L. REV. 607 (2000) (evaluating tradable pollution permit regimes from the standpoint of the "currency" used in trading).

40. See Wiener, *supra* note 1, at 715; Robert W. Hahn & Roger G. Noll, *Designing a Market for Tradable Emissions Permits*, in REFORM OF ENVIRONMENTAL REGULATION 119, 121-22 (Wesley A. Magat ed., 1982).

the case of air pollution, the height of the stack from which pollutants are emitted has an important effect on ambient air quality levels: typically, higher stacks produce greater impacts further from the source and smaller impacts closer to the source.⁴¹ The effects are also dependent on topographic and meteorological conditions, particularly wind patterns.⁴² Thus, for local and regional pollutants, trades among sources within a region can have an impact on the levels of environmental quality at particular locations even though the aggregate level of emissions in the region remains constant.

If the public policy objective were to maximize social welfare, the optimal distribution of pollution concentrations in the region would depend on the shape of the damage function – the function linking the pollutant's concentrations to its adverse effects.⁴³ If the damage function is convex (i.e., an additional unit of pollution concentration causes greater harm at higher concentrations), social welfare is maximized by spreading the pollutant concentrations throughout the region. This is the case because, under that scenario, additional levels of pollutant concentrations cause greater harm in dirtier areas. This scenario is depicted by the following:

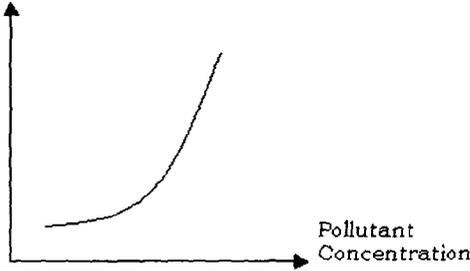
41. Richard L. Revesz, *Federalism and Interstate Environmental Externalities*, 144 U. PA. L. REV. 2341, 2351 (1996).

42. See E. WILLARD MILLER & RUBY MILLER, ENVIRONMENTAL HAZARDS: AIR POLLUTION – A REFERENCE HANDBOOK 21 (1989); Marc J. Roberts, *Some Problems of Implementing Marketable Pollution Rights Schemes: The Case of the Clean Air Act*, in REFORM OF ENVIRONMENTAL REGULATION, *supra* note 40, at 93.

43. See CLEM TISDELL, ENVIRONMENTAL ECONOMICS: POLICIES FOR ENVIRONMENTAL MANAGEMENT AND SUSTAINABLE DEVELOPMENT 62 (1993).

Graph 1: Convex Damage Function

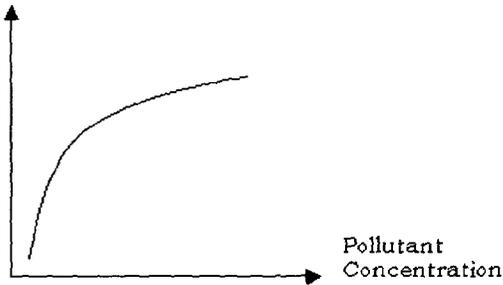
Harm to
Social Welfare



In contrast, if the damage function is concave (i.e., an additional unit of pollution concentration causes greater harm at lower concentrations), social welfare is maximized by concentrating the pollution rather than spreading it around. In this case, additional concentrations of a pollutant cause a smaller adverse effect in areas that are already highly polluted. This scenario is represented by the figure below:

Graph 2: Concave Damage Function

Harm to
Social Welfare



Whereas disproportionate concentrations of pollution at a particular location can be either desirable or undesirable from the perspective of maximizing overall social welfare, they tend to be undesirable from the standpoint of distributional concerns. For example, the environmental justice movement worries about any disproportionate concentration of pollution because of fears

that its impacts will be felt primarily by the most vulnerable members of society.⁴⁴ This concern is independent of the shape of the pollutant's damage function.⁴⁵ Even if the aggregate social welfare would be increased by concentrating pollution in a particular area, environmental justice advocates would nonetheless favor dispersion.

The academic literature has focused almost exclusively on the possibility that emissions trading will give rise to excessive concentrations of pollution at particular locations, and has expressed concern over two separate manifestations of this phenomenon: the formation of hot spots and the violation of ambient air quality standards.⁴⁶ In the case of local pollutants, such hot spots are likely to be in locations in which the levels of emissions are particularly high. Source locations are not, however, the only relevant factor. For example, for a given level of emissions, a hot spot is more likely to develop if the area is close to a topographical barrier, such as a mountain range, and where prevailing winds blow the pollution toward the range rather than away from it.⁴⁷ In the case of regional pollutants, what matters is not only the location of the emissions but also the manner in which emissions are transported. As a result, there may be a hot spot at a downwind location even if the emissions are not concentrated at any particular upwind location.⁴⁸

Environmental justice advocates, in particular, worry that marketable permit regimes will exacerbate hot spots.⁴⁹ The oldest, most highly polluting factories are often located in lower

44. For recent perspectives on environmental justice, see Sheila Foster, *Justice from the Ground Up: Distributive Inequities, Grassroots Resistance, and the Transformative Politics of the Environmental Justice Movement*, 86 CAL. L. REV. 775 (1998); Alice Kaswan, *Environmental Justice: Bridging the Gap Between Environmental Laws and "Justice"*, 47 AM. U.L. REV. 221 (1997).

45. Indeed, the environmental justice treatment of this issue focuses only on the higher levels of pollution in particular areas, and not on whether the damage from the pollution is convex or concave. See Richard Toshiyuki Drury et al., *Pollution Trading and Environmental Injustice: Los Angeles' Failed Experiment in Air Quality Policy*, 9 DUKE ENVTL. L. & POL'Y F. 231, 271 (1999); Kaswan, *supra* note 44, at 268.

46. Rena I. Steinzor, *Reinventing Environmental Regulation: The Dangerous Journey from Command to Self-Control*, 22 HARV. ENVTL. L. REV. 103, 115 (1998); Stewart, *supra* note 33, at 222; Tom Tietenberg, *Tradable Permits for Pollution Control When Location Matters*, 5 ENVTL. & RESOURCE ECON. 95, 99 (1991).

47. See *supra* text accompanying notes 41-42.

48. See Tietenberg, *supra* note 46, at 102.

49. Chinn, Comment, *supra* note 37, at 102-15; Stephen M. Johnson, *Economics v. Equity: Do Market-Based Environmental Reforms Exacerbate Environmental Injustice?*, 56 WASH. & LEE L. REV. 111, 124-39 (1999); Kaswan, *supra* note 44, at 269.

income neighborhoods.⁵⁰ If the initial allocation of permits is performed through grandfathering, these older plants will get a disproportionate number of permits and will be able to continue polluting at their historic rates without facing any additional costs. In contrast, under a command-and-control regime, they might eventually face more stringent standards. Moreover, older factories are more likely to have higher marginal costs of pollution reduction.⁵¹ As a result, they will purchase additional permits following the initial allocation, and increase their pollution rather than spend money on more effective pollution control technology.

In fact, even if older facilities are not located in predominantly poor or minority communities when the government first implements a trading program, "market dynamics" in the housing market may change that situation over time. In particular, the placement of a locally undesirable land use in a community may "convert" the community into one whose residents are more likely to be poorer and more likely to be of color.⁵² Thus, any concentration of pollution in a particular area, even if it was not originally a predominantly poor or minority area, could have adverse environmental justice consequences.

In addition to producing hot spots, trading regimes can also lead to violations of ambient standards. Several existing environmental programs feature such standards. The Clean Air Act, for example, establishes national primary and secondary ambient air quality standards (NAAQS), which provide protection against adverse effects on public health and public welfare, respectively.⁵³ Similarly, under the Clean Water Act, the states must promulgate ambient water quality standards.⁵⁴

The leading proposals for tradable permit regimes do not contain a mechanism for ensuring that ambient standards are met.⁵⁵ For example, if the ambient air quality level in an area is

50. See Vicki Been, *Locally Undesirable Land Uses in Minority Neighborhoods: Disproportionate Siting or Market Dynamics?*, 103 YALE L.J. 1383, 1384 & n.2 (1994); Chinn, Comment, *supra* note 37, at 109; Drury et al., *supra* note 45, at 271; Johnson, *supra* note 49, at 117 n.40, 130-31.

51. Keohane, Revesz & Stavins, *supra* note 5, at 315 n.10.

52. See Been, *supra* note 50, at 1388-90; Vicki Been & Francis Gupta, *Coming to the Nuisance or Going to the Barrios? A Longitudinal Analysis of Environmental Justice Claims*, 24 ECOLOGY L.Q. 1, 6 (1997).

53. See 42 U.S.C. § 7409(b) (1994).

54. See 33 U.S.C. § 1313(a) (1994).

55. See, e.g., Richard F. Kosobud & Jennifer M. Zimmerman, *Conclusions: Performance and Prospects for Market-Based Approaches*, in MARKET-BASED

equal to the ambient standard before the transition to a trading regime, subsequent purchases of permits by sources in the area could lead to a violation of the ambient standards. As a result, trading regimes lose the strong rhetorical claim that they are simply a way of achieving the same level of environmental protection more cheaply than command-and-control regulation.⁵⁶ A regulatory regime that does not ensure that such standards will be met cannot be said to provide the same level of protection as one that does, even if the aggregate amount of emissions is the same under both programs.

II

SHORTCOMINGS OF THE EXISTING TRADABLE POLLUTION PERMIT REGIMES

This Part analyzes three regulatory regimes employing tradable emission permits: the national sulfur dioxide trading program, regional trading in ozone precursors in the northeast, and local trading in sulfur and nitrogen oxides emissions in the Los Angeles metropolitan area. In each of these three programs, permits are generally traded in a single market, with no geographic restrictions.⁵⁷ We highlight how these programs are poorly designed to prevent violation of ambient standards or the formation of "hot spots," and discuss the unsuccessful efforts to ameliorate this problem.

A. *The National Sulfur Dioxide Trading Program and the Control of Acid Rain*

1. *Design of the Trading Program*

One of the principal causes of acid deposition, commonly known as acid rain, is the transformation in the atmosphere of

APPROACHES, *supra* note 6, at 325 ("Most present market designs exclude . . . complications [such as hot spots] in an effort to get a workable scheme under way."); T. H. TIETENBERG, EMISSIONS TRADING: AN EXERCISE IN REFORMING POLLUTION POLICY 64 (1985) ("One way to deal with the spatial complexity of pollution control is to ignore it."). Geographically uniform effluent taxes would have the same problem. As a result, it might be desirable for such taxes to be spatially differentiated. See Susan Rose-Ackerman, *Effluent Charges: A Critique*, 6 CANADIAN J. ECON. 512 (1973); Thomas Tietenberg, *Spatially Differentiated Air Pollutant Emission Charges: An Economic and Legal Analysis*, 54 LAND ECON. 265 (1978).

56. See RICHARD L. REVEZ, FOUNDATIONS OF ENVIRONMENTAL LAW AND POLICY 130-31 (1997).

57. The Los Angeles area trading program in sulfur and nitrogen oxides emission permits in fact has a limited geographic restriction that generally prohibits sales of permits from inland areas to coastal areas. See *infra* text accompanying notes 262-264.

sulfur dioxide emissions into sulfates.⁵⁸ These sulfates, which are acidic compounds, can travel hundreds of miles as a result of prevailing winds before being dissolved into rain or snow.⁵⁹

Although the Environmental Protection Agency (EPA) promulgated NAAQS for sulfur oxides in 1971,⁶⁰ these standards are designed to deal with the pollutant's local effects, not its transformation into sulfates.⁶¹ Over the years, there were unsuccessful attempts to compel EPA to revise these NAAQS to address acid deposition⁶² and to promulgate a separate NAAQS for sulfate particles.⁶³ In connection with part of this litigation, the Second Circuit explicitly stated that the NAAQS "were not designed to protect against the deleterious effects of [sulfur oxides] associated with acid rain and dry deposition."⁶⁴ Moreover, even though the Clean Air Act has specific provisions seeking to constrain interstate pollution,⁶⁵ the courts have consistently upheld EPA's position that the impact of transformed pollution, such as sulfates, need not be taken into account in evaluating whether the upwind pollution is excessive.⁶⁶

58. See RUSSELL E. ERBES, *AIR QUALITY COMPLIANCE* 42 (2d ed. 1996); JOHN H. SEINFELD, *ATMOSPHERIC CHEMISTRY AND PHYSICS OF AIR POLLUTION* § 18.1, at 695 (1986). See generally GUY P. BRASSEUR ET AL., *ATMOSPHERIC CHEMISTRY AND GLOBAL CHANGE* 367-70 (1999) (discussing atmospheric chemistry of acid deposition).

59. See SEINFELD, *supra* note 58, § 18.1, at 695; PAOLO ZANNETTI, *AIR POLLUTION MODELING: THEORIES, COMPUTATIONAL METHODS AND AVAILABLE SOFTWARE* 13, 17-18 (1990); EPA, *Acid Rain Program: Environmental Effects of Acid Rain*, at <http://www.epa.gov/airmarkets/acidrain/effects/index.html> (last updated Dec. 11, 2000). For discussion of the effects of acid deposition, see MILLER & MILLER, *supra* note 42, at 23-41.

60. See 36 Fed. Reg. 8186 (1971).

61. See NATIONAL AIR POLLUTION CONTROL ADMINISTRATION, *AIR QUALITY CRITERIA FOR SULFUR OXIDES* (1969) (discussing adverse effects of sulfur oxides). For discussion of the early history of federal regulation of sulfur dioxide emissions, see A. DENNY ELLERMAN ET AL., *MARKETS FOR CLEAN AIR: THE U.S. ACID RAIN PROGRAM* 13-18 (2000). For discussion of how the NAAQS created additional incentives for the interstate externalization of pollution, potentially exacerbating acid rain problems, see Revesz, *supra* note 41, at 2351-52.

62. See *Environmental Defense Fund v. Thomas*, 870 F.2d 892, 895-902 (2d Cir.), *cert. denied*, 493 U.S. 991 (1989); John R. Loxterman, Note, *The Acid Rain Provisions of the Clean Act Amendments of 1990: Environmental Responsibility or Political Necessity?*, 10 *TEMPLE ENVTL. L. & TECH. J.* 201, 203-04 (1991).

63. See *New York v. EPA*, 852 F.2d 574, 580 n.3 (D.C. Cir. 1988), *cert. denied*, 489 U.S. 1065 (1989) ("To the extent that Maine is implicitly arguing that EPA should be compelled to promulgate [NAAQS] regulations dealing with regional haze [caused by sulfate particles], its claim is beyond the jurisdiction of this Court.").

64. *Environmental Defense Fund v. Thomas*, 870 F.2d at 895.

65. See 42 U.S.C. § 7410(a)(2)(D), 7426(b) (1994).

66. See *New York v. EPA*, 716 F.2d 440, 443 (7th Cir. 1983); *New York v. EPA*, 710 F.2d 1200, 1204 (6th Cir. 1983).

During the 1980s, Congress rejected various proposals to control acid rain.⁶⁷ The failure of these initiatives was due in large part to regional feuding over how to allocate the costs of addressing the problem among the various regions.⁶⁸ After these false starts, the Clean Air Act amendments of 1990⁶⁹ finally established the national sulfur dioxide trading program as a means of controlling acid rain.⁷⁰ It was the first pollution trading program authorized by Congress, as well as the first with nationwide scope.⁷¹ Under the program, each allowance or permit⁷² authorizes the holder to emit one ton of sulfur dioxide in one year.⁷³

The program's implementation has proceeded in two stages. From January 1, 1995 through December 31, 1999, Phase I was in effect.⁷⁴ It covered 261 sources at 110 electric utilities,⁷⁵ which

67. See ELLERMAN ET AL., *supra* note 61, at 19-20; Paul L. Joskow & Richard Schmalensee, *The Political Economy of Market-Based Environmental Policy: The U.S. Acid Rain Program*, 41 J.L. & ECON. 37, 45-48 (1998); Loxterman, Note, *supra* note 62, at 204.

68. See DALLAS BURTRAW & ERIN MANSUR, THE EFFECTS OF TRADING AND BANKING IN THE SO₂ ALLOWANCE MARKET 5 (Resources for the Future Discussion Paper 99-25, March 1999) ("Legislative debates about acid rain in the 1980s had a sharp regional character."). See generally ELLERMAN ET AL., *supra* note 61, at 20-21.

69. Pub. L. No. 101-549, 104 Stat. 2399 (codified at 42 U.S.C. §§ 7401-7671q (1994)).

70. See *id.* § 401, 104 Stat. at 2584 (codified at 42 U.S.C. §§ 7651-7651o (1994)).

71. Beginning in the late 1970s, the Environmental Protection Agency (EPA) authorized limited emissions trading programs. See Robert W. Hahn & Gordon L. Hester, *Marketable Permits: Lessons for Theory and Practice*, 16 ECOLOGY L.Q. 361, 368-73 (1989) [hereinafter Hahn & Hester, *Lessons for Theory and Practice*]; Robert W. Hahn & Gordon L. Hester, *Where Did All the Markets Go? An Analysis of EPA's Emissions Trading Program*, 6 YALE J. ON REG. 109 (1989). In 1982, EPA instituted a trading program in lead among refineries in order to phase out the use of lead in gasoline. See Hahn & Hester, *Lessons for Theory and Practice*, *supra*, at 380-90.

72. The sulfur dioxide program creates a market in "allowances." See 42 U.S.C. § 7651a(3) (1994). In order to use a consistent vocabulary under the various programs, we sometimes refer to these "allowances" as permits.

73. See *id.* Congress explicitly stated that a sulfur dioxide allowance constitutes only a "limited authorization to emit sulfur dioxide," and "does not constitute a property right." 42 U.S.C. § 7651b(f) (1994). Congress thus hoped to avoid Takings Clause issues should it decide in the future to change or eliminate the rights conveyed by the allowances. See Jeanne M. Dennis, Comment, *Smoke for Sale: Paradoxes and Problems of the Emissions Trading Program of the Clean Air Act Amendments of 1990*, 40 UCLA L. REV. 1101, 1119-22 (1993). Second, there were ideological concerns about creating a property interest in a "right to pollute." See William G. Rosenberg, *An Insider's View of the SO₂ Allowance Trading Legislation*, in MARKET-BASED APPROACHES, *supra* note 6, at 95, 100.

74. See 42 U.S.C. § 7651c (1994).

75. See 42 U.S.C. § 7651c(a), (e) tbl. A (1994) (listing sources); 40 C.F.R. § 73.10(a) & tbl. 1 (2000) (same). Under both Phases I and II, sources that are not covered by the program can nonetheless opt into it. See 42 U.S.C. § 7651i (1994).

were considered the highest polluters in the nation.⁷⁶ The goal of Phase I was to achieve a nationwide annual 3.5 million ton reduction in sulfur dioxide emissions.⁷⁷ The initial allocation of permits was performed through a grandfathering scheme under which the covered sources obtained, for free, an amount equal to the product (in tons) of (i) each source's baseline fossil fuel consumption (in British Thermal Units (BTUs)), which was taken to be the average consumption during 1985 through 1987,⁷⁸ and (ii) an assumed emissions rate of 2.5 pounds of sulfur dioxide emissions per million BTUs of fuel consumption.⁷⁹ The sources covered under Phase I all had actual emissions rates greater than or equal to 2.5 pounds of sulfur dioxide emissions per million BTUs of fuel consumption.⁸⁰ Thus, their prior emissions were not fully grandfathered.

Phase II of the sulfur dioxide trading program, which began on January 1, 2000, subjects virtually all fossil-fueled electric generating plants, including new sources,⁸¹ to an annual nationwide cap on sulfur dioxide emissions.⁸² It is expected to lead to further annual reductions in sulfur dioxide emissions of 6.5 million tons.⁸³ Although the Phase II allocation provisions contain numerous rules and bonus allocations, the underlying logic of the initial grandfathering is to give each existing source a number of allowances equal to the product (in tons) of (i) the source's baseline fuel consumption, determined in the same manner as for Phase I,⁸⁴ and (ii) the lesser of 1.2 pounds of sulfur dioxide per million BTUs and its actual 1985 emissions rate (in pounds of sulfur dioxide per million BTUs).⁸⁵

A small portion of the permits to which sources would be entitled under this grandfathering formula – 2.8 percent – is

76. See Joskow & Schmalensee, *supra* note 67, at 41 & n.11.

77. *Id.* at 41.

78. See 42 U.S.C. § 7651a(4)(A) (1994). An alternative method is applicable in limited circumstances. See *id.* § 7651a(4)(B).

79. See Joskow & Schmalensee, *supra* note 67, at 51-55. This calculation is only approximate, in light of "bonus" allocations awarded under the statute to certain facilities. See *id.*; Lisa Heinzerling, *Selling Pollution, Forcing Democracy*, 14 STAN. ENVTL. L.J. 300, 329-30 (1995).

80. See ELLERMAN ET AL., *supra* note 61, at 23.

81. See 42 U.S.C. § 7651d(g)(3)-(5) (1994); 40 C.F.R. § 73.18 (2000).

82. See 42 U.S.C. § 7651d(a)(1) (1994); Joskow & Schmalensee, *supra* note 67, at 41. About 2,700 units are covered. See Kenneth Rose, *Implementing an Emissions Trading Program in an Economically Regulated Industry: Lessons from the SO₂ Trading Program*, in MARKET-BASED APPROACHES, *supra* note 6, at 101, 104.

83. See Joskow & Schmalensee, *supra* note 67, at 41.

84. See *supra* text accompanying notes 77-80.

85. See 42 U.S.C. § 7651d(b)-(f), (g)(1), (2), (h)-(j) (1994); 40 C.F.R. §§ 73.10(b) & tbl. 2, 73.19, 73.20 (2000); Joskow & Schmalensee, *supra* note 67, at 55-56.

withheld by EPA and auctioned annually.⁸⁶ The Chicago Board of Trade conducts these auctions on behalf of EPA.⁸⁷ The proceeds are distributed pro rata to sources from which the allocated allowances were withheld.⁸⁸

Following the initial allocation of allowances, the sulfur dioxide trading program authorizes their purchase and sale not only among covered pollution sources, but also among anyone who chooses to participate in the market.⁸⁹ The market is national and there are no geographic restrictions on trading.⁹⁰ The required government approvals are only ministerial.⁹¹ Brokers facilitate the functioning of the market by maintaining price information and by matching buyers with sellers.⁹²

In addition to these inter-source transfers, holders of allowances may "bank" them for use in a future year.⁹³ Such banking is a form of intra-source trade. An allowance that is valid for use in a future year, however, may not be used before that year.⁹⁴

86. See 42 U.S.C. § 7651o(b), (d) (1994). For discussion of the legislative history of these auction provisions, see Karl Hausker, *The Politics and Economics of Auction Design in the Market for Sulfur Dioxide Pollution*, 11 J. POL'Y ANALYSIS & MGMT. 553 (1992).

87. See Nash, *supra* note 21, at 490; Kosobud & Zimmerman, *supra* note 25, at 57. The allowances are not sold at a single market-clearing price. Instead, the Chicago Board of Trade determines the price at which all allowances offered for sale would be sold if all the bids at or above this price are accepted. Successful bidders pay the amount of their actual bids. See 42 U.S.C. § 7651o(d)(2) (1994); 40 C.F.R. § 73.70(d)(1) (2000); ELLERMAN ET AL., *supra* note 61, at 170; Nash, *supra* note 21, at 492.

88. See 42 U.S.C. § 7651o(d)(3)(B) (1994); ELLERMAN ET AL., *supra* note 61, at 170; Joskow & Schmalensee, *supra* note 67, at 43.

89. See 42 U.S.C. § 7651b(b) (1994). Holders of allowances may also choose to sell those allowances in the EPA auction. See *id.* § 7651o(d)(4) (1994); 40 C.F.R. § 73.70(c) (2000).

90. See Dudek et al., *supra* note 20, at 162. Some earlier bills, however, included geographic restrictions on trading. See *infra* text accompanying notes 105-140

91. See 40 C.F.R. §§ 73.50, 73.52 (2000).

92. See, e.g., Oates, *supra* note 3, at 153 ("[S]ulfur allowance trading is now handled by well-established securities dealers in a highly routine way with quite small commission charges." (footnote omitted)); Kete, *supra* note 33, at 86 (noting the involvement of brokers and brokerage firms); EPA, Buying Allowances, at <http://www.epa.gov/airmarkets/trading/buying.html> (last updated April 18, 2001) (listing brokers); Environmental Division: SO₂, at <http://www.natsource.com/environmental/so2/index.html> (visited Apr. 26, 2001) (web page for Natsource, a broker for sulfur dioxide allowances). Brokers also offer derivative products and maintain a futures market. See Environmental Division: SO₂ -Types of Transactions, at <http://www.natsource.com/environmental/so2/types.html> (Apr. 26, 2001).

93. See 42 U.S.C. § 7651a(3) (1994); 40 C.F.R. § 73.36 (2000).

94. See 40 C.F.R. § 73.51 (2000).

2. Shortcomings of the Sulfur Dioxide Trading Program

The sulfur dioxide trading program is poorly suited to guard against hot spots of acid rain. Most importantly, because trading occurs in a single national market, it pays no attention to the impact of the location of the sulfur dioxide emissions on the production of acid rain.

The region that contributes most to the problem of acid rain in the United States is the Ohio River Valley.⁹⁵ Prevailing winds generally carry sulfur dioxide emissions from this region to the Northeast,⁹⁶ where acid deposition harms fragile lakes with limited buffering capacity.⁹⁷ The sulfur dioxide trading program can exacerbate this problem by permitting sales from northeastern to midwestern polluters. Indeed, sulfur dioxide emissions in the Northeast produce acid rain over the Atlantic Ocean, which has a large buffering capacity that limits the extent of the harm.⁹⁸ When northeastern emissions are sold to the Midwest, however, the acid rain falls over the Northeast, where the harm is far larger.⁹⁹

Some commentators argue that, in practice, this problem is not serious. For example, an analysis of allowance transfer data suggests that, thus far, the trading program has not resulted in the development or exacerbation of hot spots.¹⁰⁰ The reason

95. See Russell Korobkin, Note, *Sulfur Dioxide and the Constitution: Legal Doctrine and Responses to the Clean Air Act Amendments of 1990*, 13 STAN. ENVTL. L.J. 349, 362 n.68 (1994).

96. See *id.* at 362.

97. ZANNETTI, *supra* note 59, § 1.4, at 18:

These lakes, when exposed to acid precipitation pass through three stages The first stage (bicarbonate lakes) is characterized by a steady decrease in the acid-neutralizing (i.e., buffering) capacity. The second stage (transition lakes) begins when the acid-neutralizing capacity is exhausted and concentrations of sulfate and metals begin to increase. During the third and final stage (acid lakes), the pH begins to stabilize. By this stage, however, acid-sensitive species have been eliminated. Acidified lakes remain ideal for many recreational activities except fishing.

98. While lakes can suffer greatly from acid deposition because of their limited buffering capacity, oceans hold sufficient reserves of buffers to counteract the deposition of acidic molecules. See *id.*

99. See Revesz, *supra* note 41, at 2359-60; Korobkin, Note, *supra* note 95, at 362; see also WALTER A. ROSENBAUM, ENVIRONMENTAL POLITICS AND POLICY 209 (3d ed. 1995) (“[E]nvironmental groups in the Northeast have expressed a concern that midwestern utilities will purchase permits from other areas and stockpile them, thus permitting themselves to continue emissions at unacceptably high levels.”).

100. See ELLERMAN ET AL., *supra* note 61, at 130-36; Byron Swift, *Allowance Trading and SO₂ Hot Spots - Good News from the Acid Rain Program*, 31 ENV'T REP. (BNA) 954 (May 12, 2000) (arguing that the empirical evidence suggests that trading in sulfur dioxide allowances has led to lower local pollutant concentrations).

appears to be that the number of permits received by the dirty sources in the Midwest was smaller than their historic pattern of emissions.¹⁰¹ As a result, even if such sources became net purchasers of permits, their aggregate emissions would be less than they were before the implementation of the trading program. In essence, the argument of these supporters of the current trading program is that any adverse consequences of trading are dominated by the reduction in emissions produced by the grandfathering scheme.¹⁰² Another study suggests that the Northeast will not suffer net harms as a result of Phase II trading.¹⁰³ The study acknowledges that "[t]rading leads to an increase in emissions in the Midwest and a decrease in the East and Northeast." It finds, however, that as a result of the geographic shift in emissions among sources in the Midwest, there is slight decrease in acid deposition in the Northeast.¹⁰⁴

The fact remains, however, that it might be desirable to design a trading regime without the potential to produce such adverse consequences. Regardless of what the aggregate impacts of trading might be, nothing in the sulfur dioxide trading program prevents the development or exacerbation of acid rain hot spots. More generally, the program does not allocate emissions between upwind and downwind sources in a way that minimizes their adverse consequences.

3. *Efforts to Redesign the Trading Program*

Concerns about the adverse environmental consequences of having trading take place in a single national market received sustained congressional attention during the consideration of the 1990 amendments to the Clean Air Act. Moreover, almost immediately following the passage of the legislation, states and environmental groups sought to introduce constraints into the trading program as a way to prevent the development or exacerbation of hot spots.

101. See *supra* text accompanying notes 77-80

102. See ELLERMAN ET AL., *supra* note 61, at 130-36.

103. See BURTRAW & MANSUR, *supra* note 68, at 2.

104. *Id.*; see Dallas Burtraw, *Appraisal of the SO₂ Cap-and-Trade Market*, in EMISSIONS TRADING, *supra* note 20, at 133, 143-49.

a. *Pre-Enactment*

Even though the final acid rain legislation created a single national market for the trading of sulfur dioxide allowances,¹⁰⁵ Congress did consider imposing various forms of trading constraints, in part to guard against the possibility of hot spots. A public policy study sponsored by Senators Heinz and Wirth in 1988 was the genesis of the trading scheme to control acid rain.¹⁰⁶ The study, under the direction of Robert Stavins, envisioned that trading "would occur on a national or regional basis."¹⁰⁷ The report acknowledged that "[t]he source-receptor relationship must be considered, since reducing acid rain precursors in California, for example, will not reduce acid rain on the East Coast."¹⁰⁸

On June 12, 1989, President Bush announced his proposal to control acid rain by means of a market in sulfur dioxide emission allowances.¹⁰⁹ The proposal generally restricted trading during Phase I to intrastate transfers.¹¹⁰ Interstate trading was authorized only for intra-utility trades.¹¹¹ During Phase II, "full interstate trading would be allowed."¹¹²

The Administration's bill, transmitted to Congress on July 21, 1989,¹¹³ similarly authorized only intrastate or intra-utility trading during Phase I.¹¹⁴ With respect to Phase II, however, it

105. For discussion of the legislative history of the trading program, see Larry B. Parker et al., *Clean Air Act Allowance Trading*, 21 ENVTL. L. 2021, 2035-43 (1991); Loxterman, Note, *supra* note 62, at 204-11.

106. See PROJECT 88 - HARNESSING MARKET FORCES TO PROTECT OUR ENVIRONMENT: INITIATIVES FOR THE NEW PRESIDENT 32 (1988).

107. *Id.*

108. *Id.*

109. See Remarks Announcing Proposed Legislation to Amend the Clean Air Act, I PUB. PAPERS: GEORGE BUSH 706 (June 12, 1989), available at <http://bushlibrary.tamu.edu/papers/1989/89061200.html> [hereinafter Remarks]; see also White House Fact Sheet on the President's Clean Air Plan, I PUB. PAPERS: GEORGE BUSH 708 (June 12, 1989), available at <http://bushlibrary.tamu.edu/papers/1989/89061201.html> [hereinafter Fact Sheet].

110. See Fact Sheet, *supra* note 109, at 710 ("In the first phase, trading would be allowed among electric plants within a State or within a utility system.")

111. See *id.*

112. See *id.*

113. See Message to the Congress Transmitting Proposed Legislation To Amend the Clean Air Act, II PUB. PAPERS: GEORGE BUSH 999 (July 21, 1989), available at <http://bushlibrary.tamu.edu/papers/1989/89072102.html>.

114. See H.R. 3030 § 501, reprinted in SENATE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS, A LEGISLATIVE HISTORY OF THE CLEAN AIR ACT AMENDMENTS OF 1990, at 3972 (1993) [hereinafter LEGISLATIVE HISTORY]. This provision would have added a new Clean Air Act § 503(b), which would have provided in pertinent part: "In phase I, transfers of allowances shall be limited to affected sources within a single State, except that an owner or operator of two or more affected sources may transfer

modified (or perhaps clarified) the proposal announced a month earlier to provide that "allowances may be transferred among affected sources within each of the geographic regions of the country, as prescribed by regulation."¹¹⁵ The bill did not explain how EPA would define these multi-state regions within which trading would be allowed, but commentators believed that there would be two regions.¹¹⁶

Hearings before the Subcommittee on Environmental Protection of the Senate Committee on Environment and Public Works, conducted in October 1989, devoted considerable attention to the structure of the trading markets. For example, Senator Lieberman raised questions about unfettered national trading:

If we allow an open market, free market of trading of permits here, is there any danger that the sources of the acid rain that are hitting New England will acquire the permits to continue to do so? In other words, that reductions, if they're imposed on a national basis, may actually occur in plants other than the ones in the Midwest that seem to be the source of our problem?¹¹⁷

Senator Lieberman thus was concerned that midwestern sources would buy additional permits, beyond their initial allocation, and thus exacerbate the acid rain problem in the Northeast.

Senator Heinz stated in response:

I don't think so . . . for two reasons. The first is that the first wave of reductions is largely targeted to the area that I think you believe is responsible for the most acid rain in the Northeast and second, there are as I understand it, restrictions within the President's proposal that have the effect that ensuring that you don't have those kind of bicoastal trades that you might be worried about.¹¹⁸

Senator Heinz appears to have relied on the fact that the initial allocations to midwestern sources would be less than their historical emissions.¹¹⁹ His response, however, fails to address Senator Lieberman's concern over the impact of subsequent

allowances among those sources, irrespective of State boundaries." Under the President's proposed legislation, Phase I would have begun after December 31, 1995. See H.R. 3030, § 501 (which would have added a new Clean Air Act § 504(a)).

115. *Id.*, reprinted in LEGISLATIVE HISTORY, *supra* note 114, at 3972-73.

116. See Hausker, *supra* note 86, at 555 n.4 ("The original administration proposal would have allowed transfers within two broad regions.")

117. S. Hrg. No. 101-331, pt. 5, at 13 (Oct. 3, 1989).

118. *Id.*

119. See *supra* text accompanying notes 77-80.

trades on the distribution of emissions.¹²⁰ Moreover, while the division of the country into two trading zones would indeed have prohibited bicoastal trades as indicated by Senator Heinz, it would probably have authorized the Midwest/Northeast trades that worried Senator Lieberman.¹²¹

At the same hearing, David Hawkins of the Natural Resources Defense Council, testifying on behalf of the National Clean Air Coalition, expressed concern about the effects of the trading program on the West: "We think new sources of pollution in the western United States might be tempted if they were permitted to do so to purchase allowances from the eastern United States and build dirtier plants in the West."¹²² He added: "[T]he pristine air quality in the West is a global treasure. You cannot compensate for the damage to that air quality that would be caused by building a dirty plant in the West simply by getting emission reductions hundreds of miles away in another region of the country."¹²³ Hawkins' statement reflects strong concern, consistent with a concave damage function,¹²⁴ that one unit of sulfur dioxide emissions produces greater harm in pristine western areas, which include many important national parks, than in industrialized areas, which already have high levels of such emissions.

The bill reported out of the Senate Committee on Environment and Public Works on November 16, 1989, directed that EPA regulations "shall permit transfers only within each of the two major geographic regions of the country as defined by such regulations."¹²⁵ The Report accompanying the bill explains: "Allowances transferred between the owners and operators of units that receive allowances or others who lawfully hold allowances under this title may only be transferred to units within the region in which the unit for which the allowances were originally issued is located."¹²⁶ It adds that "[t]he Administrator should give exclusive consideration to the

120. See *supra* text accompanying notes 95-99.

121. See S. Hrg. 101-331, *supra* note 117, pt. 5, at 23 (testimony of Daniel Dudek, Environmental Defense Fund) (referring to 31-state eastern trading region and 17-state western trading region).

122. *Id.* at 38.

123. *Id.*

124. See *supra* text accompanying notes 43-44 and Graph 1: Convex Damage Function.

125. S. 1630, 101st Cong., § 401 (1989), reprinted in LEGISLATIVE HISTORY, *supra* note 114, at 8205.

126. S. REP. NO. 101-228 (1989), reprinted in LEGISLATIVE HISTORY, *supra* note 114, at 8645.

environmental protection objectives of this title in defining such regions."¹²⁷ A plausible goal for EPA would therefore have been to define the regions in the manner least likely to lead to the violation of the NAAQS for sulfur oxides or to the formation of acid rain hot spots.

The bill passed by the Senate on April 3, 1990, provided for a single national market, with no geographic restrictions on trading.¹²⁸ The debate on the Senate floor does not explain why the two-region restriction on trading was dropped.

On the House side, the bill reported out of the House Committee on Energy and Commerce on May 17, 1990, provided for two trading regions.¹²⁹ It delegated to EPA the definition of "the 2 major geographic regions of the country." Trading across regions was prohibited, with two exceptions.¹³⁰ First, new sources could buy allowances without geographic restriction.¹³¹ Second, the bill permitted intra-firm trades among units in operation on the date of the enactment of the legislation.¹³² The restrictions on interregional trading, applicable during both Phase I and Phase II,¹³³ were retained in the bill passed by the House on May 23, 1990, following only limited floor debate.¹³⁴

The conference bill followed the Senate model of interstate trading in a single national market with no geographic restrictions.¹³⁵ The bill was passed by the House on October 26, 1990,¹³⁶ by the Senate on the following day,¹³⁷ and was signed by President Bush on November 15, 1990.¹³⁸

The decision to adopt a trading program with no geographic restrictions appears to be largely attributable to the fact that the

127. *Id.*, reprinted in LEGISLATIVE HISTORY, *supra* note 114, at 8661.

128. See S. 1630, *supra* note 125, § 401, reprinted in LEGISLATIVE HISTORY, *supra* note 114, at 4584-99.

129. H.R. 3030 was also referred briefly to the House Ways and Means Committee and the Public Works Committee. Neither of these committees addressed the bill's allowance trading regime in their deliberations, however. See Parker et al., *supra* note 105, at 2041 & n.90.

130. See H.R. 3030, 101st Cong. §§ 501, 503(b)(1)(E) (1990), reprinted in LEGISLATIVE HISTORY, *supra* note 114, at 3124, 3126; see also H.R. REP. NO. 101-490, at 369 (1990), reprinted in LEGISLATIVE HISTORY, *supra* note 114, at 3393 (committee report's explanation of trading restrictions).

131. See sources cited *supra* note 130.

132. See sources cited *supra* note 130.

133. See sources cited *supra* note 130.

134. See LEGISLATIVE HISTORY, *supra* note 114, at 1809; *Clean Air Act Rewritten, Tightened*, 46 CONG. Q. ALMANAC 229, 242 (1990).

135. See Loxterman, Note, *supra* note 62, at 210.

136. See *Clean Air Act Rewritten, Tightened*, *supra* note 134, at 229.

137. See *id.*

138. See *id.*; Loxterman, Note, *supra* note 62, at 211.

emphasis throughout the debate was on the large decrease in aggregate sulfur dioxide emissions.¹³⁹ Ultimately, Congress believed that for a sufficiently large reduction, the acid rain problem would have to be ameliorated across the board even if the emissions were not allocated between upwind and downwind sources in an optimal manner. As one commentator explained, "it was understood that the greater the overall size of the reduction [in overall emissions], the more indifferent society could be to the spatial impacts of trades"¹⁴⁰

b. Post-Enactment

The concern over geographically unrestricted trading was not laid to rest with the passage of the legislation. Commenting on EPA's proposed regulations setting forth the details of the sulfur dioxide markets, several northeastern states criticized EPA for crafting a program that focused on the total sulfur dioxide emissions rather than on the existence of acid rain hot spots.¹⁴¹ They urged EPA to consider the effects of the structure of the trading program on the formation of acid rain.¹⁴² In addition, New York filed separate comments urging EPA to preclude emission permit trading between sources in different regions of the country until EPA could develop appropriate trading ratios.¹⁴³ For example, if one ton of sulfur dioxide had a greater impact on acid rain if emitted by the purchaser rather than the seller, the purchaser would have to buy more than one ton in permits in order to emit an additional ton, with the ratio being determined by the relative contributions of the two sources to the acid rain problem.¹⁴⁴

In adopting its final regulations, EPA rejected these criticisms and established a single national market in which allowances for sulfur dioxide emissions traded on a one-to-one

139. Karl Hausker, the Chief Economist for the Senate Committee on Energy and Natural Resources at the time of the passage of the 1990 amendments to the Clean Air Act, asserted that "a reduction in aggregate emissions was the most important goal of the legislation." Hausker, *supra* note 86, at 555 n.4.

140. Kete, *supra* note 33, at 83.

141. See Susan Millington Campbell & Andrew S. Holmes, *Going Once, Going Twice, Sold! EPA Auctions Pollution Rights; Market-Based System Permits Sale of Allowances to Emit Sulfur Dioxide*, N.Y.L.J., June 7, 1993, at S10. The attorneys general of Connecticut, New Hampshire, New York, and Rhode Island submitted joint comments on the proposed regulations. See *id.*

142. See *id.*

143. See *id.*

144. For discussion of trading schemes with unequal trading ratios, see *infra* Section III.C.

ratio, with no geographic constraints.¹⁴⁵ The agency indicated that Congress had already made the policy choice on this matter: "Geographical limitations on allowance transfers were included in early Senate and House versions of the bill, but later rejected in favor of national transfers."¹⁴⁶ The regulations, moreover, bar the states from prohibiting or otherwise restricting the ability of sources within their jurisdiction from purchasing or selling permits.¹⁴⁷

The concerns voiced by some states about the sale of in-state allowances to out-of-state sources soon became a reality. In 1992, the Wisconsin Power and Light Company sold 35,000 allowances to the Tennessee Valley Authority¹⁴⁸ and sought to keep the transaction secret.¹⁴⁹ Similarly, in 1993, a New York utility – the Long Island Lighting Company (LILCO) – sold allowances to AMAX, a non-utility supplier of energy, that in turn intended to resell the allowances to midwestern utilities.¹⁵⁰ LILCO also tried to keep the identity of the purchaser a secret, but New York's public service commission denied its request.¹⁵¹

In March 1993, New York State and an environmental group, the Adirondack Council, filed an action in the D.C. Circuit complaining that the sulfur dioxide trading program improperly permitted such trades.¹⁵² The action sought to compel EPA to

145. See Acid Rain Program: General Provisions and Permits, Allowance System, Continuous Emissions Monitoring, Excess Emissions and Administrative Appeals, 58 Fed. Reg. 3590, 3614-15 (1993) [hereinafter Acid Rain Program: General Provisions].

146. See *id.*

147. See 40 C.F.R. § 72.72(a)(1), (2), (7) (2000).

148. Deborah M. Mostaghel, *State Reactions to the Trading of Emissions Allowances Under Title IV of the Clean Air Act Amendments of 1990*, 22 B.C. ENVTL. AFF. L. REV. 201, 210 (1995).

149. Rosenberg, *supra* note 73, at 100.

150. See Jeffrey Taylor & Dave Kansas, *Environmentalists Vie for Right to Pollute*, WALL ST. J., Mar. 26, 1993, at C1; Nicole Fradette et al., *New Strategies for a New Market: The Electric Industry's Response to the Environmental Protection Agency's Sulfur Dioxide Emission Allowance Trading Program*, in *Project: Regulatory Reform: A Survey of the Impact of Reregulation and Deregulation on Selected Industries and Sectors*, 47 ADMIN. L. REV. 469, 485 (1995); Mostaghel, *supra* note 148, at 208; Korobkin, Note, *supra* note 95, at 361-62. LILCO tried to sell "some portion of the 40,000 to 50,000 excess allowances it expect[ed] to be awarded each year between 1995 and 2000 under phase I of the acid rain program," Korobkin, Note, *supra* note 95, at 361, by virtue of pollution control measures it had instituted in the 1980s, Mostaghel, *supra* note 148, at 208. "According to LILCO, it agreed to sell an option to purchase the credits, not the credits themselves." Korobkin, Note, *supra* note 95, at 361 n.63.

151. See Fradette et al., *supra* note 150, at 485.

152. See Campbell & Holmes, *supra* note 141 (citing *New York v. Browner*, No. 93-1214 (D.C. Cir. filed Mar. 11, 1993); *Air Pollution: New York Sues to Limit Acid Rain Trading; EDF Suit Seeks to Close Credit "Loophole"*, 23 ENV'T REP. (BNA) 3024 (Mar. 19, 1993) (citing *New York v. EPA*, No. 93-1214 (D.C. Cir. filed Mar. 12, 1993)); Taylor

restrict trades that would lead to heightened acid deposition damage in environmentally sensitive areas of New York.¹⁵³

Moreover, bills introduced in the New York and Wisconsin legislatures sought to constrain or discourage the sale of in-state allowances to out-of-state sources. Wisconsin's bill, which was never enacted, would have required public disclosure of, and the approval of the state Public Service Commission for, any transaction of allowances by a Wisconsin utility.¹⁵⁴ In New York, similar bills introduced first in 1993¹⁵⁵ and again in subsequent years also failed to be enacted.¹⁵⁶

In 1998, LILCO entered into a memorandum of understanding with New York State not to sell allowances to sources in upwind states, in certain nearby states, or in New York.¹⁵⁷ The agreement also contained a provision purporting to prohibit any purchaser of LILCO allowances from selling those allowances to polluters in states with which LILCO was not permitted to trade.¹⁵⁸ Between 1994 and the date of this agreement, however, LILCO had sold 260,000 allowances, "the vast majority of them going to polluters in the upwind states."¹⁵⁹

In 2000, New York enacted a law designed to remove the incentive for sales of sulfur dioxide allowances to utilities located in upwind states.¹⁶⁰ The law applies to sales of so-called "select

& Kansas, *supra* note 150; *Environment: New York State and Utilities File Suit Against EPA to Alter Clean Air Rules*, ELEC. UTIL. WK., Mar. 22, 1993, at 12.

153. See Mostaghel, *supra* note 148, at 208

154. See *id.* at 210; *Wisconsin Utilities Oppose Disclosure Proposal*, 24 ENV'T REP. (BNA) 336 (June 18, 1993).

155. See Campbell & Holmes, *supra* note 141; Fradette et al., *supra* note 150, at 486; Mostaghel, *supra* note 148, at 209-10; Korobkin, *supra* note 95, at 361-62.

156. See Russell Korobkin, *The Local Politics of Acid Rain: Public versus Private Decisionmaking and the Dormant Commerce Clause in a New Era of Environmental Law*, 75 B.U. L. REV. 689, 704 n.87 (1995); *New York: Governor Proposes Bill to Limit Sales of Sulfur Dioxide Emission Allowances*, 28 ENV'T REP. (BNA) 605 (July 25, 1997).

157. Raymond Hernandez, *LILCO Is to Stop Selling Credits to Upwind Polluters*, N.Y. TIMES, Apr. 30, 1998, at B2 (restrictions applied to sales to sources in Virginia, North Carolina, Tennessee, West Virginia, Ohio, Michigan, Illinois, Kentucky, Indiana, Wisconsin, New Jersey, Pennsylvania, and New York); see Paul Zielbauer, *State, Utility Sign Pollution-Credit Pact*, ALBANY TIMES UNION, Apr. 30, 1998, at B2; *Lilco to Halt Sale of Pollution Credits to Ten Southern, Midwestern States*, UTIL. ENV'T REP., May 8, 1998, at 3.

158. See Hernandez, *supra* note 157.

159. *Id.*

160. N.Y. PUB. SERV. LAW § 66-k (2000); N.Y. ENVTL. CONSERV. LAW. § 19-0921(3) (2000); N.Y. STATE FIN. LAW § 99-G (2000); N.Y. PUB. AUTH. LAW § 1854(10-a) (2000);. See Raymond Hernandez, *Pataki Signs Two Measures Aimed at Cutting Back Pollution*, N.Y. TIMES, May 25, 2000, at B1; Raymond Hernandez, *Albany Battles Acid Rain Fed By Other States*, N.Y. TIMES, May 2, 2000, at B1 (describing passage of bill by the legislature).

SO₂ allowance credits," which are defined as sulfur dioxide permits under the national sulfur dioxide program "issued to generating sources located within the boundaries of the state of New York."¹⁶¹ The law effectively allows the State Public Service Commission to deprive a New York seller of proceeds from the sale of such credits to a polluter located in an "acid precipitation source state"¹⁶² – generally states located upwind from New York.¹⁶³

The statute provides that "[n]othing in this section shall discourage or prohibit allowance trades (such as for retirement purposes) that will have a beneficial impact on sensitive receptor areas in the state of New York."¹⁶⁴ Under this provision, however, it is unclear whether a sale to a source in an "acid precipitation source state" might be exempted if the trade nonetheless would have a beneficial impact on acid deposition in environmentally sensitive areas of New York – perhaps by reducing in-state emissions causing worse harm.

The statute also contains a safe harbor to sellers of allowances that include a restrictive covenant in the sale documents. To be effective, the covenant must restrict the use of the transferred allowances in an acid precipitation source

161. N.Y. PUB. SERV. LAW § 66-k(1)(c) (2000). Insofar as the statute, by its literal terms, applies only to allowances "issued to generating sources located within the boundaries of the state of New York," it is unclear whether the law applies to the sale of allowances (i) that holders acquired through auction or (ii) that were issued originally to a source outside New York that a generating source in New York subsequently acquired.

162. The law defines "acid precipitation source states" as "New Jersey, Pennsylvania, Maryland, Delaware, Virginia, North Carolina, Tennessee, West Virginia, Ohio, Michigan, Illinois, Kentucky, Indiana and Wisconsin." N.Y. PUB. SERV. LAW § 66-k(1)(d) (2000).

163. See *supra* note 162. The statute states:

The [Public Service] Commission shall assess an air pollution mitigation offset equal to any sum received by any utility corporation, person or entity entering into contracts or engaging in the sale or trade of select SO₂ allowance credits for use in operations, permits or for maintaining compliance with SO₂ emission requirements in acid precipitation source states, where such select SO₂ allowance credits are found to have been transferred to the allowance deductions reserve account by a generating source located in an acid rain [sic] source state.

N.Y. PUB. SERV. LAW § 66-k(2)(a) (2000). (The reference in the last portion of the provision contains an apparent typographical error, where the reference probably should be to an "acid precipitation source state," and not an "acid rain source state.")

The statute empowers the Public Service Commission to determine whether the sale of allowances falls within the scope of this provision and requires anybody who contracts to sell or in fact sells a select SO₂ allowance credit to give notice of the transaction with five days thereof to the Commission. N.Y. PUB. SERV. LAW § 66-k(2)(b) (2000).

164. N.Y. Pub. Serv. Law § 66-k(5) (2000).

state.¹⁶⁵ This safe harbor suggests that the law's scope may extend to sales of an allowance originally issued to New York sources, even where the original New York holder sold the allowance to an out-of-state entity not located in an acid precipitation state, where this latter entity subsequently transfers the allowance to a source in a covered state. Absent the safe harbor, at the time of the second sale the New York seller would apparently become liable for the proceeds of the first sale.

4. *Assessing the State Efforts to Constrain the Trading Market*

Piecemeal efforts undertaken by the states are unlikely to be a desirable solution to the acid rain problem. Laws such as New York's may encourage a state-by-state patchwork approach to ameliorating the poor design of the national sulfur dioxide trading program. Such a piecemeal approach would undermine the market for sulfur dioxide allowances and potentially render the national program ineffective by subjecting it to multiple, and possibly inconsistent, state regulations. A national market subject to multiple limitations on trading may well not survive.¹⁶⁶ Such approaches would also discourage sales that produce adverse effects in the state in which the seller is located even if there are greater beneficial effects elsewhere.

Moreover, the New York law does not necessarily promote even the state's own interest. Presumably not every sale of an allowance by a New York holder to a source in an "acid precipitation source state" would result in an increased acid rain problem in New York. Merely because some portion of a state is upwind from New York does not mean that emissions from every

165. N.Y. Pub. Serv. Law § 66-k(3) (2000). The restrictive covenant should follow the form of a model restrictive covenant – to be developed by the Public Service Commission with the help of the State Department of Environmental Conservation – and must

include at a minimum, the requirement to give notice to the Commission of any SO₂ allowance transaction covered by the restrictive covenant; the requirement that any subsequent holders of the SO₂ allowance covered by the restrictive covenant include an identical restrictive covenant in any document relating to the sale or purchase of the covered SO₂ allowances; provisions restricting usage in acid precipitation source states; and provisions for the enforcement of the terms of the restrictive covenant by the state of New York.

N.Y. Pub. Serv. Law § 66-k(3)(a) (2000). A seller who faithfully adheres to the safe harbor rules will be "exempt from the assessment of an air pollution mitigation offset." *Id.* § 66-k(3)(c).

166. See Acid Rain: General Provisions, *supra* note 145, 58 Fed. Reg. at 3615 ("The allowance market would likely fail if State or local permitting authorities had the ability to restrict the transfer of allowances.").

location in that state adversely affect New York. Thus, the law would constrain sales that, on balance, might be good for New York by reducing local pollution.¹⁶⁷

In addition to these policy flaws, the constitutionality of laws such as New York's is at best uncertain.¹⁶⁸ The New York law may run afoul of the dormant Commerce Clause by unduly burdening the interstate market in sulfur dioxide allowances.¹⁶⁹ Although New York might argue that its statute is necessary to protect in-state health and welfare,¹⁷⁰ this argument is somewhat compromised because the law overbroadly reaches transactions that might not produce adverse effects on New York. Moreover, the New York law may be preempted by the provisions of the Clean Air Act establishing the market in sulfur dioxide emissions.¹⁷¹ New York's constraints on the market for transfer of allowances arguably undermine Congress' goal of achieving the most cost-effective pollution reduction on a nationwide scale, imposing impermissible constraints on the ability of sources outside New York to purchase allowances.¹⁷²

167. Some sales of this type, however, might be exempted from the law's confiscation provisions by the safe harbor. See *supra* text accompanying notes 164-165.

168. In November 2000, an alliance of electricity-generating companies, pollution credit brokers, mining firms, and trade associations filed suit challenging the New York law as violative of the federal Constitution's Supremacy and Commerce Clauses. See John Caher, *State Pollution Credits Law Faces Challenge; Supremacy, Commerce Clause Violations Alleged*, N.Y.L.J., Nov. 16, 2000, at 1 (citing *Clean Air Markets Group v. Pataki*, No. 00-CV-1738 (N.D.N.Y. filed Nov. 15, 2000)).

169. See *City of Philadelphia v. New Jersey*, 437 U.S. 617 (1978) (holding dormant Commerce Clause applicable to state statutes regulating interstate transport of and trading in goods that have environmental impacts). For applications of the dormant commerce clause to state statutes adopted in response to the 1990 amendments to the Clean Air Act, see *Alliance for Clean Coal v. Miller*, 44 F.3d 591 (7th Cir. 1995) (holding unconstitutional Illinois law that afforded utilities more flexibility in achieving environmental reduction and thus gave them the option to import lower cost (and lower sulfur-content) coal from out of state); *Alliance for Clean Coal v. Bayh*, 72 F.3d 556 (7th Cir. 1995) (holding unconstitutional similar Indiana law). For criticisms of the Court's treatment of waste products under the dormant Commerce Clause, see Richard A. Epstein, *Waste & the Dormant Commerce Clause*, 3 GREEN BAG 2d 29, 33-41 (1999); Lisa Heinzerling, *The Commercial Constitution*, 1995 SUP. CT. REV. 217 (1996); Robert R.M. Verchick, *The Commerce Clause, Environmental Justice, and the Interstate Garbage Wars*, 70 S. CAL. L. REV. 1239 (1997).

170. See *Maine v. Taylor*, 477 U.S. 131 (1986).

171. See *Silkwood v. Kerr-McGee*, 464 U.S. 238, 248 (1984); Paul S. Weiland, Comment, *Federal and State Preemption of Environmental Law: A Critical Analysis*, 24 HARV. ENVTL. L. REV. 237 (2000).

172. See Korobkin, Note, *supra* note 95, at 372-75.

B. Regional NO_x Trading Programs and the Control of Tropospheric Ozone

1. Processes of Ozone Formation

Nitrogen oxides (NO_x) are the primary precursors of tropospheric, or ground-level, ozone.¹⁷³ Ozone, in turn, is the primary ingredient in smog,¹⁷⁴ which causes numerous human health risks, adversely affects plants and ecosystems, and contributes to acid deposition.¹⁷⁵

Tropospheric ozone is formed by the photolysis¹⁷⁶ of nitrogen dioxide (NO₂).¹⁷⁷ Other compounds, however, affect the rate at which ozone is produced. In particular, through a series of complex chemical reactions, certain volatile (highly reactive) organic compounds (VOCs) help to convert nitrogen monoxide (NO) into nitrogen dioxide, thereby increasing the production of ozone.¹⁷⁸

173. See ERBES, *supra* note 58, at 42; Jamie Larmann, Note, *Comparing Apples to Oranges? EPA Faces Difficulties in Bringing to Fruition an Emissions Trading Program for NO_x*, 6 ENVTL. LAW. 603, 604 (2000). Nitrogen oxides consist of nitrogen oxide (NO) and nitrogen dioxide (NO₂). MILLER & MILLER, *supra* note 42, at 12.

174. See Paul D. Brown, Comment, *Lofty Goals, Questioned Motives, and Proffered Justifications: Regional Transport of Ground-Level Ozone and the EPA's NO_x SIP Call*, 60 U. PITT. L. REV. 923, 928 (1999); Larmann, Note, *supra* note 173, at 603. In contrast, ozone in the upper atmosphere (i.e., the stratosphere) provides a beneficial shield against dangerous radiation from the Sun. See ZANNETTI, *supra* note 59, § 1.4, at 19; Brown, Comment, *supra*, at 928; Larmann, Note, *supra* note 173, at 603.

175. See Brown, Comment, *supra* note 174, at 929; Sarah A. Fox, *Towards Ozone Attainment? A Critique of the NO_x Budget Trading Program*, at 5 (April 6, 2000) (manuscript on file with authors); Larmann, Note, *supra* note 173, at 606; EPA, Fact Sheet: Final Rule for Reducing Regional Transport of Ground-Level Ozone (Smog) and Two Related Proposals 4-5, available at http://www.epa.gov/ttn/oarpg/t1/fact_sheets/noxsipf.pdf (Sept. 24, 1998).

176. "Photolysis is the process by which reactant gases are broken down by sunlight to form products." MARK Z. JACOBSON, FUNDAMENTALS OF ATMOSPHERIC MODELING § 1.3, at 3 (1999) (emphasis in original).

177. *Id.* § 2.1.2.4, at 10; NATIONAL RESEARCH COUNCIL, RETHINKING THE OZONE PROBLEM IN URBAN AND REGIONAL AIR POLLUTION 116 (1991). By contrast, stratospheric ozone is the result of photolysis of molecular oxygen (O₂). JACOBSON, *supra* note 176, § 2.1.2.4, at 10. "Photolysis of molecular oxygen does not occur near the ground, since the wavelengths of radiation required to break apart oxygen are absorbed by molecular oxygen and ozone higher in the atmosphere." *Id.*

178. See NATIONAL RESEARCH COUNCIL, *supra* note 177, at 116 ("[T]he presence of [VOCs] causes enhanced NO-to-NO₂ conversion and hence the production of concentrations of ozone that exceed those encountered in the clean background troposphere . . ." (citation omitted)). For discussion of the specific chemical reactions, see BRASSEUR ET AL., *supra* note 58, § 13.3.1, at 472 (1999); NATIONAL RESEARCH COUNCIL, *supra* note 177, at 166-67.

The production of ozone, however, does not vary proportionately with the concentrations of NO_x and VOCs in the atmosphere. As a result, decreasing NO_x and/or VOC concentrations does not necessarily result in a proportionate decrease in ozone production. Indeed, for certain ratios of VOC to NO_x concentrations, a *decrease* in the concentration of NO_x actually will lead to an *increase* in ozone production. The reason for this facially counterintuitive result is the role of the hydroxyl radical (OH) in the atmospheric photochemistry that leads to the formation of ozone. Its presence is a prerequisite for the series of reactions that allows VOCs to accelerate the conversion of nitrogen monoxide into nitrogen dioxide.¹⁷⁹ The hydroxyl radical, however, also reacts with nitrogen dioxide.¹⁸⁰ Thus, at comparatively low VOC to NO_x concentration ratios (i.e., where NO_x is relatively abundant), the nitrogen dioxide "effectively competes with the VOCs for the [hydroxyl] radical."¹⁸¹ This reaction decreases the ability of VOCs to convert nitrogen monoxide into nitrogen dioxide, and thus reduces the rate of production of ozone.¹⁸² As a result, if NO_x concentrations are lowered relative to VOC concentrations, "more of the [hydroxyl] radical pool is available to react with the VOCs, leading to greater formation of ozone."¹⁸³

A consequence of these complex interactions is that the best strategy for reducing ozone production depends on the local ratio of VOC to NO_x concentrations.¹⁸⁴ At relatively low VOC to NO_x concentration ratios (of around 10 or less), reductions in NO_x concentrations may have little impact on, or even increase, ozone concentrations; the preferable strategy is to decrease VOC

179. See NATIONAL RESEARCH COUNCIL, *supra* note 177, at 167-68.

180. See *id.* at 167.

181. *Id.* at 167-68.

182. *Id.* at 167 ("In this region of low VOC/ NO_x ratio, the radicals that propagate VOC oxidation and the NO-to- NO_2 conversion are scavenged . . . by the relatively high concentrations of NO_x "). Another commentator noted:

The inverse impacts of NO_x reductions on ozone levels have long been recognized. The effect of NO_x on ozone, known as "scavenging," is a result of the unstable nature of the ozone molecule and the ratio of NO_x to VOC emissions in the atmosphere. In urban areas, where the percentage of NO_x in the emissions inventory is relatively high, NO_x acts as a natural damper on ozone formation. Reducing NO_x emissions, in effect, removes the damper, allowing additional ozone to form.

Stephen L. Gerritson, *The Lake Michigan Ozone Study: Findings and Implications for Emissions Trading*, in MARKET-BASED APPROACHES, *supra* note 6, at 140, 145-46.

183. NATIONAL RESEARCH COUNCIL, *supra* note 177, at 168.

184. See generally *id.* at 351-77.

concentrations.¹⁸⁵ At larger ratios (in excess of 20), reductions in NO_x will be far more effective than VOC reductions.¹⁸⁶ For moderate ratios (between 10 and 20), there is no global "best strategy" – the control of NO_x emissions, VOCs emissions, or both, might work best, depending upon the particular circumstances.¹⁸⁷

NO_x emissions affect not only the local concentrations of ozone,¹⁸⁸ but also pose a regional pollution problem.¹⁸⁹ Winds that carry chemicals great distances and mix atmospheric components can significantly augment the rate of ozone production.¹⁹⁰ In the United States, interstate pollution transport is generally a greater problem in the eastern portion of the country, as a result of a combination of prevailing weather patterns, topography, and a sizeable concentration of pollution sources east of the Continental Divide.¹⁹¹ In the case of NO_x and ozone, regional disputes have erupted between the South and Midwest – where many NO_x and ozone emissions originate – and the Northeast – where the impact of these emissions is often felt.¹⁹²

To date, the Clean Air Act's attempts to address the problem of long-distance ozone transport have been unsuccessful.¹⁹³ The NAAQS for nitrogen dioxide and ozone are poorly suited to control interstate spillovers.¹⁹⁴ They simply establish the minimum permissible levels of environmental quality at a location. They do not constrain the amount of the pollution at that location that can come from upwind sources. In fact, "a

185. See *id.* at 353.

186. See *id.*

187. See *id.*

188. See, e.g., Larmann, Note, *supra* note 173, at 627 ("The closer a community is to a NO_x source, the more that source contributes to air pollution problems in that community's air.")

189. See EPA, Fact Sheet: Final Rule for Reducing Regional Transport of Ground-Level Ozone (Smog) and Two Related Proposals, *supra* note 175, at 3:

Ground-level ozone tends to be a problem over broad regional areas, particularly in the eastern United States, where it is transported by the wind. When emitted, NO_x reacts in the atmosphere to form compounds that contribute to the formation of ozone. These compounds, as well as ozone itself, can travel hundreds of miles across State boundaries to affect public health in areas far from the source of the pollution.

190. See Larmann, Note, *supra* note 173, at 605-06.

191. See *id.* at 609.

192. See *id.*

193. See *id.* at 607-08.

194. For the levels of these NAAQS, see 40 C.F.R. § 50.9 to 50.11 (2000).

state might meet its ambient standards precisely *because* it exports a great deal of its pollution."¹⁹⁵

In the 1990 amendments to the Clean Air Act, Congress tried to address the problem of regional NO_x transport by imposing emissions limitations on certain sources.¹⁹⁶ Unlike the case of sulfur dioxide, however, Congress did not create the possibility of trading. The resulting high costs imposed on polluting facilities by this command-and-control regime make it politically unpalatable for EPA to regulate at a level that would make a significant dent on the regional ozone problem.

As a result, there has been increasing momentum for a NO_x allowance trading regime in the eastern United States, even though Congress has not specifically authorized such an approach. In the last few years, three independent regimes have been designed: the Ozone Transport Commission's program, EPA's optional state model program, and EPA's mandatory federal program. All three are modeled generally on the EPA's sulfur dioxide trading program.¹⁹⁷ In particular, they create a single market with no restrictions on trading.¹⁹⁸

The preceding discussion of the chemistry of ozone production suggests problems with a single regional trading market. First, while NO_x emissions have a regional impact on ozone levels, they also have a substantial local impact. As a result, trades in nitrogen oxides emissions may lead to local ozone hot spots. For example, because of the higher concentration of VOCs in urban areas, trades that increase urban NO_x concentrations may lead to a net increase in the production of ozone.¹⁹⁹ Second, because the best strategy for reducing ozone levels turns heavily on the ratio of VOCs to NO_x concentrations, trades between regions with different ratios can have negative effects at both the buyer's and seller's locations. For example, in rural areas reductions in NO_x lead to reductions in ozone formation, but in many urban areas such reductions lead to increased ozone concentrations.²⁰⁰ Thus, a sale of a

195. Revesz, *supra* note 41, at 2350 (emphasis in original).

196. See 42 U.S.C. § 7651f (1994); ERBES, *supra* note 58, at 194.

197. See Larman, Note, *supra* note 173, at 611.

198. See *infra* text accompanying notes 218-219, 238-240, 252-254.

199. JACOBSON, *supra* note 176, § 2.1.2.4, at 10-11.

200. NATIONAL RESEARCH COUNCIL, *supra* note 177, at 363, 371; see Roger A. Kanerva & Richard F. Kosobud, *Development of an Emissions Reduction Market System for Northeastern Illinois*, in MARKET-BASED APPROACHES, *supra* note 6, at 61, 64-65 ("Ozone formation presents challenges . . . to the design of a workable market. . . . Can the market adjust to policy changes as they reflect the latest scientific findings of the ways in which NO_x and [volatile organic materials] combine

permit from such an urban area to a rural area would have adverse effects at both locations.

2. *The Ozone Transport Commission's Trading Program*

To address the problem of regional ozone transport, the 1990 amendments to the Clean Air Act established the Ozone Transport Commission (OTC), which is composed of twelve Northeastern and mid-Atlantic states and the District of Columbia.²⁰¹ In September 1994, the members of OTC – with the exception of Virginia – signed a memorandum of understanding to reduce regional NO_x emissions in two stages – from a baseline of 490,000 tons in 1990 to 219,000 tons by 1999 and then to 143,000 tons in 2003.²⁰² The memorandum divided the OTC region into three zones defined by reference to geography and the degree by which ambient air quality levels exceeded the NAAQS.²⁰³ It established different emission reduction requirements in each zone on the basis of the relative impact of emissions from different zones on regional air quality.²⁰⁴

with hot weather to form ozone?"). *But see* Dudek et al., *supra* note 20, at 175 (suggesting that policymakers begin to address the ozone pollution problem by taking a total loading approach and instituting cap-and-trade programs). For a proposal of a NO_x market in units of environmental degradation, see Fox, *supra* note 175.

201. See 42 U.S.C. §§ 7506a, 7511c (1994).

202. See Acid Rain Program – Ozone Transport Commission NO_x Budget Program: An Overview, at <http://www.epa.gov/airmarkets/arp/overview.html> (last updated Dec. 11, 2000) [hereinafter OTC NO_x Budget Program Overview]; Jason S. Grumet, *Old West Justice: Federalism and Clean Air Regulation 1970-1998*, 11 TUL. ENVTL. L.J. 375, 406 n.108 (1998); Karl James Simon, *The Application and Adequacy of the Clean Air Act in Addressing Interstate Ozone Transport*, 5 ENVTL. LAW. 129, 166 n.513 (1998).

203. One commentator explained:

The three zones are defined as Northern, Inner, and Outer. The Northern Zone encompasses the areas in Maine, New Hampshire, and Vermont with designated attainment and areas of nonattainment below "moderate" classification, and the attainment counties in northeastern New York. The contiguous moderate and above non-attainment areas in Connecticut, Delaware, the District of Columbia, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island and Virginia comprise the inner zone. The outer zone is the non-contiguous areas designated nonattainment for ozone and classified serious, severe, or moderate, as well as nonattainment areas classified as marginal, and attainment areas within the boundaries of the [ozone transport region] in Delaware, Maryland, Pennsylvania, New York, and Virginia as in effect on September 27, 1994.

LAUREL J. CARLSON, NESCAUM/MARAMA NO_x BUDGET MODEL RULE § 5.0, at 17 (1996), available at <http://envinfo.com/caain/mact/n158df.html>.

204. See *id.*; *id.* § 3.0, at 6.

In 1996, OTC, in conjunction with EPA, developed a model rule that envisioned the implementation of a regional cap-and-trade NO_x emission allowance regime designed to achieve OTC's regional reduction goals.²⁰⁵ The model rule departed from the three-zone approach of OTC's memorandum of understanding by designing a unified regional market.²⁰⁶ It did not, however, formally adopt such a system, instead leaving this decision to the OTC members.²⁰⁷

OTC's NO_x trading program is based upon tradable emission allowances, each of which authorizes the holder to emit one ton of NO_x.²⁰⁸ Each state annually receives a quota of emission allowances; the quota is set by reference to a 1990 baseline that is reduced proportionately to reflect the emission reduction goals.²⁰⁹ The states can choose how to distribute their allocations to their various sources.²¹⁰ No source may emit more NO_x than authorized by its allowance holdings during the months of May through September²¹¹ – the period when ozone concentrations are most problematic.²¹²

Moreover, in an application of "regulatory tiering,"²¹³ a holder of an allowance may not use the allowance if to do so would result in a violation of some other federal or state limit on emissions.²¹⁴ Participants are generally free to bank allowances

205. See CARLSON, *supra* note 203, § 5.0, at 3. "NESCAUM" stands for the Northeast States for Coordinated Air Use Management; "MARAMA" stands for the Mid-Atlantic Regional Air Management Association. *Id.* at 1. These two agencies were responsible for organizing the OTC task force that developed the model rule. See *id.*

206. See *id.*

207. See OTC NO_x Budget Program Overview, *supra* note 202. Some jurisdictions have already done so. See EPA, Acid Rain Program – Ozone Transport Commission NO_x Budget Program: State Rules available at <http://www.epa.gov/airmarkets/otc/staterules/index.html> (last updated Dec. 11, 2000).

208. See OTC NO_x Budget Program Overview, *supra* note 202.

209. See *id.*

210. Notably, the model rule does not address the question of allocation of allowances, leaving that instead for the individual jurisdictions to decide. See CARLSON, *supra* note 203, § 4.0, at 8. Pursuant to the 1994 OTC memorandum of understanding, large stationary fossil-fuel fired boilers and indirect heat exchangers. Participating jurisdictions may decide to include other sources, and other stationary sources may choose to opt in to the program. See *id.* § 5.0, at 18-19; OTC NO_x Budget Program Overview, *supra* note 202.

211. See OTC NO_x Budget Program Overview, *supra* note 203.

212. See CARLSON, *supra* note 203, § 5.0, at 10. But see DALLAS BURTRAW ET AL., COST-EFFECTIVE REDUCTION OF NO_x EMISSIONS FROM ELECTRICITY GENERATION (Resources for the Future Discussion Paper 00-55, Dec. 2000) (arguing in favor of regulation of NO_x emissions on an annual, rather than seasonal, basis).

213. See *infra* text accompanying notes 327-328.

214. See OTC NO_x Budget Program Overview, *supra* note 202.

for use in a future control period if they so choose. If too many allowances for a given annual control period are banked, however, a certain proportion of them become unusable.²¹⁵

OTC acknowledged the 1994 memorandum's division of the region into zones and noted that, "[o]ptimally, inter-zone trading would be established to encourage actual emission reductions where such reductions would do the most good for air quality."²¹⁶ It relied, however, on a simulation that demonstrated to OTC's satisfaction that there was "no discernible difference" in terms of environmental impacts between a scenario in which trading between zones was strictly prohibited and one in which trading was authorized region-wide with no trading ratios.²¹⁷ OTC concluded that "institution of a trading ratio would appear to have no influence on where emissions would be reduced in the region."²¹⁸ Accordingly, it decided "not to apply a trading ratio to discount allowances if they are traded across zones."²¹⁹

3. EPA's Trading Programs

While EPA was helping OTC develop its NO_x trading program, it also endeavored to establish a broader program into which the OTC scheme could eventually be merged. It designed both a model program that would be implemented, on a voluntary basis, by the states in their State Implementation Plans (SIPs), and a mandatory, but more limited, federal program.

a. The State Model Program

The Clean Air Act requires each state to submit to EPA for its approval a SIP detailing how it intends to control sources within

215. The program asks what percentage of allowances for a given control period have been banked. If that percentage is less than or equal to 10%, all allowances that have been banked can be used. If, however, that percentage exceeds 10%, some limitations apply. To determine the extent of this limitation, one calculates the ratio of 10% to the percentage of allowances that have been banked. Each source is then entitled to withdraw "at full value" the number of allowances it banked times that ratio. For the remaining allowances, each source may use only half as many as it originally banked. See CARLSON, *supra* note 203, § 5.0, at 13-14.

216. See *id.* § 5.0, at 17.

217. *Id.*

218. *Id.* See also Interview with Bill Gillespie, Senior Program Manager, OTC (June 27, 2000) (stating that OTC relied on regulatory tiering and the fact that overall reductions in emissions would outweigh likelihood, and extent, of local hot spots).

219. CARLSON, *supra* note 203, § 5.0, at 17. But see *id.* ("Implementation of a trading ratio is still an option for 2003 if modeling becomes available to help establish ratios based on the influence of emission reductions in various areas on air quality.").

its jurisdiction so that the NAAQS are met within its borders.²²⁰ If, subsequent to such approval, EPA determines that a SIP has become inadequate “to attain or maintain” the NAAQS or “to mitigate adequately . . . interstate pollution transport”, it can issue a “SIP call” requiring the state to correct the inadequacies in its SIP.²²¹ In October 1998, EPA issued a SIP call and promulgated a so-called NO_x SIP rule requiring upwind states to take action to ensure that the transport of ozone precursors – primarily NO_x – would not contribute significantly to nonattainment of the ozone NAAQS, or impede their maintenance, in downwind states.²²² Various states and industry groups challenged EPA’s authority to issue the SIP call and promulgate the NO_x SIP Rule, but on March 3, 2000, the D.C. Circuit upheld EPA’s action.²²³ As a result of this challenge, however, EPA extended the initial date by which states were required to file SIPs complying with the NO_x SIP Rule to September 1, 2000.²²⁴

The NO_x SIP Rule requires 22 Eastern states²²⁵ and the District of Columbia to reduce NO_x emissions sufficiently to bring the majority of non-attainment areas into attainment with the NAAQS. In fashioning its remedial approach, EPA relied upon the work of the Ozone Transport Assessment Group (OTAG) – a working group comprised of representatives of states, EPA, and

220. See 42 U.S.C. § 7410(a)(2) (1994).

221. *Id.* § 7410(k)(5).

222. See Finding of Significant Contribution and Rulemaking for Certain States in the Ozone Transport Assessment Group Region for Purposes of Reducing Regional Transport of Ozone, 63 Fed. Reg. 57,356 (1998) (codified at 40 C.F.R. pts. 51, 72, 75, 96 (2000)) [hereinafter NO_x SIP Final Rule]. For the proposal, see Notice of Proposed Rulemaking, 62 Fed. Reg. 60,318 (1997) [hereinafter NPRM]. For EPA’s action supplementing the proposal, see Supplemental Notice for the Finding of Significant Contribution and Rulemaking for Certain States in the Ozone Transport Assessment Group Region for Purposes of Reducing Regional Transport of Ozone, 63 Fed. Reg. 25,902 (1998) [hereinafter SNPRM].

223. See *Michigan v. EPA*, 213 F.3d 663, 672 (D.C. Cir. 2000), *cert. denied*, 121 S. Ct. 1225 (2001).

224. See EPA, Summary of EPA’s Approach to the NO_x SIP Call in Light of the March 3rd Court Decision *available at* <http://www.epa.gov/ttn/rto/sip/data/attachme.pdf> (Apr. 11, 2000) [hereinafter NO_x SIP Court Summary]. The NO_x SIP Rule’s requirement that states implement their SIPs by May 1, 2003 remains unchanged. See *id.*

225. The states are: Alabama, Connecticut, Delaware, Georgia, Illinois, Indiana, Kentucky, Massachusetts, Maryland, Michigan, Missouri, North Carolina, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, South Carolina, Tennessee, Virginia, Wisconsin, and West Virginia. *Michigan v. EPA*, 213 F.3d at 669 n. 1.

industry and environmental groups.²²⁶ OTAG had envisioned two possible trading programs.²²⁷ Under the first, states could adopt a NO_x emission permit cap-and-trade scheme. All states that elected this option would combine to form a single market in NO_x emissions.²²⁸

Alternatively, states could elect to implement a trading regime without emission caps. Under such schemes, sources generally receive credits for emission reductions beyond those required by law, and are free to sell those credits to other sources.²²⁹ Trading would initially be intrastate, with the possibility of multistate arrangements evolving over time.²³⁰

Although OTAG did not incorporate the notion of trading zones into its proposal, its final recommendation recognized the problem of hot spots and directed a workgroup to consider the possibility of trading zones:

Subregional modeling and air quality analysis should be carefully evaluated to determine whether geographical constraints should be placed on emissions trading. Appropriate mechanisms, such as trading ratios or weights, could be developed if significant effects are expected.²³¹

In the NO_x SIP Rule, EPA followed OTAG's first recommended track, announcing a model NO_x trading program that states could adopt as part of their revised SIPs.²³² The model program is designed to allow incorporation of the preexisting OTC NO_x trading program.²³³ It applies to sources with high capacities,²³⁴ although certain other sources can opt into the program.²³⁵

226. See *Michigan v. EPA*, 213 F.3d at 672. OTAG was formed upon the recommendation of the Environmental Council of the States. *Id.*; Brown, Comment, *supra* note 174, at 937.

227. For the details of OTAG's deliberations in developing its trading program framework, see Mary A. Gade & Roger A. Kanerva, *Emissions Trading Designs in the OTAG Process*, in EMISSIONS TRADING, *supra* note 20, at 91. OTAG's final recommendation for a trading program framework is presented in Appendix A thereto. See *Final Recommendation: Trading Program Framework* [hereinafter *OTAG Final Recommendation*], reprinted in *id.* app. A, in EMISSIONS TRADING, *supra* note 20, at 112-14.

228. See *OTAG Final Recommendation*, *supra* note 227, reprinted in Gade & Kanerva, *supra* note 227, app. A, at 113.

229. See Dudek et al., *supra* note 20, at 158-59.

230. See *OTAG Final Recommendation*, *supra* note 227, reprinted in Gade & Kanerva, *supra* note 227, app. A, at 113.

231. *Id.* at 114.

232. See NPRM, 62 Fed. Reg. at 60,371.

233. See NO_x SIP Final Rule, 63 Fed. Reg. at 57,475.

234. See *id.* at 57,518-19 (codified at 40 C.F.R. § 96.4(2000)).

235. See *id.* at 57,458-62; *id.* at 57,536-38 (codified at 40 C.F.R. §§ 96.80-96.88 (2000)).

EPA's model trading program suggests a procedure states might use to allocate the allowances in their budgets, but like the OTC program leaves the decision to the individual states.²³⁶ Also, like its OTC counterpart,²³⁷ the EPA program allows for banking but places certain limits on the use of banked allowances.²³⁸

In structuring its model NO_x trading program, EPA considered the possibility of imposing geographic restraints on trading. When EPA proposed the trading regime, it described a single-zone scheme, but invited comments on the issue.²³⁹ The agency raised the possibility of constructing subregions between which trading would either be barred, or allowed only subject to an interregional exchange ratio.²⁴⁰

EPA received over 50 comments on the appropriateness of geographic constraints on trading.²⁴¹ According to EPA,

[t]he majority of commenters on this subject favored unrestricted trading within areas having a uniform level of control. Most commenters supporting unrestricted trading stated that restrictions would result in fewer cost-savings without achieving any additional environmental benefit and would increase the administrative burden of implementing the program. They expressed concern that discounts or other adjustments or restrictions would unnecessarily complicate the trading program, and therefore reduce its effectiveness.²⁴²

EPA decided to structure the model program as "a single jurisdiction trading program allowing all emissions to be traded on a one-for-one basis, without restrictions or limitations on trading allowances within the trading area."²⁴³ In justifying its decision, EPA relied on a model predicting that "significant shifts in the location of emissions reductions would not occur with unrestricted trading compared to where the reductions would occur under command-and-control and intrastate only trading scenarios."²⁴⁴

236. See NO_x SIP Final Rule, 63 Fed. Reg. at 57,459.

237. See *supra* text accompanying notes 213-215.

238. See NO_x SIP Final Rule, 63 Fed. Reg. at 57,473-74.

239. See SNPRM, 63 Fed. Reg. at 25,919.

240. See *id.*

241. NO_x SIP Final Rule, 63 Fed. Reg. at 57,459.

242. *Id.*

243. *Id.*

244. *Id.*

b. *The Federal Program*

EPA also developed a mandatory federal NO_x trading program in response to petitions filed by eight states,²⁴⁵ under section 126 of the Clean Air Act,²⁴⁶ complaining about an excessive upwind contribution to their failure to meet the NAAQS for ozone.²⁴⁷ EPA upheld portions of six of the eight petitions in May 1999.²⁴⁸ In a final rule issued in January 2000, EPA required that certain sources participate in a federal NO_x trading program to address the problems asserted in the petitions filed by the downwind states.²⁴⁹ This program formally applies to a limited number of large NO_x emitters in upwind states.²⁵⁰ In addition, certain other sources in those states may opt into the program.²⁵¹

The program generally follows the structure of the SIP Model NO_x trading program.²⁵² Sources covered by the federal NO_x

245. The states are Connecticut, Maine, Massachusetts, New Hampshire, New York, Pennsylvania, Rhode Island, and Vermont. Findings of Significant Contribution and Rulemaking on Section 126 Petitions for Purposes of Reducing Interstate Ozone Transport, 65 Fed. Reg. 2674, 2675 (2000) [hereinafter Section 126 Final Rule].

246. Section 126(b) of the Clean Air Act authorizes states and political subdivisions to petition EPA if "any major source or group of stationary sources emits or would emit any air pollutant" such that compliance with Clean Air Act requirements is frustrated. 42 U.S.C. § 7426(b) (1994). Under section 126, as interpreted by the courts and EPA,

upwind pollution is never constrained if the downwind state meets the federal ambient standards; upwind pollution that exacerbates a violation of the federal ambient standards in the downwind states is constrained only if the upwind sources "significantly contribute" to the violation; and upwind pollution that is the but-for cause of the violation of federal ambient standards in the downwind state is always constrained.

Revesz, *supra* note 41, at 2371. See generally *id.* at 2362-74 (outlining and critiquing procedures under section 126).

247. See Section 126 Final Rule, 65 Fed. Reg. at 2675.

248. See Findings of Significant Contribution and Rulemaking on Section 126 Petitions for Purposes of Reducing Interstate Ozone Transport, 64 Fed. Reg. 28,250 (1999) (codified at 40 C.F.R. § 52.34(c)-(h) (2000)).

249. See Section 126 Final Rule, 65 Fed. Reg. at 2674 (codified at 40 C.F.R. pts. 52, 97 (2000)).

250. See 40 C.F.R. § 97.4 (2000). See also *id.* at §§ 97.40-97.43 (addressing allocations of allowances). For EPA's proposed findings, see Findings of Significant Contribution and Rulemaking on Section 126 Petitions for Purposes of Reducing Interstate Ozone Transport Wednesday, 63 Fed. Reg. 56,292 (1998). The states are Alabama, Delaware, the District of Columbia, Kentucky, Illinois, Indiana, Maryland, Massachusetts, Michigan, Missouri, New Jersey, New York, North Carolina Ohio, Pennsylvania, Rhode Island, Tennessee, Virginia, and West Virginia. See 40 C.F.R. § 52.34(c)-(h) (2000); Section 126 Final Rule, 65 Fed. Reg. at 2731 (codified at 40 C.F.R. § 97.2 (2000)).

251. See 40 C.F.R. § 97.83 (2000).

252. See 65 Fed. Reg. at 2687; see also *id.* at 2687-94 (highlighting the similarities and differences between the two programs). In particular, the rules

trading program and located in states that choose to implement the model program can buy and sell allowances on that market.²⁵³ In authorizing this integration of the two programs, EPA relied on computer simulations showing that trading under the integrated programs "will not significantly change the location of emissions reductions."²⁵⁴

C. *The Los Angeles Metropolitan Area's Local Smog Precursor Trading Program*

The South Coast Air Quality Management District (SCAQMD) administers an urban smog trading program in the Los Angeles metropolitan area.²⁵⁵ The program is a part of the California SIP, and relies on a market in emission permits of two smog precursors: sulfur oxides and nitrogen oxides.

SCAQMD's trading regime consists of three distinct programs. The principal program, the Regional Clean Air Incentives Market (RECLAIM),²⁵⁶ is designed to achieve a regional 75% reduction in nitrogen oxide emissions and a 60% reduction in sulfur oxide emissions by 2003.²⁵⁷ All facilities within the SCAQMD's jurisdiction that emit at least four tons of either pollutant annually are subject to RECLAIM; other facilities can choose to participate in the program.²⁵⁸

concerning banking mirror the SIP Model NO_x trading program. See *id.* at 2743-44 (to be codified at 40 C.F.R. §§ 97.54(f), 97.55 (2000)).

253. See *id.* at 2693.

254. *Id.*

255. SCAQMD's trading region encompasses four counties - Los Angeles, Orange, San Bernardino, and Riverside. See Matthew Polesetsky, Comment, *Will a Market in Air Pollution Clean the Nation's Dirtiest Air? A Study of the South Coast Air Quality Management District's Regional Clean Air Incentives Market*, 22 *ECOLOGY L.Q.* 359, 362-63 (1995). Smog conditions in that region are among the worst in the nation. See Scott Lee Johnson & David M. Pekelney, *Economic Assessment of the Regional Clean Air Incentives Market: A New Emissions Trading Program for Los Angeles*, 72 *LAND ECON.* 277, 278-79 (1996); Polesetsky, Comment, *supra*, at 362; Nancy J. Cohen, Comment, *Emissions Trading and Air Toxics Emissions: RECLAIM and Toxics Regulation in the South Coast Air Basin*, 11 *UCLA J. ENVTL. L. & POLY* 255, 255-56 (1993).

256. Trading on RECLAIM began on January 1, 1994. See Marla Cone, *Smog Market to Offer Pollution by the Pound Environment: RECLAIM, the World's First Free-Enterprise Program to Clean Up Urban Air, Will Make Its Debut Jan. 1 with the Participation of Nearly 400 Businesses*, *L.A. TIMES*, Dec. 28, 1993, at 1. For a discussion of the historical development of the RECLAIM market, see James M. Lents, *The RECLAIM Program (Los Angeles' Market-Based Emissions Reduction Program) at Three Years*, in *EMISSIONS TRADING*, *supra* note 20, at 219, 220-27. For a discussion of how modeling was used to structure the RECLAIM trading program, see Johnson & Pekelney, *supra* note 255, at 281-95.

257. Drury et al., *supra* note 45, at 248; Chinn, Comment, *supra* note 37, at 91.

258. See Chinn, Comment, *supra* note 37, at 90.

Each permit entitles the holder to emit one pound of a specific pollutant.²⁵⁹ Participating facilities receive annual emission permits in proportion to prior pollution levels.²⁶⁰ In order to meet the air quality improvement mandated by federal law, SCAQMD decreases the total number of RECLAIM permits, as well as the total number of permits allocated to each facility, by approximately five to eight percent each year.²⁶¹

The RECLAIM program establishes two trading zones – a coastal zone and an inland zone. Restrictions on trading between these zones apply only to new sources, sources that relocate, and sources that seek to increase emissions above their initial allocation of permits within the coastal zone.²⁶² Such sources may purchase permits only from sources in their zone. In contrast, inland facilities may purchase permits from either zone.²⁶³ These trading restrictions were predicated on the use of

259. Johnson & Pikelney, *supra* note 255, at 281.

260. Initial allocations in the first years of the program were based upon each source's highest year of production in 1989 through 1992, the four years preceding the program's implementation. Lents, *supra* note 256, at 223. Firms that had already undertaken steps to reduce emission asserted that such an allocation method actually punished them for this action. Some firms also maintained that they had been in an economic slump during that four-year period, so that the data for that period were atypical. See *id.* at 224. Accordingly, SCAQMD adopted a compromise approach for allocating permits in future years. The compromise developed an "ending point" for allocating permits that consists of four elements:

The first element in determining a company's ending allocation was to identify the facilities' highest production in the most recent six years before the start of the program (as opposed to the four years for the starting allocation). Then the facility's year 2000 emissions were calculated assuming the control measures defined in the 1991 [local air quality management plan] were applied to the source operating at its peak production year. The use of these three elements . . . resulted in overall emissions greater than the [air quality management plan] attainment allocation. Thus, element four of the process was to proportionally reduce each facilities [sic] emission allocations by 26 percent for NO_x and 14 percent for SO_x to achieve allocations in conformance with those set out in the [air quality management plan].

Id. at 224. Allocations in the interim years are "calculated by making a linear fit between the starting and points for each source." *Id.* at 225; see Chinn, Comment, *supra* note 37, at 90; Drury et al., *supra* note 45, at 247-48; ERBES, *supra* note 58, at 158.

261. See Chinn, Comment, *supra* note 37, at 91; Drury et al., *supra* note 45, at 248; Johnson & Pikelney, *supra* note 255, at 281.

262. See Johnson & Pikelney, *supra* note 255, at 281.

263. See *id.*; Richard F. Kosobud, *Emissions Trading Emerges from the Shadows*, in EMISSIONS TRADING, *supra* note 20, at 3, 20 tbl. 1.1, 23-24. In contrast, SCAQMD's earlier offset program for new sources established 38 zones and complex restrictions governing exchanges of offsets across zonal boundaries. See Johnson & Pikelney, *supra* note 255, at 287, 294. The scheme was quite complex:

computer models: "In view of modeling results of the prevailing winds, trading was permitted from coastal sources to inland but not the other way around."²⁶⁴

The second component of SCAQMD's trading regime is a mobile source emissions credit program.²⁶⁵ It is designed to address the complaint that the RECLAIM program, standing alone, did not incorporate automobile emissions, one of the largest sources of air pollution in the area. Under this program, which is voluntary,²⁶⁶ SCAQMD awards allowances to "licensed car scrappers," who purchase and destroy old cars, based upon the predicted emissions of the cars had they not been destroyed.²⁶⁷ Mobile source emissions credits awarded for sulfur and nitrogen oxide reductions can be bought and sold on the RECLAIM market.²⁶⁸

SCAQMD's third trading regime is a source credit program.²⁶⁹ This program, which is also voluntary,²⁷⁰ brings small pollution sources such as household and small business furnaces, which otherwise would be unregulated, into the trading fold. Owners of these small sources can earn area source credits by upgrading older, high emission equipment.²⁷¹ Area source credits can be traded on the RECLAIM market.²⁷²

Before June 1990, trading ratios varied between 1.2:1 and 1.6:1, depending on the geographic location of trading partners. Following the reforms, a single trading ratio of 1.2:1 was used, but the market was segmented into 38 distinct zones, with rules governing exchanges between them. The overall effect of these was to only allow trades of credits from east to west or within each zone. The purpose of the restriction was to prevent deterioration in air quality in the zone in which the emissions reduction was made.

Vivien Foster & Robert W. Hahn, *Designing More Efficient Markets: Lessons from Los Angeles Smog Control*, 38 J.L. & ECON. 19, 41 (1995) (footnotes omitted).

264. Kosobud, *supra* note 263, at 24; see Dudek et al., *supra* note 20, at 167; cf. Tietenberg, *supra* note 46, at 107 (noting that, under the earlier 38-zone structure, "firms were only allowed to sell emission reduction credits to downwind trading partners").

265. An early version of the program was instituted in 1993, and therefore predates RECLAIM. See Drury et al., *supra* note 45, at 245-47.

266. Chinn, Comment, *supra* note 37, at 93.

267. See Chinn, Comment, *supra* note 37, at 92; Drury et al., *supra* note 45, at 246-47, 249.

268. While mobile source credits are also awarded for pollutants other than sulfur and nitrogen oxides, these credits cannot be traded on the RECLAIM market. See Chinn, Comment, *supra* note 37, at 92-93.

269. The program was instituted in 1997. See Drury et al., *supra* note 45, at 248.

270. See Chinn, Comment, *supra* note 37, at 94; Drury et al., *supra* note 45, at 248.

271. See Chinn, Comment, *supra* note 37, at 93-94.

272. See *id.* at 94; Drury et al., *supra* note 45, at 248.

Data from the first three years of the RECLAIM program reveal a "robust" trading market.²⁷³ Through December 31, 1997, there had been 1200 trades, with a total value of \$42 million.²⁷⁴ These trades represent the transfer of 244,000 tons of nitrogen and sulfur oxides.²⁷⁵

Environmental justice groups have assailed SCAQMD's emission trading regime. These groups allege, consistent with the general environmental justice criticism of trading,²⁷⁶ that areas immediately proximate to pollution sources have not seen improvement, or have experienced deterioration, in air quality.²⁷⁷ According to these groups, the adversely affected areas tend to be economically disadvantaged and contain relatively higher percentages of ethnic and racial minorities.²⁷⁸

Of particular concern is the fact that mobile source credits can be sold on the RECLAIM market. Environmental justice advocates find this arrangement problematic because automobile emissions are dispersed, so that their effects are distributed fairly homogeneously across the regulated area. In contrast, a small number of industrial polluters, primarily four oil companies, has purchased these allowances.²⁷⁹ These polluters are disproportionately located in minority areas. Indeed, commentators note that of the four companies that have purchased most of the emission credits, "three are located close together" in two communities that are heavily populated by Latinos.²⁸⁰

In 1997, one local environmental group, Communities for a Better Environment (CBE), filed an administrative complaint with the EPA against SCAQMD and the California Air Resources Board,²⁸¹ under Title VI of the Civil Rights Act of 1964.²⁸² It

273. Lents, *supra* note 256, at 232.

274. *Id.* at 233.

275. *Id.* For further information and analysis, see Thomas H. Klier, *Assessing Market Performance and Firm Trading Behavior in the NO_x RECLAIM Program*, in EMISSIONS TRADING, *supra* note 20, at 241.

276. See *supra* text accompanying notes 43-46.

277. Other criticisms have been lodged against SCAQMD's trading regime. See generally Drury et al., *supra* note 45, at 268-83.

278. See *id.* at 251-58.

279. See *id.* at 252.

280. *Id.* at 252-53. Initial data from the first three years of the RECLAIM program, however, do not show a trend toward the accumulation of emission permits in particular areas. Lents, *supra* note 256, at 237.

281. See Marla Cone, *Civil Rights Suit Attacks Trade in Pollution Credits*, L.A. TIMES, July 23, 1997, at A1; Chinn, Comment, *supra* note 37, at 96. CBE also filed suits in federal courts against five oil company polluters. See Cone, *supra*; Chinn, Comment, *supra* note 37, at 83 n.9.

claimed that the mobile source program exacerbates hot spots in Latino communities.²⁸³ Although there have been calls to halt the trading during the pendency of the litigation,²⁸⁴ the SCAQMD's various programs remain in place.²⁸⁵

III

ADDRESSING THE PROBLEM OF AMBIENT STANDARD VIOLATIONS AND THE FORMATION OF HOT SPOTS

As we have explained, for local and regional pollutants, the location and extent of the damage caused by a unit of emissions vary according to the location of the emissions.²⁸⁶ Markets in emissions permits, such as those implemented in the regulatory programs discussed in Part II, however, treat emissions at different locations as interchangeable. As a result, such markets cannot ensure against the violation of ambient standards or the formation of hot spots.

In this Part, we analyze the three leading proposals for constructing marketable permits schemes that avoid or at least mitigate this problem: subdividing the emissions market into zones and prohibiting interzonal trading; designing markets in units of environmental degradation, rather than units of

282. See Chinn, Comment, *supra* note 37, at 96-102. Section 601 of the Civil Rights Act of 1964 provides:

No person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance." 42 U.S.C. § 2000d (1994). Section 602 both authorizes and directs federal departments and agencies that distribute federal funds as a form of financial assistance to "effectuate the provisions of section 2000d of this title with respect to such program or activity by issuing rules, regulations, or orders of general applicability which shall be consistent with achievement of the objectives of the statute authorizing the financial assistance in connection with which the action is taken.

Id. § 2000d-1. In turn, EPA's regulations provide:

A recipient shall not use criteria or methods of administering its program which have the effect of subjecting individuals to discrimination because of their race, color, national origin, or sex, or have the effect of defeating or substantially impairing accomplishment of the objectives of the program with respect to individuals of a particular race, color, national origin, or sex.

40 C.F.R. § 7.35(b) (2000); see EPA, *Interim Guidance for Investigating Title VI Administrative Complaints Challenging Permits* § VI, available at <http://www.epa.gov/civilrights/docs/interim.pdf> (last visited May 30, 2001).

283. See *supra* text accompanying notes 278-280.

284. Interview with Natalia Porsch, SCAQMD, Environmental Justice Division (Apr. 14, 2000).

285. Interview with Susan Tsai, SCAQMD, Engineering Division (Apr. 14, 2000); Interview with Vasken Yardemian, SCAQMD, Rule 1610 Division (Apr. 14, 2000).

286. See *supra* text accompanying notes 40-44.

emissions; and establishing emissions offset markets, in which the trading in units of emissions does not take place on a one-to-one ratio.

For expositional ease, our primary focus in the remainder of the Article is on the violation of ambient standards rather than on the formation of hot spots. The analysis we present, however, is equally relevant to both problems.

A. Emissions Trading with Multiple Zones

One way to reduce the potential negative effects of emissions trading is to divide a region into separate zones, create a separate permit market in each zone, and prohibit interzonal trades.²⁸⁷ The market price for permits in each zone would be determined by the supply and demand for permits within that zone. Market prices would therefore differ across zones.²⁸⁸

In Part II, we discussed proposals, which ultimately were not implemented, to divide the nation into two trading zones in the national sulfur dioxide trading regime,²⁸⁹ and the possible division of the OTC NO_x trading program into three trading zones.²⁹⁰ The RECLAIM program in Los Angeles, in contrast, does feature two zones, with trading prohibited from the inland zone to the coastal zone.²⁹¹

The division of a regulated region into distinct trading zones may ameliorate the threat of ambient standard violations for two reasons. First, by precluding trades across zonal boundaries, a zoned market limits the number of permits that any source can acquire. Second, emissions from different sources in a smaller zone are likely to have a more similar impact – in terms both of location and magnitude – than emissions from different sources in a larger zone. Especially if the policymaker takes topography and the prevailing wind patterns into account in constructing zonal boundaries, emissions from within a trading zone may have substantially equivalent adverse effects. Under such circumstances, trading within the zone might not generate ambient standard violations.

287. For a discussion of different variations of zonal trading regimes, see TIETENBERG, *supra* note 55, at 76; Scott E. Atkinson & T. H. Tietenberg, *The Empirical Properties of Two Classes of Designs for Transferable Discharge Permit Markets*, 9 J. ENVTL. ECON. & MGMT. 101, 107 (1982).

288. See, e.g., Johnson & Pkelney, *supra* note 255, at 282.

289. See *supra* text accompanying notes 109-116, 125-127, 129-134.

290. See *supra* text accompanying notes 202-204.

291. See *supra* text accompanying notes 261-264.

A zoned emission permit regime, however, does not eliminate the possibility of ambient standard violations. No matter how much attention the policymaker devotes to constructing zonal boundaries in light of topography and wind patterns, emissions of local and regional pollutants from different locations, even within the zone, are not equivalent. Rather, they remain spatially differentiated and will have somewhat different impacts – in terms of location and magnitude. As Alan Krupnick, Wallace Oates, and Eric Van De Verg explain:

[T]he assumption under [emissions permit trading] that a unit of emissions from one source in a zone is precisely equivalent in its effects on air quality to a unit of emissions from any other source in the zone *may*, under certain circumstances, do serious violence to reality. The ambient effects of emissions do not depend solely on the geographical location of the source; they depend in important ways on such things as stack height and diameter, and on gas temperature and exit velocity.²⁹²

A further complication is raised by the fact that the ambient air quality levels in a zone depend not only on emissions from sources in that zone but also on transported pollution from upwind zones. Thus, for example, if an upwind source with a relatively short stack sells a permit to a source with a taller stack, the ambient air quality levels in the downwind zone will worsen.

Moreover, even if zoned regimes performed relatively well in terms of avoiding violations of ambient standards, one needs to worry about other complications. First, they reduce the size of each trading market (and increase the number of markets). In a smaller market, it is more likely that some participants would have market power. Such participants – whether buyers or sellers – would have the incentive to engage in anticompetitive practices. In particular, sellers with power would be able effectively to set the price for allowances above the efficient market price, while buyers with power would do the opposite.²⁹³

292. See Alan J. Krupnick et al., *On Marketable Air-Pollution Permits: The Case for a System of Pollution Offsets*, 10 J. ENVTL. ECON. & MANAGEMENT 233, 244 (1983) (emphasis in original); George S. Tolley & Brian K. Edwards, *Slippage Factors in Emissions Trading*, in MARKET-BASED APPROACHES, *supra* note 6, at 187, 190 (“No two emissions sources are likely to be identical in damages caused by a pound of pollutant.”).

293. See TIETENBERG, *supra* note 55, at 126-38; Krupnick et al., *supra* note 292, at 237; Atkinson & Tietenberg, *supra* note 287, at 104. See generally TIETENBERG, *supra* note 55, at 125-47 (discussing effect of market power in a permit market).

A policymaker must consider the nature of a non-global pollutant when endeavoring to design a zonal trading system for emissions of that pollutant. A non-global pollutant, by definition, causes different damage – in terms both of magnitude and location – depending on the location from which it is emitted. The factors giving rise to these spatially differentiated effects, such as topography, temperature, and wind patterns, can vary significantly across relatively small distances. As a result, to achieve a viable market that respects ambient standards one of two conditions must hold: the regulated pollutant must have the characteristic that only relatively large shifts in its emission locations affect the spatial distribution of the harm, or there must be a sufficiently large concentration of potential market participants. Under the former condition, the trading zone can be relatively large; under the latter, the zone's small geographic size does not stand in the way of a robust market.²⁹⁴

If neither of these conditions is met, the policymaker must make a tradeoff. It can assign sufficiently numerous sources to each zone, but heighten both the probability and magnitude of ambient standard violations. Alternatively, it can mitigate the probability and magnitude of ambient standard violations by assigning fewer sources to each zone, but heighten the probability of thin markets and the resulting deleterious effects.

Another negative consequence of the division of a region into trading zones is that the lowest-cost reduction of pollution to the desired level (one of the primary promises of tradable permit schemes) is unlikely to be realized. Indeed, dividing the regulated region into zones among which trading is barred can result in the preclusion of some cost-saving trades that would not lead to ambient standard violations.²⁹⁵

More generally, a zoned scheme will not achieve the most cost-effective pollution reduction unless the policymaker allocates the "correct" number of permits to each of the various zones.²⁹⁶ That will not happen unless – as seems unlikely – the policymaker is privy to pollution-reduction cost information for polluters in each zone. Because trading across zonal boundaries is prohibited, subsequent trading cannot ameliorate the initial

294. See Atkinson & Tietenberg, *supra* note 287, at 104 (to function properly, a zoned emission permit market requires that "[b]uyers and sellers of permits are sufficiently numerous within each zone so that permit prices are independent of individual actions").

295. See *id.* at 104.

296. See *id.*

misallocation of permits.²⁹⁷ The policymaker could adjust the allocation of permits across zones over time as it gains more information about control costs, but the administrative costs of such an approach are likely to be substantial.²⁹⁸

To address the shortcomings of zoned schemes, some commentators have suggested allowing trading across zonal boundaries under an exchange ratio that converts permits traded in one market into permits traded in another.²⁹⁹ Consider, for example, a situation in which permits traded within Zone I cause twice as much damage at a given location as permits traded within Zone II. A buyer in Zone I could then purchase permits for two units of emissions from a seller in Zone II for every unit of emissions that it wishes to discharge. But this relatively straightforward exchange works only because, in the example, the location of the damage is independent of the location of the emissions. If, instead, emissions in Zone I affected ambient air quality in both Zones I and II, but emissions in Zone II affected ambient air quality levels only in Zone II, trading at a fixed exchange rate would not guarantee the attainment of ambient standards.³⁰⁰

B. Markets in Units of Environmental Degradation

To address the problem of ambient standard violations caused by trading, commentators have proposed schemes in which permits are denominated in units of environmental degradation, rather than in units of emissions. Under this approach – often referred to in the literature as an “ambient permit system” – the policymaker determines the ambient quality that it deems acceptable at numerous receptor points

297. See Krupnick et al., *supra* note 292, at 237-38; cf. TIETENBERG, *supra* note 55, at 75 (“Determining the share of the total emission reduction to be assigned to each zone [under a zoned credit market system] is a crucial responsibility of the control authority in evaluating the cost effectiveness of this approach.”).

298. See TIETENBERG, *supra* note 55, at 75.

299. See Tietenberg, *Tradable Permits for Pollution Control*, *supra* note 46, at 107 (“Prohibiting trades across zonal boundaries is an excessively severe response to spatial concerns. In principle, it would be possible to formulate a more measured response by allowing transboundary trading subject to predefined trading ratios.”); Stewart, *supra* note 33, at 222 (“The ‘hot spot’ issue can be addressed through zoning mechanisms that vary trading ratios between geographical zones or seasons of the year”); Krupnick et al., *supra* note 292, at 236 n.6 (“trading may take place across zones at ‘exchange rates’ set by the administering agency to reflect the damage attributable to emissions from the various zones”); see also LEONARD ORTOLANO, ENVIRONMENTAL PLANNING AND DECISION MAKING 99 (1984) (providing a numerical example).

300. We discuss a more general scheme of this sort at *infra* Section III.C.

distributed over the region. For each receptor point, the policymaker issues permits of environmental degradation, so that the sum of the environmental degradation authorized by all the permits issued at a given receptor point is set by reference to the ambient standard at this point.³⁰¹

Each receptor point defines a separate market. A firm wanting to increase its emissions would have to determine, through the use of computer modeling, which receptor points are affected by its emissions and the extent of the environmental degradation at each such point. Then, it would need to obtain sufficient permits at each relevant market. As long as the policymaker chooses representative receptor points, the computer modeling accurately predicts the ambient impacts of emissions at different locations, and robust markets for the various environmental degradation permits develop, the trading will not interfere with the attainment of the ambient standards throughout the region.³⁰²

Markets in units of environmental degradation have certain undesirable features, which in some cases may be sufficiently severe to undermine the vitality of the markets and compromise the benefits of trading. First, such schemes require the establishment and maintenance of permit markets at each of the receptor points. Thus, the system is likely to impose substantial market supervision costs, as well as costs on prospective market participants who must enter multiple markets.³⁰³

Second, markets in units of environmental degradation will be thinner than single-zone emission markets. Indeed, polluters

301. See Revesz, *supra* note 41, at 2410-14. From the perspective of ensuring that ambient standards are attained, every point in the region would be treated as a receptor point. Such an approach, however, would be impractical, since it would entail constructing an infinite number of markets. For a variant of an ambient permit system - called a "highest ambient permit system" - under which the policymaker establishes only one permit market based upon conditions at the receptor point with the poorest ambient air quality, see Atkinson & Tietenberg, *supra* note 287, at 107.

302. If the permit market is for a local pollutant but the pollutant is also transformed over long distances into a regional pollutant, a more complex market would have to be designed. See Scott E. Atkinson, *Marketable Pollution Permits and Acid Rain Externalities*, 16 CANADIAN J. ECON. 704 (1983) (suggesting that, while a local ambient permit system may meet local ambient standards and reduce pollution as cost-effectively as possible, it also may increase long-range transport of pollutants and lead to increased pollution deposition at great distances).

303. See Atkinson & Tietenberg, *supra* note 287, at 102 ("The chief problem with the ambient permit system is its administrative complexity."); Robert W. Hahn, *Trade-offs in Designing Markets with Multiple Objectives*, 13 J. ENVTL. ECON. & MGMT 1, 2 (1986) (noting that "[t]here are costs associated with participating in markets, and there are costs associated with administering them," and that these costs are exacerbated with multiple markets).

participate only in the markets at which their emissions cause damage; thus, not every polluter participates in every market.³⁰⁴ At some receptor points, the number of prospective market participants might not be sufficient to support an efficient market.³⁰⁵

Third, the establishment of a market in units of environmental degradation involves dividing the rights associated with traditional emissions permits into constituent rights to cause damage at various locations. The problems of multiple markets and thinner markets are exacerbated by this segmentation of rights. As we noted above, a firm that seeks to increase its emissions must obtain additional permits at each receptor point at which its emissions cause damage. If the firm is able to purchase permits only in some markets but not others, the purchased permits would be useless. Only a full portfolio of permits gives the firm the right to increase its emissions.³⁰⁶

This emphasis on portfolios is likely to affect a firm's bidding strategy. For example, if a firm knew that obtaining permits in one market would be especially difficult, it might wait until it obtained those permits before attempting to purchase permits in other markets.³⁰⁷

Prospective sellers face similar problems. While brokers presumably would work to match willing buyers to willing

304. See Kete, *supra* note 33, at 83.

305. Thomas Tietenberg explains:

Problems could arise, for example, if there were few sellers in one or more of the markets, since markets with few sellers provide less assurance that competitive prices will prevail. When credit prices are not competitive, the transactions will not generally lead to a cost-effective solution.

TIETENBERG, *supra* note 55, at 61-62; see Hahn & Noll, *supra* note 40, at 122 ("[A] system with numerous interrelated markets may have some markets in which only one or a few polluters participate, leading to inefficiencies resulting from market concentration.").

306. See Krupnick et al., *supra* note 292, at 236 ("Note that a firm emitting wastes must assemble a 'portfolio' of permits from *each* of the receptor points that is affected by its emissions." (emphasis in original)).

307. Thomas Tietenberg explains:

When a source is required to negotiate in more than one market (as it is in an ambient permit approach), its problem becomes acute. The demand for credits in any one of these markets would depend not only on permit prices in that market, but on the prices in all other markets as well. The source could not definitively negotiate in market A until it knew the price in market B and vice versa. The interdependency among these markets creates an indeterminacy which can only be resolved in general by negotiating simultaneously in two or more markets at once. Though not impossible, this is a difficult burden for the source to bear.

TIETENBERG, *supra* note 55, at 62.

sellers, it is unlikely that the seller would find a buyer that needed the precise portfolio of permits that the seller was offering. Only in relatively rare instances would the seller be able to dispose of its permits in one transaction. In the more likely scenario, it would have to engage in multiple transactions, with the consequent rise in transaction costs.

The interlinking of the different markets, which results from the need of both buyers and sellers to trade portfolios of permits, gives rise to the potential that thin markets at some receptors will cause a domino effect. If the market for a permit to degrade the environment at one receptor point has an insufficient number of prospective market participants, markets at other points also might become thin if too many prospective participants rely on purchasing or selling permits on the first market to make transacting on the other markets worth their while.

C. Pollution Offset Markets

Given the problems of zoned emission markets and of markets in units of environmental degradation, environmental economists have searched for alternative ways to construct pollution markets.³⁰⁸ Alan Krupnick, Wallace Oates, and Eric Van De Verg have proposed a pollution offset market,³⁰⁹ which

308. See Atkinson & Tietenberg, *supra* note 287, at 103 ("The fact that neither of these permit systems is optimal from all points of view has triggered a search for alternative permit designs which, while they may not be optimal, may represent a reasonable compromise. The search is for a permit design with low compliance cost as well as low administrative and enforcement cost which provides reasonable assurance that 'hot spots' will not arise over time.").

309. See Krupnick et al., *supra* note 292, at 233. Thomas Tietenberg identifies two variants on this approach: a nondegradation offset system, and a modified pollution offset system. Tietenberg, *Tradable Permits for Pollution Control*, *supra* note 46, at 108. He explains:

The *pollution offset* approach allows offsetting trades among sources so long as they do not violate *any* ambient air quality standard. The *nondegradation offset* allows trades among sources as long as no ambient air quality standard is violated *and* total emissions do not increase. The *modified pollution offset* allows trades among sources as long as neither the pretrade air quality nor the concentration target (whichever is more stringent) is exceeded at any receptor. Total emissions are not directly controlled.

Id. (emphases in original). For discussion of other variants, see Hahn, *supra* note 303, at 4-6; Albert McGartland & Wallace E. Oates, *Marketable Permits for the Prevention of Environmental Deterioration*, 12 J. ENVTL. ECON. & MGMT. 207 (1985).

W.D. Montgomery first suggested the idea of a market for pollution offsets in *Markets in Licenses and Efficient Pollution Control Programs*, 5 J. ECON. THEORY 395 (1972). Montgomery's proposed constraint, however, was stricter than the constraint that the current conception of an offset market system imposes: Montgomery would

entails a single market in emission permits but in which trades are not effected on a one-to-one basis.³¹⁰ Rather, "the parties exchange emission permits at ratios depending on the relative effects of the associated emissions on ambient air quality at receptors with potential to violate the standard."³¹¹ Under a pollution offset market regime, a buyer need only purchase emission permits if the buyer's emissions would otherwise cause a violation of an ambient standard at a receptor point.³¹² A buyer requiring permits in order to increase its emissions can purchase them from a particular seller only if the emissions of both the buyer and seller adversely impact ambient air quality at a common receptor point. The exchange rate is determined by reference to the relative rates by which emissions of the regulated pollutant by the buyer and seller contribute to ambient concentrations at this receptor point: it equals the ratio of the seller's contribution to that of the buyer.³¹³

A numerical example is illustrative. Let us say that an ambient standard of $10 \mu\text{g}/\text{m}^3$ of pollutant P governs at receptor point ρ , and that emissions from firms A and B contribute to levels of P at ρ . In particular, let us say that the level of P at ρ increases by $3 \mu\text{g}/\text{m}^3$ for every ton of P emitted annually by A , while the level of P increases by $1 \mu\text{g}/\text{m}^3$ for every ton of P emitted annually by B . At present, A has 2 permits and B has 4; each permit entitles the holder to emit 1 ton of P annually. Thus, the ambient level of P at ρ precisely equals the ambient standard:

$$(2 \text{ tons}) \times (3 \mu\text{g}/\text{m}^3 \text{ per ton}) + (4 \text{ tons}) \times (1 \mu\text{g}/\text{m}^3 \text{ per ton}) = 10 \mu\text{g}/\text{m}^3.$$

Now say that A decides to purchase 1 permit from B . If the trade were conducted on a one-to-one basis, then A and B each could emit 3 tons of P per year, with the resulting annual average ambient level of P at ρ :

have precluded any trade that resulted in a deterioration in ambient air quality at any receptor. See *id.* Krupnick, Oates and Van De Verg built on Montgomery's idea but, in place of Montgomery's restriction, required only that no trade result in an ambient standard violation at any receptor. See Krupnick et al., *supra* note 292, at 241-42.

310. See McGartland & Oates, *supra* note 309, at 210.

311. Albert McGartland, *A Comparison of Two Marketable Discharge Permits Systems*, 15 J. ENVTL. ECON. & MGMT. 35, 37 (1988).

312. See McGartland, *supra* note 311, at 39 ("The [pollution offset market system] effectively allows each polluter to be concerned with only those receptors whose air quality would violate the standard as a result of an increase in its emissions.").

313. The discussion in this paragraph assumes that the buyer and seller share only one common receptor point. For discussion of the more general situation, see *infra* text accompanying note 314.

$$(3 \text{ tons}) \times (3 \mu\text{g}/\text{m}^3 \text{ per ton}) + (3 \text{ tons}) \times (1 \mu\text{g}/\text{m}^3 \text{ per ton}) = 12 \mu\text{g}/\text{m}^3.$$

This concentration exceeds the ambient limit of $10 \mu\text{g}/\text{m}^3$. Instead, the trade must be accomplished using an exchange rate based on *A*'s and *B*'s relative contribution to the level of *P* at ρ . Here, the exchange rate is $1/3$. Thus, the seller *B* reduces its emissions by 1 ton (since it is selling 1 permit), but the amount by which *A* is permitted to increase its emissions is restricted by the exchange rate:

$$(1/3) \times (1 \text{ ton/permit}) \times (1 \text{ permit}) = 1/3 \text{ ton}.$$

Thus, the additional permit obtained by *A* enables *A* to emit a total of $2\text{-}1/3$ tons of *P* per year; *B* is permitted to emit 3 tons annually. The $10 \mu\text{g}/\text{m}^3$ ambient level of *P* at ρ is thus not violated:

$$(2\text{-}1/3 \text{ tons}) \times (3 \mu\text{g}/\text{m}^3 \text{ per ton}) + (3 \text{ tons}) \times (1 \mu\text{g}/\text{m}^3 \text{ per ton}) = 10 \mu\text{g}/\text{m}^3.$$

The calculation of ratios is more complicated where a buyer and seller share more than one common receptor point, because the trade cannot result in an ambient standard violation at *any* receptor point. Thus, the trading ratio is determined by reference to the receptor at which the ratio of the buyer's to the seller's impact on ambient quality is lowest.³¹⁴

Offset markets have another layer of complexity: the treatment of "slack." Slack occurs when the pollution level at a receptor is below the ambient standard, so that this standard is not constraining.³¹⁵ Under the logic of a pollution offset regime, a

314. A pollution offset market system is a hybrid between an emission permit system and a system of markets in units of environmental degradation. As one group of commentators noted:

The hybrid character of the offset approach is apparent. Like [an emission permit market system], it involves the purchase and sale of emission permits; the permits are not associated explicitly with a particular receptor market as under [an ambient permit market system]. At the same time, however, it captures the spirit of the ambient-based system in that the ratio at which permits exchange for one another depends on the relative effects of the associated emissions on ambient air quality at the receptor points.

Krupnick et al., *supra* note 292, at 238; see also Tomkins & Twomey, *supra* note 28, at 46 (describing a pollution offset market system as "an amalgamation" of an environmental degradation market system and an emission market system).

Along similar lines, McGartland demonstrates that, under conditions of perfect competition, an ambient permit market system and a pollution offset market system are equivalent. McGartland, *supra* note 311, at 37-38. See Hahn, *supra* note 303, at 6 ("Pollution offsets are more closely aligned with an ambient permit system and, hence, can be expected to have many of the same problems associated with this approach.").

315. For a technical definition, see Hahn, *supra* note 303, at 4.

source can simply increase its emissions without purchasing any permit if these emissions affect only receptors at which the ambient standard is not constraining. This feature leads to a "first-come, first-served" allocation of the slack in which, by increasing its pollution, a source can claim a valuable economic right.³¹⁶

An offset market system is fraught with complexity, both for the market supervisor and for market participants. This complexity arises in large measure because the commodity subject to trade, while nominally an emissions permit, in fact conveys different rights to different holders at different times. The government must therefore maintain a record of the rights accompanying each permit. This complexity imposes higher transaction costs on prospective market participants. Also, the presence of slack gives rise to additional difficulties, again leading to higher administration and transaction costs.

IV

A PROPOSAL FOR A CONSTRAINED EMISSIONS PERMIT REGIME

In this Part, we present our proposal for a constrained emission permit regime that respects ambient standards. Our regime relies upon the preclearance of transactions by a website containing information on the impacts of emissions on ambient air quality levels throughout a region. Section A sets forth the elements of our proposal. Section B explains why it is superior to the alternative means of structuring markets to avoid or mitigate the violation of ambient standards. Section C analyzes the impact of our approach on the structure of the emissions markets. Finally, Section D illustrates the operation of our proposal by means of a simulation of the air pollution dispersion model recommended by EPA.

A. *Structure of the Proposal*

The constrained trading regime that we propose consists of a single market in units of emissions, but in which a proposed trade is rejected if it leads to the violation of an ambient standard at any receptor point. The determination of whether a proposed trade should be approved is performed through computer modeling,³¹⁷ using an atmospheric dispersion model

316. See Revesz, *supra* note 41, at 2372.

317. Krupnick, Oates, and Van De Verg endorse this concept in the context of a pollution offset market system:

that predicts the impact of emissions from each source in the region on ambient air quality levels at the various receptor points.³¹⁸ The model calculates the impacts on ambient air quality levels of the increase in emissions by the prospective purchaser and the decrease by the prospective seller, and determines whether these changes cause a violation of an ambient standard.³¹⁹

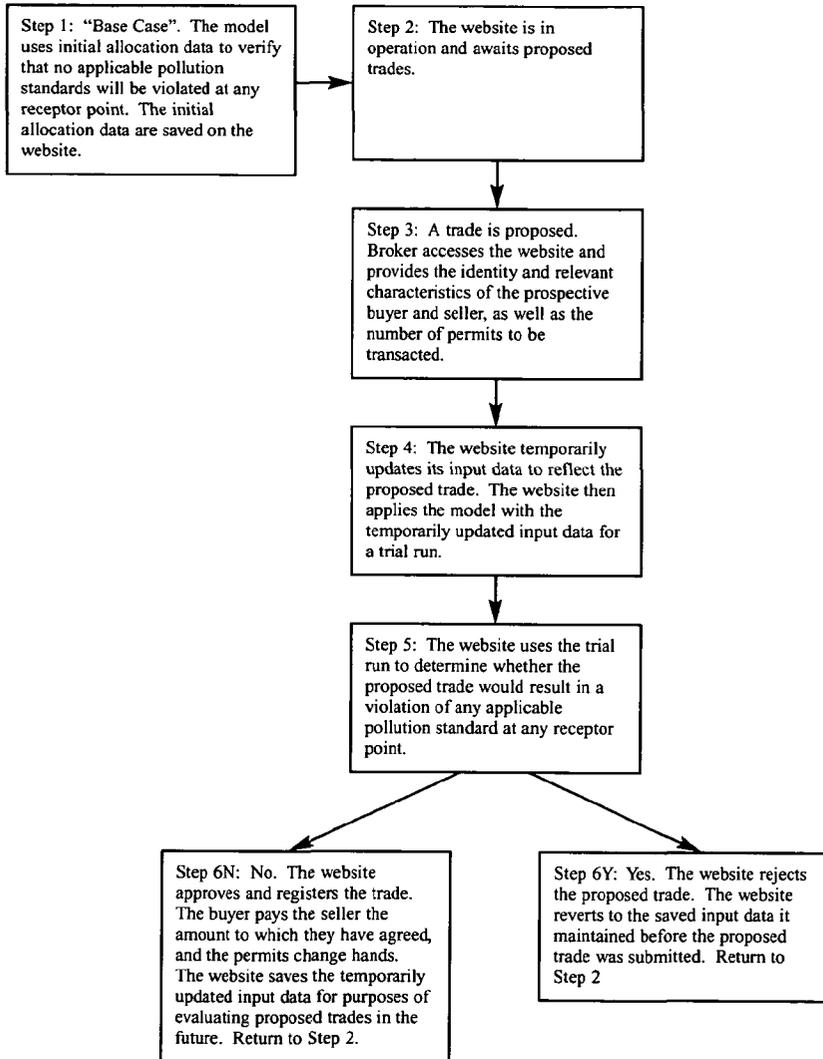
Our proposed trading scheme consists of six steps, which are illustrated in Figure 1.

Th[e] determination [of whether or not a trade would be approved] . . . would involve a fairly straightforward procedure making use of an air-quality model. One would simply enter a new emissions vector (incorporating the proposed addition to emissions and deleting the offsetting reductions) and examine through a simulation exercise the projected effects on pollutant concentrations at each of the receptor points. The proposed transaction would be approved so long as there were no violation of standards at any receptor point.

Krupnick et al., *supra* note 292, at 242 n.16.

318. See *infra* text accompanying notes 345-350.

319. EPA has identified numerous models that are appropriate for modeling the dispersion patterns of various pollutants. In *infra* Section IV.D we present a numerical simulation of how our proposal would work using one of these models to regulate trading in sulfur dioxide emissions. In *infra* Part V we consider the possible use of more advanced models.

FIGURE 1—FLOWCHART OF PROPOSAL

At Step 1, EPA, as the market supervisor,³²⁰ uses the computer model to verify that the initial allocation of permits did not result in the violation of any applicable ambient standards at any receptor point within the regulated region. This distribution of permits constitutes the "base case" scenario.³²¹ Thereafter, at Step 2, the website is ready to consider proposals for trades. We assume, as is currently the case in the sulfur dioxide emissions market, that brokers match prospective buyers with prospective sellers.³²²

Under a simple emissions trading regime, once the buyer and seller agree on a price and quantity, the transaction is finalized, and the exchange of permits is registered with the government or other market supervisor. In contrast, under our proposal, the trade is approved and registered only if the computer model predicts no violations of the applicable ambient standards at any receptor point.

The market supervisor facilitates this process by granting brokers (or the market participants themselves) access to its computer model over the internet. This verification takes place at Step 3 of Figure 1. In particular, the website allows the broker to enter the sources' identities, the quantity of permits that would change hands, and those characteristics of the sources that have an impact on ambient air quality levels at any points (such as location, stack height, stack diameter, and speed and temperature of emissions).³²³

The website program then prepares a trial run. As Step 4 in Figure 1 indicates, for purposes of the trial run, the website modifies temporarily the saved input data by increasing the

320. EPA could hire a subcontractor to perform this task, just as it has contracted with the Chicago Board of Trade to conduct the annual sulfur dioxide auctions. See *supra* text accompanying notes 86-88.

321. If the model predicts a violation, the initial allocation would have to be redone. Thus, it would be desirable to conduct Step 1 contemporaneously with the initial allocation.

322. See *supra* text accompanying notes 91-92.

323. EPA would collect such data from all sources and enter them into the website at Step 1. The computer model requires these data to estimate the dispersion of pollution emissions. The relevant characteristics are the height at which the source emits the pollutant, the temperature and velocity of pollution emissions, and the diameter of the pipe from which pollutants are emitted. See *infra* text accompanying notes 345-350; cf. Krupnick et al., *supra* note 292, at 244 (noting that the ambient effects of pollution emissions depend on "the geographical location of the source" as well as "such things as stack height and diameter, and on gas temperature and exit velocity"). EPA would also load topographical information onto the website. See *infra* text accompanying note 354.

buyer's emissions, and decreasing the seller's emissions, to reflect the proposed trade.³²⁴

At Step 5, the website uses the computer modeling program to predict how pollution will disperse, given the temporarily modified input data. It thereby determines whether the proposed trade will result in the violation of an ambient standard at any receptor point.

If the model indicates that the proposed trade will not result in a violation of any applicable pollution standard at any receptor point, then – as Step 6N indicates – the trade is approved and registered. The buyer pays the seller for the permits, and the permits change hands. Following approval of a trade, the website automatically updates the input data to incorporate the buyer's and seller's new emissions profiles. Thus, at the time that other prospective buyers and sellers approach the website with proposals for trades, the website's input data will reflect all the previously approved trades.

In contrast, if the computer simulation reveals that the proposed trade will result in a violation of an ambient standard at any receptor point, then – as Step 6Y indicates – the trade is not allowed to go forward.³²⁵ In the case of disapproved trades, the website does not update its input data. After the website finishes with Step 6, either by approving the trade at Step 6N or rejecting it at Step 6Y, the website returns to Step 2. There, it awaits the next proposal for a trade.

B. *Comparison of the Alternative Trading Regimes*

We turn now to a comparison of our proposal for a constrained single-zone emission regime with other pollution trading regime structures. We perform this analysis by reference to four criteria: the likelihood that the trading will result in the attainment of the applicable ambient standards; the thickness of the markets; the transaction costs of market supervision and participation; and the

324. This discussion assumes that both buyer and seller are polluters, and that the buyer intends to use the permits immediately. We discuss below the possibilities of (i) environmental organizations purchasing permits solely to retire them; (ii) non-polluters purchasing permits with an eye to sell the permits shortly thereafter at a profit; and (iii) polluters purchasing permits with the intent of "banking" the permits for use at a future time. *See infra* Part V.

325. The website would inform the broker. It should also provide the broker with information as to why the trade was rejected (i.e., the location(s) at which ambient standards would have been violated had the trade gone forward, and the extent of those violations) to allow the broker to recraft the trade (for example, by reducing the number of permits to be transacted or by substituting for the buyer or seller) so that it receives approval.

treatment of slack. Table 1 presents our conclusions with respect to each of the criteria.

TABLE 1 - CHARACTERISTICS OF TRADABLE POLLUTION PERMIT SCHEMES

	Traditional Single- Zone Markets	Multiple Zone Markets	Environ- mental Degradation Markets	Offset Markets	Constrained Single-Zone Markets
Attainability of Ambient Standards	Poor	Fair	Very Good	Very Good	Very Good
Thickness of Markets	Very Good	Poor	Fair	Good	Good
Transaction Costs	Very Good	Fair	Poor	Poor	Good
Treatment of Slack	Very Good	Very Good	Fair	Poor	Very Good

1. Attainability of the Ambient Standards

Only three of the five trading regimes that we analyze – environmental degradation markets, offset markets, and our proposal for constrained single-zone markets – provide for the actual attainment of ambient standards. As we have explained, of the remaining two regimes, multiple-zone markets perform somewhat better from this perspective than single-zone markets, but fall short of meeting the goal.³²⁶

Even single- and multiple-zone markets can lead to the attainment of ambient standards if they are coupled with a second regulatory tier. This tier would impose use restrictions on certain permits in order to attain ambient standards.³²⁷ We believe that our approach is preferable in that it provides a tangible means by which a prospective purchaser can ascertain, in advance of the purchase, whether the permits that it seeks would in fact allow it to increase its emission. In contrast, under a system of use restrictions, there is not a clear way of determining when an ambient violation takes place. Presumably such a violation would come to the attention of a regulator only

326. See *supra* Section III.A.

327. See *supra* notes 213-215 and accompanying discussion (discussing regulatory tiering).

after the violation had already occurred. Moreover, to the extent that more than one source contributes to the degradation of ambient air quality at the point of the violation, it is not clear how the use restrictions would be apportioned among the various contributing sources. A determination of this type would need to be made through some kind of administrative procedure, adding further delay and expense to the resolution of the problem.³²⁸

In contrast, our approach is quite specific as to what trades can and cannot go forward. Thus, it lowers the transaction costs and provides better assurances that the ambient standards will, in fact, be met.

2. *Thickness of Markets*

Thin markets can interfere with the goal of reducing pollution in a cost-effective manner.³²⁹ They can produce situations in which either buyers or sellers have market power and in which, as a result, trades do not take place at competitive prices.³³⁰ Multiple-zone emission markets fare most poorly in this regard because they permit trading only between buyers and sellers in the same zone, rather than among all the sources in the region.

Environmental degradation markets may fare somewhat less poorly. Prospective purchasers seeking permits to degrade ambient air quality at a receptor point can buy only from firms

328. Thomas Tietenberg explains that sulfur dioxide emissions are subject to two tiers of regulation:

Sulfur oxide pollution in the United States is controlled both by the regulations designed to achieve ambient air quality standards as well as by the sulfur allowance trading program. All transactions have to satisfy both programs. Thus trading is not restricted by spatial considerations (national trades are possible), but the use of acquired allowances is subject to local regulations protecting the ambient standards. The second regulatory tier protects against local hot spots (by disallowing any specific trades that would create them), while the first tier allows unrestricted trading of allowances.

Tietenberg, *Tradable Permits for Pollution Control*, *supra* note 46, at 103 (footnote omitted). Tietenberg is unclear whether a trade that would result (if the permits exchanged were in fact used by the purchasing source) in an ambient standard would be "disallow[ed]", or whether the trade would be allowed but the "use of the acquired allowances" would be restricted. *Id.* (emphasis in original). Our proposal takes the former approach. We note, further, that our approach incorporates a specific process by which this determination is made in respect of every proposed trade; in contrast, it is unclear how Tietenberg envisions the interaction between the two regulatory tiers.

329. See *supra* text accompanying notes 304-305.

330. See *supra* text accompanying notes 292-293.

that affect ambient air quality levels at that point.³³¹ Unlike the zoned-market scheme, eligibility for trading on a market is determined not by location of the source, but by the location of the receptor points at which the source's emissions cause damage. Sources, however, typically trade in multiple markets, potentially ameliorating the problem of thin markets.

Pollution offset markets also permit only less-than-universal trading. Like environmental degradation markets, they preclude trades that would produce ambient violations at a particular point. Unlike environmental degradation markets, however, they allow trades between parties that do not affect ambient levels at the same point. Thus, the resulting markets are somewhat thicker.

From the perspective of market thickness, our proposal for constrained single-zone markets has comparable properties to pollution offset markets. It leads to somewhat thicker markets, however, because any increase in emissions requires resort to the market, whereas under pollution offset markets, increases that do not produce any ambient violations can be appropriated as slack.³³² Only a single-zone market with no trading constraints produces thicker markets.

3. *Transaction Costs*

Transaction costs, whether borne by the government as market organizers or by the trading parties, impede the effectiveness of market systems, both by consuming resources that could otherwise be used in more productive endeavors and by preventing trades that otherwise would be socially beneficial.³³³ Single-zone markets give rise to the lowest transaction costs because they require the establishment of, and participation in, a single market, and impose no trading constraints. The government needs only to keep track of who holds which permits at what times.

Environmental degradation market systems and offset markets have comparatively high transaction costs. The former require the government to establish a market at each receptor point, and requires each source to purchase permits at each receptor point at which it has an adverse impact on ambient concentrations. The latter require the government and market participants to keep track of what rights are associated with

331. See *supra* text accompanying notes 303-313.

332. See *supra* text accompanying notes 314-316.

333. See Ronald H. Coase, *The Problem of Social Cost*, 3 J.L. & ECON. 1 (1960).

each permit at all times. Moreover, the proposals for such trading schemes do not contain a low-cost mechanism for determining the appropriate trading ratios.

A multiple-zone market scheme does only slightly better. It too involves the establishment of multiple markets. It also imposes on the government the burden of determining how to allocate permits among the various zones.³³⁴ On the other hand, each source needs to buy permits in only one market.

The constrained trading regime that we propose adds some complexity to the standard single-zone market. We believe, however, that the website containing the atmospheric dispersion model provides a fast and straightforward way to determine whether ambient standards would be violated, thereby imposing relatively low transaction costs on the government and market participants.

4. *Slack*

Market-based schemes that contain slack give rise to conceptual and administrative problems.³³⁵ If slack is offered on a "first-come, first-served" basis, it results in inefficient expenditures by sources to capture the slack as well as in inefficient allocations of the slack among the sources.³³⁶ The government must also keep track of which sources have obtained the right to utilize slack. If the government allocates the slack in some other way, such as by periodic auctions, it faces complicated design problems in determining at what rate and in what manner to make the slack available to the market.

As we discuss above, slack is endemic to pollution offset schemes and has received the attention of academic commentators.³³⁷ Slack is also a problem for environmental degradation markets, though the literature has not addressed the issue. Environmental degradation markets exhibit slack if the government's goal is to meet an ambient standard where some areas had ambient quality levels that are better than this standard. Then, a source could increase its emissions without purchasing any permits if this increase did not lead to the violation of an ambient standard at any receptor point.

In contrast, single-zone markets, multiple-zone markets, and the constrained single-zone markets that we propose do not have

334. See *supra* text accompanying notes 296-298.

335. See *supra* text accompanying notes 314-316.

336. See *supra* text accompanying note 316.

337. See Hahn, *supra* note 303, at 4.

slack problems. Any source that wishes to increase its emissions needs to buy permits from another source.

In sum, our proposal performs well across the relevant criteria. It dominates multiple-zone markets, environmental degradation markets, and offset markets, doing better along some dimensions but no worse along any dimension. Our proposal does not perform as well as single-zone markets with respect to two of the criteria: thickness of markets and transaction costs. If one attaches sufficient importance to the attainment of ambient standards, however, our proposal is preferable.

C. Likely Impacts of the Proposal

This Section analyzes some likely features of the market for permits under our proposal to require website approval as a precondition to a valid trade. We focus on the impact of our proposal on the order of trades, the ability of particular prospective buyers and sellers in fact to engage in trades, and the price of permits.³³⁸

1. Importance of the Order of Trades

The order in which trades occur may have an impact on what trades will be permitted thereafter. Recall that the website modifies its saved input data when – and only when – a trade is approved and registered. Although the website would modify temporarily the saved data to reflect a proposed trade for purposes of a trial run, that modification would become permanent only if the trade ultimately were approved; if not, the saved input data would remain unchanged.

This structure has ramifications for prospective market participants. For example, it is possible that multiple pairs of buyers and sellers may contemplate trades at substantially the

338. In this Section, we limit our consideration to transfers of permits that occur on a spot market, not by means of auction. Under the sulfur dioxide trading program, most trades occur on the spot market; only a minimal number of permits are auctioned off annually. See *supra* text accompanying notes 86-89. We consider how our proposal would work in conjunction with auctions of permits below. See *infra* Section V.E.1.

Our discussion in this Section also applies generally only to typical emissions trading regimes, where the concentration of pollutant varies directly with emissions. It does not apply generally to regimes, such as a NO_x trading regime, where the concentration of the pollutant (ozone) may at times vary indirectly with the emissions and concentration of emitted substance (NO_x). See *supra* Section II.B.1. Some of the lessons we draw, however, may apply in such situations.

same time. Even if each of the trades would be accepted if it were the first to be presented to the website for approval, some trades might not be acceptable if presented later, after other trades have been registered. Conversely, a prior trade may render viable a subsequent trade that otherwise would have been impermissible.

The following example illustrates this feature. Let us say that *A* is contemplating purchasing 10 permits from *B*, and at the same time that *C* is contemplating purchasing 100 permits from *D*. Assume that emissions from *A* and *C* contribute substantially to high pollution levels – though not in excess of any applicable standards – at a receptor point ρ . In the case of a local pollutant, this effect could be attributable to the proximity of the sources, whereas in the case of a regional pollutant it might be caused by their relative stack heights and the prevailing wind patterns at and around their respective locations. Assume further that, given the existing distribution of permits, the website would approve either trade – separate trial runs of the computer model would reveal no violation of any applicable ambient standard.

Let us say that *A* and *B* carry out their trade before *C* and *D* do so. The shift of 10 permits from *A* to *B* is approved, and the website modifies – now permanently – its saved input data to reflect the transaction.

C and *D* now seek approval for their trade. Assume that the additional 10 permits purchased by *A* have increased the ambient concentration at receptor point ρ enough that the acquisition of another 100 permits by *C* would produce a violation of the ambient standard. In that case, the website would disapprove the proposed transaction between *C* and *D*, even though it would have approved this trade before *A*'s transaction with *B*.³³⁹ Similarly, had *C* and *D* carried out their transaction first, *A*'s transaction with *B* would have been precluded.

2. Ability of Particular Buyers and Sellers to Engage in Trades

The constrained emissions trading regime that we propose potentially precludes certain sellers from selling permits to certain buyers. We discuss in this Section a common pattern of constraints on the permissibility of trades.³⁴⁰

339. It is also possible that *C* might be able to purchase a smaller number of permits from *D*.

340. The empirical simulation in *infra* Section IV.D provides support for our general analysis and conclusion.

We consider a situation in which emissions from a group of sources cause harm at the same location. This location has the worst ambient air quality levels of the region throughout which trading is allowed and the ambient standard constrains further degradation. As already indicated, in the case of a local pollutant this location would be in the vicinity of the sources, whereas in the case of a regional pollutant it could be hundreds of miles away.³⁴¹

Our proposed trading regime generally would allow sources in this group to trade permits with one another. In such cases, the increase in the purchaser's emissions would be counteracted by a decrease in the seller's emissions. If the emissions of the two parties have similar impacts on ambient air quality at the point at which the standard is constraining, the transaction should not lead to the violation of these standards.

Similarly, our trading regime would generally allow sales from the concentrated group of polluters to sources elsewhere in the region. Such transactions would ease the pressure on ambient air quality levels at the location with the highest concentrations. A comparable increase in ambient concentrations at locations with better air quality would be less problematic.³⁴²

In contrast, our trading regime would not allow sources in the concentrated group to purchase permits from outside the group. Increased net emissions from within the group would lead to the violation of the ambient standards. Thus, sources in this group can generally trade permits with one another and can sell permits to sources outside the group, but cannot purchase permits from sources outside the group.

This discussion highlights an important difference between our constrained single-zone trading regime and a multiple-zone regime. Under the latter, a group of sources located close together would presumably be placed in the same zone in which trading among the sources was authorized, and trading with sources outside the zone would be prohibited.³⁴³ Our scheme

341. See *supra* text accompanying notes 35-39.

342. It is possible, given stack heights and meteorological conditions, that the increase in emissions by this purchaser could have more serious impacts on ambient air quality levels and perhaps produce a violation of the ambient standards. In such cases, the website would disapprove the transaction. If a unit of emissions in the hands of the purchaser or the seller had the same impact on ambient air quality levels, however, the transaction would be permissible.

343. That result would be modified if the policymaker allowed for trades of permits between zones, subject to an exchange ratio. See *supra* text accompanying notes 298-300.

preserves the ability of sources within the group to trade with one another. But unlike the case of multiple-zone markets, it also allows sources in this group to sell to sources at other locations, thus reducing the barriers on permissible transactions.

3. *Price of Permits*

The preceding discussion shows how our proposal would inhibit the ability of certain polluters to sell permits to certain buyers. This feature implies that, at any given time, permits in the market might sell at different prices.

The price of permits, like prices of all goods, is determined by their supply and demand. If a potential purchaser affects ambient air quality levels at a receptor at which the ambient standard is constraining, the universe of potential sellers will be reduced. In particular, the potential purchaser will not be able to buy permits from sources that do not have an impact at the same location, or from sources for which the impact of a unit of emissions at the constraining location is smaller.

This reduced supply potentially leads to an increase in the price of the permits that the prospective purchaser can acquire. In particular, sellers that might have been able to supply permits at relatively low prices would not be permitted to participate in certain transactions.

In contrast, a potential purchaser that affects ambient levels in areas in which the quality is better than the ambient standard would not face similar constraints. Its market for permits would not be similarly truncated. The larger supply of potential sellers would reduce the market price.

Last, we note that our proposal has the desirable effect of creating incentives not to site new sources in locations from which new sources' emissions would affect adversely areas that already are highly polluted. This is because, were a new source to choose such a location, it would have a limited set of permit holders from which it could purchase permits (lest its purchases result in an ambient standard violation). As a result, the price the new source would have to pay for permits should be higher than the price it would have had to pay had it chosen another, less environmentally problematic location. We regard this feature of our regime to be highly desirable.

D. A Simulation of the Functioning of the Constrained Emission Permit Regime

In this Section, we illustrate the functioning of our proposed trading regime by means of a computer simulation. We consider trades in permits to emit sulfur dioxide,³⁴⁴ and describe how our scheme would ensure that the annual NAAQS for this pollutant are not violated.

1. The Computer Model and the Input

The atmospheric dispersion³⁴⁵ model we use for our simulation is the Industrial Source Complex (ISC3) Short Term Dispersion Model³⁴⁶ - a Gaussian model.³⁴⁷ It is the most commonly used gaseous pollutant model that relies upon actual meteorological data,³⁴⁸ and, as we discuss below, is currently recommended by EPA for use by new sources and states to determine their compliance with regulatory requirements.³⁴⁹ As inputs, the model requires information about the sources from which pollution is emitted and the receptor points at which

344. The proposal can work for other pollutants as well.

345. "The term 'dispersion' refers to all of the processes that serve to dilute the plume [of emitted air pollutant] as it is transported through the atmosphere by the local winds." ERBES, *supra* note 58, at 50.

346. The source code for this model can be downloaded from the EPA website. See EPA: Air Quality Models, at <http://www.epa.gov/ttn/scram/>. The source code for the model we used last was updated on April 27, 2000. See *id.*

347. "The Gaussian plume model is the most common air pollution model. It is based on a simple formula that describes the three-dimensional concentration field generated by a point source under stationary meteorological and emission conditions." ZANNETTI, *supra* note 59, § 7.1, at 141.

348. ERBES, *supra* note 58, at 58 (describing the SCREEN and ISC models as "the most commonly used models"); James A. Westbrook, *Air Dispersion Models: Tools to Assess Impacts from Pollution Sources*, 13 NAT. RESOURCES & ENV'T 546, 549 (1999) (noting that the SCREEN and ISC models "have become regulatory 'work-horses' that "have been consistently applied in regulatory programs").

Mathematical models of air pollution dispersion come in two varieties: "deterministic models, based on fundamental mathematical descriptions of atmospheric processes, in which effects (i.e., air pollution) are generated by causes (i.e., emissions)," and "statistical models, based upon semiempirical statistical relations among available data and measurements." ZANNETTI, *supra* note 59, § 2.1, at 27. Of the two, "[d]eterministic models are the most important ones for practical applications since, if properly calibrated and used, they provide an unambiguous, deterministic source-receptor relationship." *Id.* § 2.1, at 28. The model we use is deterministic.

349. See *infra* Section V.A.1.

ambient concentrations need to be predicted, as well as meteorological data.³⁵⁰

In constructing our simulation, we placed twenty point sources³⁵¹ of sulfur dioxide emissions across a 200 kilometer by 200 kilometer area. For each source, the model requires (i) its location, expressed in terms of Cartesian (x,y) coordinates; (ii) its elevation³⁵²; (iii) its emissions rate; (iv) the height of its stack; (v) the temperature of its emissions; (vi) the velocity of its emissions; and (vii) the diameter of its stack.³⁵³ Table 2 shows the values of the variables that we chose for each source.

350. The model allows for numerous optional entries, most of which we do not employ in our simulation. In particular, we have chosen to operate the model under "regulatory default options", pursuant to which it follows the following instructions:

Use stack-tip downwash (except for Schulman-Scire downwash);

Use buoyancy-induced dispersion (except for Schulman-Scire downwash);

Do not use gradual plume rise (except for building downwash);

Use the calms processing routines;

Use upper-bound concentration estimates for sources influenced by building downwash from super-squat buildings;

Use default wind speed profile exponents; and

Use default vertical potential temperature gradients.

I U.S. ENVIRONMENTAL PROTECTION AGENCY, USER'S GUIDE FOR THE INDUSTRIAL SOURCE COMPLEX (ISC3) DISPERSION MODELS § 3.2.2, at 3-6 to 3-7 (1995), available at EPA: Air Quality Models, <http://www.epa.gov/ttn/scram/userg/regmod/iscv1.pdf> [hereinafter USER'S GUIDE].

In addition, we have chosen not to have the dispersion of emissions at any Source be affected by building downwash. Downwash occurs when a "cavity wake" develops because of the proximity of a building to a low smokestack; the cavity wake tends to draw the emission plume toward the ground. See ERBES, *supra* note 58, at 51. The model includes an algorithm to account for the effects of building downwash on emissions from nearby or adjacent point sources. See I USER'S GUIDE, *supra* note 350, § 3.3.3.

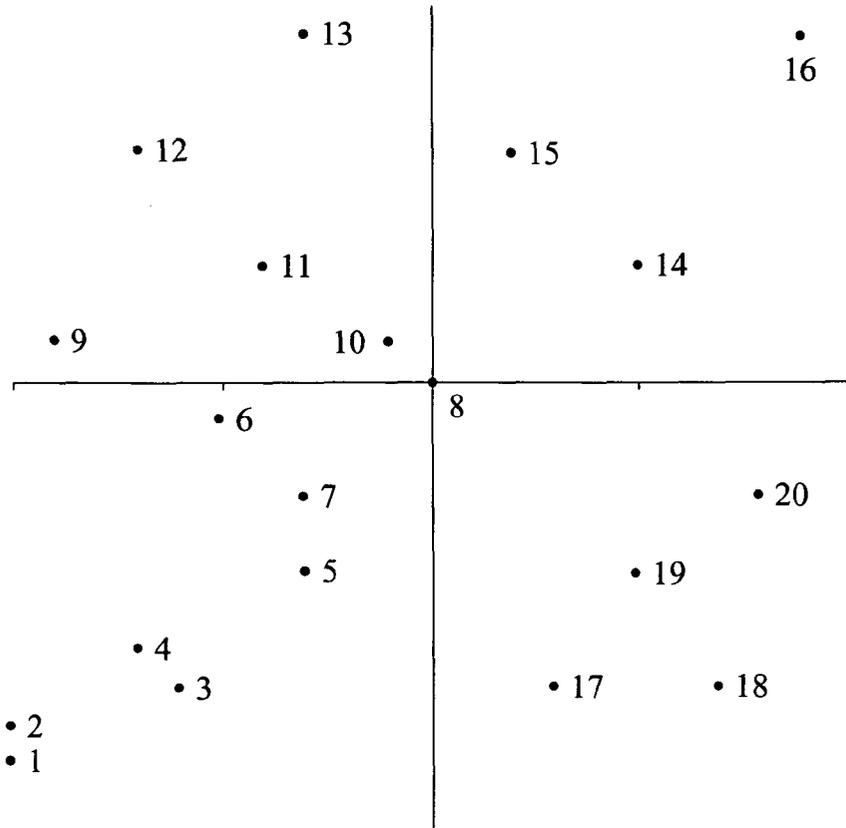
351. In the case of point sources, the emissions are released "from stacks and isolated vents." I USER'S GUIDE, *supra* note 350, § 3.3.2.1, at 3-28. The model can also analyze the impact of emissions from different types of sources. *Id.* § 3.3.2.2, at 3-29 (volume sources); *id.* § 3.3.2.3, at 3-31 (area sources); *id.* § 3.3.2.4, at 3-36 (open pit sources).

352. The model permits the assumption that all sources have an elevation of zero. See I USER'S GUIDE, *supra* note 350, § 3.2.6. We have chosen, however, to vary the elevations of sources slightly. See *infra* text accompanying note 354.

353. All these factors affect pollution dispersion. See *supra* text accompanying notes 347-350.

TABLE 2—INITIAL SOURCE DATA

Source Number	x-Coordinate (meters)	y-Coordinate (meters)	Elevation (meters)	Emissions Rate (grams per second)	Stack Height (meters)	Emissions Temperature (degrees Kelvin)	Emissions Velocity (meters per second)	Stack Diameter (meters)
1	-100,000.00	-100,000.00	500.00	8,547.50	375.00	432.00	11.70	4.60
2	-100,000.00	-90,000.00	0.00	5,983.25	325.00	447.00	10.00	3.80
3	-60,000.00	-80,000.00	0.00	4,602.50	380.00	425.00	9.00	6.00
4	-70,000.00	-70,000.00	0.00	3,945.00	340.00	437.00	12.20	5.50
5	-30,000.00	-50,000.00	0.00	5,917.50	380.00	446.00	9.90	4.00
6	-50,000.00	-10,000.00	0.00	7,561.25	330.00	410.00	8.20	7.40
7	-30,000.00	-30,000.00	0.00	4,931.25	360.00	450.00	7.70	3.10
8	0.00	0.00	1,000.00	4,997.00	85.30	392.00	18.70	5.40
9	-90,000.00	10,000.00	0.00	9,205.00	275.50	410.00	9.60	8.60
10	-10,000.00	10,000.00	0.00	3,945.00	393.00	439.00	11.70	8.00
11	-40,000.00	30,000.00	0.00	2,827.25	315.90	441.00	15.40	7.70
12	-70,000.00	60,000.00	0.00	1,709.50	399.00	429.00	13.60	4.40
13	-30,000.00	90,000.00	0.00	4,010.75	300.30	405.00	11.10	6.40
14	50,000.00	30,000.00	0.00	4,208.00	310.60	420.00	7.90	9.80
15	20,000.00	60,000.00	0.00	1,315.00	320.30	458.00	11.10	6.40
16	90,000.00	90,000.00	0.00	657.50	293.10	443.00	12.30	7.50
17	30,000.00	-80,000.00	0.00	3,945.00	311.30	453.00	10.90	6.60
18	70,000.00	-80,000.00	0.00	4,602.50	287.30	434.00	8.60	7.40
19	50,000.00	-50,000.00	0.00	2,235.50	307.80	485.00	10.30	4.50
20	80,000.00	-30,000.00	0.00	3,550.50	301.50	402.00	10.50	8.40

FIGURE 2: LOCATION OF SOURCES

We placed the sources heterogeneously throughout the region. Their locations are shown in Figure 2. Sources 1 through 7 are located in the lower left quarter of the region, where we have concentrated the emissions; Source 8 is located at the origin; Sources 9 through 13 are located in the upper left quarter of the region; Sources 14 through 16 are located in the upper right quarter of the region; and Sources 17 through 20 are located in the lower right quarter of the region.

We placed Source 1 at an elevation of 500 meters, to reflect a small hill located in the region's lower left corner, and Source 8 at a 1000-meter elevation, on a ridge that runs along the negative x- and y-axes and passes through the origin.³⁵⁴ Otherwise, all sources are at sea-level.

354. See *supra* text accompanying notes 41-42 (discussing impact of topography).

We chose emission rates to correspond roughly to the rates of sources to which permits were distributed under Phase I of the sulfur dioxide trading program.³⁵⁵ To draw an equivalence between emissions rates and number of permits, we assumed that each source emits sulfur dioxide at a constant rate,³⁵⁶ eight hours each day, 20 days each month, and 12 months each year. Under these assumptions, a permit to emit one ton of sulfur dioxide per year allows a source to emit 0.1315 grams of sulfur dioxide per second during the periods in which it operates.

Table 3 presents the number of permits we assigned to each source and its equivalent emissions rate.³⁵⁷ The maximum number of permits we allocated is 65,000 to Source 1, and the minimum is 5,000 to Source 16, whereas the maximum and minimum numbers under Phase I of the sulfur dioxide trading program were 94,840 and 760, respectively.³⁵⁸

355. See *supra* text accompanying notes 76-80.

356. The model allows for the input of variable emission rates. See I USER'S GUIDE, *supra* note 350, §§ 3.3.4, 3.3.8.

357. Thus, the third column of Table 3 is identical to the fifth column of Table 2.

358. See 42 U.S.C. § 7651c tbl. A. See generally Joskow & Schmalensee, *supra* note 67, at 43-45 (discussing Phase I allocations).

TABLE 3 - INITIAL PERMIT ALLOCATION AND EQUIVALENT EMISSIONS RATES

Source Number	Number of Permits Allocated	Emissions Rate (grams per second)
1	65,000	8,547.50
2	45,500	5,983.25
3	35,000	4,602.50
4	30,000	3,945.00
5	45,000	5,917.50
6	57,500	7,561.25
7	37,500	4,931.25
8	38,000	4,997.00
9	70,000	9,205.00
10	30,000	3,945.00
11	21,500	2,827.25
12	13,000	1,709.50
13	30,500	4,010.75
14	32,000	4,208.00
15	10,000	1,315.00
16	5,000	657.50
17	30,000	3,945.00
18	35,000	4,602.50
19	17,000	2,235.50
20	27,000	3,550.50

For other source-specific variables, we chose stack heights between 85.30 and 399 meters;³⁵⁹ temperatures of emissions between 392 to 485 degrees Kelvin;³⁶⁰ velocities of emissions between 7.70 to 18.70 meters per second, and stack diameters between 3.10 to 9.80 meters.³⁶¹

359. Cf. Revesz, *supra* note 41, at 2353 ("[W]hereas in 1970 only two stacks in the United States were higher than 500 feet, by 1985 more than 180 stacks were higher than 500 feet and twenty-three were higher than 1000 feet." (footnote omitted)).

360. A Kelvin degree is exactly equal to a Celsius degree. To obtain the temperature in degrees Celsius from the temperature in degrees Kelvin, one simply subtracts 273 degrees. Thus, our choice of range for temperature of emissions is equivalent to 119 to 212 degrees Celsius.

361. We obtain these parameters (other than stack height) by varying within a range the parameters EPA uses for a sample run of the model. See I USER'S GUIDE, *supra* note 350, § 2.4.3, at 2-20 (using emission rate of 1.00 grams/second; emission temperature of 432 degrees Kelvin; exit velocity of 11.7 meters per second; and stack diameter of 2.4 meters).

The model also requires that we specify receptor points, for which it calculates, based upon the input data, the ambient air quality levels of sulfur dioxide that result from the emissions of the various sources. We placed the receptors homogeneously, in order to sample air quality uniformly throughout the region.³⁶² Specifically, we have located 400 receptors in a grid formation of 20 rows by 20 columns. The rows are 10 kilometers, as are the columns. The receptor grid, which is shown in Figure 2, is centered at the origin, and the four centermost receptors lie at the coordinates (5,000, 0), (0, 5,000), (-5,000, 0), and (0, -5,000).

Finally, the model requires the input of meteorological data. We chose sample data, provided by EPA, from 20 days in the Pittsburgh area in 1964.

2. *Function of the Website*

To demonstrate how the website functions, we proceed by reference to the flowchart presented in Figure 1. To begin, in accordance with Step 1, we verify that the initial allocation of permits does not produce a violation of ambient standards at any point. We thus run the model,³⁶³ using the initial inputs for the emissions profiles of various sources, which are set forth in Table 2. The model calculates the predicted annual average sulfur dioxide concentrations at each receptor, in micrograms per cubic meter ($\mu\text{g}/\text{m}^3$). Table 4 lists the five highest concentrations, which are found along the ridge on the negative x- and y-axes.³⁶⁴

362. As we explain below, it may be desirable to add additional receptors in areas where the model predicts pollutant concentrations close to (but below) the applicable ambient standard. See *infra* text accompanying notes 398-400.

363. Each run of the model that we performed took approximately one minute. We recognize that our simulation includes far fewer sources and relied upon meteorological data that was temporally truncated (as discussed *supra* Section IV.D.1). However, we ran the model on a stand-alone personal computer; more powerful, and faster, computers could be used to accelerate the time in which the website could make decisions. In short, we are confident that the website itself could render its decision on approval of a trade within a matter of hours after approval was sought.

364. The receptors located on the ridge are at an elevation above sea level, contributing to the higher concentrations in those locations.

TABLE 4 – FIVE HIGHEST PREDICTED ANNUAL AVERAGE SULFUR DIOXIDE CONCENTRATIONS UNDER THE INITIAL ALLOCATION OF PERMITS

RECEPTOR		CONCENTRATION ($\mu\text{g}/\text{m}^3$)
X-Coordinate (m)	Y-Coordinate (m)	
-25,000	5,000	78.73147
-35,000	-5,000	76.49808
5,000	-25,000	75.92374
-35,000	5,000	69.44678
-25,000	-5,000	67.07206

As Table 4 shows, under the initial allocation of permits, the highest predicted annual average concentration of sulfur dioxide is $78.73147 \mu\text{g}/\text{m}^3$, at the receptor located at (-25,000, 5,000).³⁶⁵ The annual average NAAQS for sulfur dioxide is $80 \mu\text{g}/\text{m}^3$.³⁶⁶ Thus, the initial allocation does not result in violation of the applicable ambient standard. Accordingly, pursuant to Step 1 of Figure 1, the initial data are loaded on the website and, pursuant to Step 2, the website is placed in operation and is ready to await proposed trades.

We now illustrate how the model would deal with a series of hypothetical trades, presented in sequence. For each proposed trade, Table 5 presents the identities of the buyer and seller, the number of permits involved, and the ultimate disposition.

365. We have programmed the model to list the five receptors with the highest predicted concentrations. See generally 1 USER'S GUIDE, *supra* note 350, § 3.8 (discussing output options). In addition, the model can be programmed automatically to flag violations of a pertinent ambient standard. See *id.* § 3.8.1, at 3-117 to 3-120.

366. See 40 C.F.R. § 50.4(a) (2000).

TABLE 5 – SEQUENCE OF PROPOSED TRADES

Proposed Trade	Purchaser Source	Seller Source	Number of Permits	Disposition
A	16	12	5,000	Approved
B	7	13	10,000	Disapproved
C	7	8	10,000	Approved
D	11	13	5,000	Approved
E	18	15	5,000	Preliminarily approved, ultimately disapproved³⁶⁷

Proposed Trade A. – In Proposed Trade A, Source 16 seeks to purchase 5,000 permits from Source 12 at a price agreeable to both sources.³⁶⁸ Pursuant to Step 3 of Figure 1, the broker who brought the buyer and seller together submits the proposed trade to the website for approval. The website translates the number of permits in the proposed trade into changes in the rates of emissions for the buyer and seller. The conversion factor of 0.1315 grams of sulfur per second, per permit, reveals that a transfer of 5,000 permits would authorize Source 16 to emit 657.50 more, and Source 12 to emit 657.50 fewer, grams per second of sulfur dioxide. Accordingly, pursuant to Step 4, the website preliminarily – solely for purposes of a test run – adjusts the emissions profiles in Table 2 to reflect this change.³⁶⁹ If the trade were approved, Source 12 would have 8,000 allowances – its initial allocation of 13,000 minus the 5,000 it wishes to sell – and be permitted to emit 1,052.00 grams of sulfur dioxide per

367. As discussed in greater detail below, the buyers and sellers involved in Proposed Trades D and E seek preliminary “advice” from the website as to whether the trades at that juncture would be permitted, and the website indicates that both trades would receive approval. Thereafter, Proposed Trade D is finalized first and is approved. The approval and implementation of Proposed Trade D, however, results in the subsequent disapproval of Proposed Trade E.

368. We consider the demand and supply for permits, and therefore the price at which permits will trade, to be exogenous to our simulation.

369. The other input data as set out in Table 1 – including the location of each Source, each Source’s stack height, and the temperature and velocity of pollution emissions – remain unchanged.

In running our simulation, we have manually executed the changes to the input data and then run the model using the modified input data. If the model predicts an ambient standard violation, we revert to the previous data for the next proposed trade; otherwise, we rely on the modified input data going forward. We do not believe that it would be complicated to program the website to perform these tasks automatically.

second. Source 16 would have 10,000 allowances – its initial allocation of 5,000 plus the 5,000 it seeks to purchase – and be permitted to emit 1,315.00 grams of sulfur dioxide per second.

Pursuant to Step 4, the website performs the test run and, pursuant to Step 5, determines whether the proposed trade would result in a violation of the ambient standard at any receptor. The five highest sulfur dioxide concentrations predicted by the model, and the corresponding receptor coordinates, are set forth in Table 6. In particular, the model reveals that, after the proposed trade, the highest concentration of sulfur dioxide would be 78.67684 $\mu\text{g}/\text{m}^3$ at the receptor located at (-25,000, 5,000).

TABLE 6 – FIVE HIGHEST PREDICTED ANNUAL AVERAGE SULFUR DIOXIDE CONCENTRATIONS AFTER PROPOSED TRADE “A”

RECEPTOR		CONCENTRATION
X-Coordinate(m)	Y-Coordinate(m)	($\mu\text{g}/\text{m}^3$)
-25,000	5,000	78.67684
-35,000	-5,000	76.50882
5,000	-25,000	75.92568
-35,000	5,000	69.41383
-25,000	-5,000	67.00747

Because this maximum concentration is less than the ambient standard of 80 $\mu\text{g}/\text{m}^3$, the website proceeds to Step 6N. The website approves and registers the trade. Source 16 pays Source 12, and takes possession of the 5,000 permits. The website saves permanently the new emissions profiles and returns to Step 2 to await the next proposed trade.

Proposed Trade B. – Following the approval of Trade A, Source 7 proposes to purchase 10,000 permits held by Source 13. The broker proposes the trade to the website pursuant to Step 3, and the website, pursuant to Step 4, modifies the data preliminarily for the test run. The proposed transfer would result in an allocation of 47,500 allowances to Source 7, permitting it to emit 6,246.25 grams of sulfur dioxide per second; and an allocation of 20,500 allowances to Source 13, permitting it to emit 4,010.75 grams of sulfur dioxide per second.

Table 7 presents the five highest sulfur dioxide concentrations. It indicates that Proposed Trade B would result in an increase in the predicted concentration at the receptor located at (5,000, -25,000) from 75.92568 $\mu\text{g}/\text{m}^3$ to 80.00536

$\mu\text{g}/\text{m}^3$, because Source 7 is located closer to the ridge along the negative x- and y-axes than is Source 13. This level exceeds the applicable NAAQS of $80 \mu\text{g}/\text{m}^3$. Accordingly, the website proceeds to Step 6Y and rejects Proposed Trade B. Source 13 retains its 10,000 permits and the website reverts to the input data it maintained before the submission of Proposed Trade B.

TABLE 7 - FIVE HIGHEST PREDICTED ANNUAL AVERAGE SULFUR DIOXIDE CONCENTRATIONS AFTER PROPOSED TRADE "B"

RECEPTOR		CONCENTRATION ($\mu\text{g}/\text{m}^3$)
X-Coordinate (m)	Y-Coordinate (m)	
5,000	-25,000	80.00536
-25,000	5,000	79.85377
-35,000	-5,000	77.55901
-35,000	5,000	70.21914
-25,000	-5,000	67.97992

Proposed Trade C. - Having had its bid to obtain 10,000 permits from Source 13 rejected, Source 7 proposes the purchase of 10,000 permits from Source 8. The broker submits the proposed trade to the website, which modifies its emissions data preliminarily for a test run. Here, the proposed transfer of 10,000 permits would result in an allocation of 47,500 allowances to Source 7, permitting it to emit 6,246.25 grams of sulfur dioxide per second; and an allocation of 28,000 allowances to Source 8, permitting it to emit 3,682.00 grams of sulfur dioxide per second.

Results from the trial run appear in Table 8, which shows that the highest concentration, at the receptor located at (-25,000, 5,000), would be $79.73281 \mu\text{g}/\text{m}^3$. Like Proposed Trade B - and unlike Proposed Trade A - Proposed Trade C increases the highest predicted sulfur dioxide concentration. But like Proposed Trade A - and unlike Proposed Trade B - the highest concentration that would result from Proposed Trade C is below the NAAQS level of $80 \mu\text{g}/\text{m}^3$. Thus, pursuant to Step 6N, the website approves Proposed Trade C. The 10,000 permits change hands and the website saves the new emissions profiles.

TABLE 8 - FIVE HIGHEST PREDICTED ANNUAL AVERAGE SULFUR DIOXIDE CONCENTRATIONS AFTER PROPOSED TRADE "C"

RECEPTOR		CONCENTRATION ($\mu\text{g}/\text{m}^3$)
X-Coordinate (m)	Y-Coordinate (m)	
-25,000	5,000	79.73281
5,000	-25,000	79.51790
-35,000	-5,000	77.01582
-35,000	5,000	69.96073
-25,000	-5,000	67.12720

The different dispositions of Proposed Trades B and C illustrate that where several sources are grouped close together (thus contributing to a relatively high concentration at one or more receptor points), sources in the group may be precluded from obtaining permits from sources outside the group. In contrast, however, sources in the group may be able to obtain permits from one another.³⁷⁰ In our simulation, Source 7 is located in close proximity to Sources 5, 6, 8, 9, 10, and 11; Source 13 is not close to that group. Source 7 is able to purchase 10,000 permits from Source 8 because Source 7's increase in emissions is offset (at least enough to avoid an ambient standard violation) by Source 8's decrease in emissions. In contrast, if Source 7 bought the permits from Source 13, there would be no corresponding offset.

Proposed Trades D and E. - Sources 13 and 15 both are contemplating the sale of 5,000 permits. Although neither source is yet ready to commit to a transaction, each approaches a broker to explore whether such a transaction could be achieved. The first broker matches Source 13 with Source 11, which wants to purchase the 5,000 permits (Proposed Trade D). The second broker matches Source 15 with Source 18, which also wishes to purchase 5,000 permits (Proposed Trade E). In accordance with the prospective sellers' wishes, both brokers submit the proposed trades to the website to see whether they would receive approval at that time.

Under Proposed Trade D, Source 11 would have an allocation of 26,500 allowances, permitting it to emit 3,484.75 grams of sulfur dioxide per second; and Source 13 would have an allocation of 25,500 allowances, permitting it to emit 3,353.25 grams of sulfur dioxide per second. In contrast, Proposed Trade

370. See *supra* text accompanying notes 341-342.

E would leave the allowances allocations to Sources 11 and 13 unmodified, but would result in an allocation of 5,000 allowances to Source 15, permitting it to emit 657.50 grams of sulfur dioxide per second, and an allocation of 40,000 allowances to Source 18, permitting it to emit 5,260.00 grams of sulfur dioxide per second. The results of the model's preliminary runs using these two alternative modified data sets are presented in Tables 9 and 10, respectively.

TABLE 9 - FIVE HIGHEST PREDICTED ANNUAL AVERAGE SULFUR DIOXIDE CONCENTRATIONS AFTER PROPOSED TRADE "D"

RECEPTOR		CONCENTRATION ($\mu\text{g}/\text{m}^3$)
X-Coordinate (m)	Y-Coordinate (m)	
-25,000	5,000	79.92408
5,000	-25,000	79.53375
-35,000	-5,000	76.95300
-35,000	5,000	69.88169
-25,000	-5,000	67.25922

TABLE 10 - FIVE HIGHEST PREDICTED ANNUAL AVERAGE SULFUR DIOXIDE CONCENTRATIONS AFTER PROPOSED TRADE "E"

RECEPTOR		CONCENTRATION ($\mu\text{g}/\text{m}^3$)
X-Coordinate (m)	Y-Coordinate (m)	
-25,000	5,000	79.85539
5,000	-25,000	79.77068
-35,000	-5,000	77.28320
-35,000	5,000	70.35979
-25,000	-5,000	67.26674

The model predicts that the highest sulfur dioxide concentrations would be $79.92408 \mu\text{g}/\text{m}^3$ for Proposed Trade D and $79.85539 \mu\text{g}/\text{m}^3$ for Proposed Trade E – in both cases at receptor (-25,000, 5,000). Neither maximum concentration exceeds the NAAQS limit of $80 \mu\text{g}/\text{m}^3$. The website therefore determines that, as of that time, each transaction would receive approval.

The brokers inform their respective clients of this preliminary finding, and the parties to Proposed Trade D are first to direct their broker to submit the trade to the website for final approval. We assume that no other trades have been approved

and registered in the interim, and so the website approves Proposed Trade D and saves the new emissions profiles.

Subsequently, the parties to Proposed Trade E seek final approval for their trade. The intervening trade, however, changes the effect of Proposed Trade E. A run of the model, with the emissions profiles reflecting the purchase by Source 11 of Source 13's permits in Proposed Trade E, indicates that the highest sulfur dioxide concentration - again at the Receptor at (5,000, -25,000) - will be 80.07030 $\mu\text{g}/\text{m}^3$. Because this level exceeds the applicable NAAQS, the website disapproves of Proposed Trade E. No permits change hands, and the emissions profiles remain the same.

TABLE 11 - FIVE HIGHEST PREDICTED ANNUAL AVERAGE SULFUR DIOXIDE CONCENTRATIONS AFTER EFFECTED TRADE 3 AND PROPOSED TRADE "E"

RECEPTOR		CONCENTRATION
X-Coordinate (m)	Y-Coordinate (m)	($\mu\text{g}/\text{m}^3$)
-25,000	5,000	80.04666
5,000	-25,000	79.78654
-35,000	-5,000	77.22038
-35,000	5,000	70.28074
-25,000	-5,000	67.39875

The different dispositions of Proposed Trades D and E illustrate that under our trading regime the order of trades matters.³⁷¹ Here, the transaction between Sources 11 and 13 foreclosed the trade between Sources 18 and 15.

V

REFINEMENTS OF THE PROPOSAL

In this Part, we analyze several possible refinements to our proposed trading regime. The first two relate to the choice of and use of the air pollution dispersion model. Then, we consider the purchase of allowances by new sources, the use of allowances by reconfigured sources, and the possibility of having different ambient standards at different locations. The remaining refinements concern ways to incorporate into our proposal certain practices of existing trading regimes, such as auctions of

371. See *supra* Section IV.C.1.

allowances, retirement of allowances, purchases of allowances for investment purposes, and banking of allowances. All of these extensions could easily be incorporated into our simulation.

A. *The Choice and Use of the Air Pollution Dispersion Model*

1. *Choice of Model*

One objection that might be leveled against our proposal concerns the reliability of the air pollution dispersion model used to determine violations of the ambient standards. Such models are useful devices to predict what should happen to air pollutants based upon physical formulae and prior empirical data.³⁷² It is possible, however, that a model does not accurately capture all the intricacies of weather patterns, topography, and chemistry that determine air pollution dispersion.³⁷³ Further, even if a model is otherwise designed accurately to predict air dispersion, the model's predictions will be only as good as the empirical data that are used as inputs.³⁷⁴

Our proposal, however, does not rely on models and input data any more than existing EPA programs and regulations do.³⁷⁵

372. See ZANNETTI, *supra* note 59, § 2.2.

373. See *id.* § 2.6, at 35; Craig N. Oren, *Prevention of Significant Deterioration: Control-Compelling Versus Site-Shifting*, 74 IOWA L. REV. 1, 40 (1988).

374. See ZANNETTI, *supra* note 59, § 2.2; Westbrook, *supra* note 348, at 550 tbl. 1; Oren, *supra* note 373, at 40. In particular, the meteorological data used in atmospheric dispersion models play a major role in the predictions made by such models. See Seventh Conference on Air Modeling (June 29, 2000) (meteorological modeling and data "can be the largest source of error" in atmospheric dispersion models) (statement of Jeffrey McQueen, NOAA).

375. See ERBES, *supra* note 58, at 64-65:

Under the best of circumstances that precisely match the assumption built into the Gaussian formulation (i.e., flat terrain, constant wind conditions, 5- to 10-minute averaging times), the models predict concentrations within about a factor of two of actual observations. However, the regulatory and parameter assumptions and defaults used often cause the models to overpredict concentrations by factors of 10 or more. Therefore, it is not unusual for monitoring results to be much, much different than modeled results. However, EPA and local agencies routinely use models on which to base their permitting and other air quality decisions.

See also Westbrook, *supra* note 348, at 546 ("[D]ispersion modeling results can be 'wrong,' as long as everyone consistently uses the same modeling tools and methods to get similar wrong results."); *id.* at 551 ("Regulatory dispersion models are designed to be conservative (i.e., to overpredict air concentrations)"). Thus, regulatory agencies can be assured that modeling output will err on the side of being protective of health. Since regulatory compliance under most state air toxics programs are tied to fixed concentration ceilings, regulations usually require precise model results without regard to model inaccuracy.").

For example, the Clean Air Act requires states to develop SIPs indicating how they will control their existing sources in order to meet the NAAQS.³⁷⁶ EPA mandates that states use atmospheric modeling to demonstrate that their SIPs will lead to the attainment of the NAAQS.³⁷⁷ The Act also requires that SIPs include a means of evaluating modifications of existing sources and constructions of new sources to ensure that such changes do not interfere with the attainment of the ambient standards.³⁷⁸ Atmospheric models must be used to make these determinations.³⁷⁹

EPA maintains a list of approved atmospheric dispersion models.³⁸⁰ For our simulation, we used one of the models that EPA recommends, the ISC3 Model, which is the "work-horse" for EPA's compliance determinations.³⁸¹ Thus, to the extent that the ISC3 Model might lead to inaccurate predictions, its use under our trading scheme would not lead to more inaccurate results than those generated under the current regime.

We recognize, however, that, as technology and science's understanding of the physics of air and weather patterns and the chemistry of air pollutants advance, more accurate atmospheric models will emerge. For example, two newer models were

376. See 42 U.S.C. § 7410(a)(2) (1994). The state implementation plan also must ensure that the requirements applicable to any areas designated as either "nonattainment areas" or "prevention of significant deterioration areas" are met. See *id.* § 7410(a)(2)(I), (J). We discuss below the application of our proposal to such areas. See *infra* text accompanying notes 400-401.

377. See 40 C.F.R. § 51.112(a)(1) (2000) ("The adequacy of a [state implementation plan's] control strategy shall be demonstrated by means of applicable air quality models, data bases, and other requirements specified in appendix W of this part (Guideline on Air Quality models).").

378. See 42 U.S.C. § 7410(a)(2)(C) (1994); 40 C.F.R. § 51.160 (2000).

379. See 40 C.F.R. § 51.160(f)(1) (2000) ("All applications of air quality modeling involved in this subpart [relating to review of new sources and modification of existing sources] shall be based on the applicable models, data bases, and other requirements specified in appendix W of this part (Guideline on Air Quality Models.); *id.* pt. 51, app. W § 1.0 ("The Guideline recommends air quality modeling techniques that should be applied to State Implementation Plan (SIP) revisions for existing sources and to new source reviews, including prevention of significant deterioration (PSD).") (footnotes omitted)).

380. See 40 C.F.R. pt. 50 app. W (2000). Courts generally defer to EPA's recommendations and choices regarding the use of computer models. See Charles D. Case, *Problems in Judicial Review From the Use of Computer Models and Other Quantitative Methodologies in Environmental Decisionmaking*, 10 B.C. ENVTL. AFF. L. REV. 251 (1982); Camille V. Otero-Phillips, Note, *What's in the Forecast? A Look at the EPA's Use of Computer Models in Emissions Trading*, 24 RUTGERS COMPUTER & TECH. L.J. 187 (1998).

381. See *supra* text accompanying notes 345-350.

presented at a recent EPA conference on air quality modeling³⁸² – AERMOD and CALPUFF. AERMOD, another Gaussian dispersion model,³⁸³ is more advanced than ISC3.³⁸⁴ Accordingly, EPA has proposed that AERMOD replace the ISC3 Model “for many air quality impact assessments.”³⁸⁵ Moreover, EPA is proposing to recommend the use of CALPUFF³⁸⁶ “for refined use in modeling long-range transport and dispersion to characterize reasonably attributable impacts from one or a few sources for [prevention of significant deterioration] Class I impacts.”³⁸⁷

Another atmospheric dispersion model is the Regional Air Pollution Information and Simulation (RAINS) model.³⁸⁸ RAINS was developed by the Austrian-based International Institute for Applied Systems Analysis to evaluate problems of transboundary transport of air pollutants in Europe, and has been relied upon in treaty negotiations.³⁸⁹ In particular, RAINS has been used to

382. See Requirements for Preparation, Adoption, and Submittal of State Implementation Plans (Guideline on Air Quality Models); Conference on Air Quality Modeling, 65 Fed. Reg. 31,858 (2000) (announcing conference to be held June 28-29, 2000).

383. See Requirements for Preparation, Adoption, and Submittal of State Implementation Plans (Guideline on Air Quality Models), 65 Fed. Reg. 21,506, 21,506 (2000) (proposed Apr. 21, 2000). For a discussion of Gaussian dispersion models, see *supra* note 347.

384. AERMOD was developed by a committee formed by the EPA and the American Meteorological Society. See Requirements for Preparation, Adoption, and Submittal of State Implementation Plans, *supra* note 383. The AERMOD model, then in development, was initially presented at the EPA's Sixth Conference on Air Quality Modeling. See *id.*; Notice, Conference on Air Quality Modeling, 60 Fed. Reg. 33,411, 33,412 (1995). The model consists of three components: “AERMOD – the air dispersion model; AERMET – the meteorological data preprocessor; and AERMAP – the terrain data preprocessor.” Seventh Modeling Conference, at <http://www.epa.gov/ttn/scram/> (last updated June 22, 2000).

AERMOD's improvements over the ISC3 Model “include better dispersion and plume rise simulation within the well-mixed atmosphere near the earth's surface, and better terrain handling procedures.” Westbrook, *supra* note 348, at 551; see 65 Fed. Reg. at 21,506 (describing it as a “state-of-the-practice Gaussian plume dispersion model whose formulation is based on planetary boundary layer principles”).

385. 65 Fed. Reg. at 21,507.

386. CALPUFF is “a Lagrangian dispersion model that simulates pollutant releases as a continuous series of puffs.” *Id.* at 21,507.

387. 65 Fed. Reg. at 21,508. We discuss the application of our proposal to such areas. See *infra* text accompanying notes 400-401.

388. See The RAINS 7.2 Model of Air Pollution: General Overview at <http://www.iiasa.ac.at/~rains/doc/manual/intro.htm> (visited June 16, 2000); Cleaner Air for a Cleaner Future: Controlling Transboundary Air Pollution – A Description of the RAINS Model at <http://www.iiasa.ac.at/Admin/INF/OPT/Summer98/description.htm> (1998).

389. See Cleaner Air for a Cleaner Future: Controlling Transboundary Air Pollution, at <http://www.iiasa.ac.at/Admin/INF/OPT/Summer98/feature.htm> (1998). The Institute for Applied Systems Analysis also has developed a version of

match areas that contribute sulfur emissions with the areas and ecosystems that are harmed by those emissions, and to determine what emission reductions would be required from what regions to protect adequately the downwind areas and ecosystems.³⁹⁰

The use of the ISC3 Model is not essential to our proposal. The website could be programmed to rely upon any atmospheric dispersion model to make predictions as to ambient pollutant concentrations at the receptor points. Thus, there is nothing in our proposal that would preclude the integration of AERMOD, CALPUFF, or RAINS (or of any more advanced, and more accurate, atmospheric dispersion model) in place of the ISC3 Model when EPA determines that other models are indeed preferable.³⁹¹

2. *Refining the Use of the Model*

In our simulation, we placed receptors homogeneously throughout the regulated region.³⁹² Because our regime bars a trade only if it would result in the violation of an ambient standard at a receptor point, a trade might result in a violation at a location between receptor points but nonetheless be approved. While current models do not allow for the calculation of expected pollutant concentrations at all points within a region, which would involve the inclusion of an infinite number of receptor points, three modifications to our trading regime would ameliorate this potential problem.

One possibility is simply to place more receptors.³⁹³ For example, the ISC3 Model, as run on a DOS system, allows for the

RAINS to address transboundary pollutant transport in Asia. See *Cleaner Air for a Cleaner Future: Controlling Transboundary Air Pollution - A Description of the RAINS Model*, at <http://www.iiasa.ac.at/Admin/INF/OPT/Summer98/description.htm> (1998).

390. See *Cleaner Air for a Cleaner Future: Controlling Transboundary Air Pollution - RAINS and Its Role in Negotiations*, at <http://www.iiasa.ac.at/Admin/INF/OPT/Summer98/negotiations.htm> (1998).

391. Some transition rule would be required to deal with the upgrading of the atmospheric model, since it might lead to a change in the predicted concentrations. In particular, the new model could predict the violation of ambient air quality standards in areas in which the previous model predicted compliance. Presumably, the new model could be integrated into the system only at the end of a permit period, so that current distributions of permits would not be affected by the change in models. By contrast, a transition rule would be required to address permits that have been banked, as well as futures and options contracts that span permit periods in which different models were in effect.

392. See *supra* text accompanying notes 351-353.

393. As one group of commentators noted:

placement of up to 500 receptors and up to five receptor networks.³⁹⁴ Moreover, those numbers can be increased, depending upon the available memory capacity.³⁹⁵ Additional receptor points, however, may slow down the computations. Thus, there may be a tradeoff between more accurate predictions and predictions that are sufficiently fast to satisfy the market participants.³⁹⁶

Second, receptors should be placed where violations of ambient standards are most likely to occur. For example, if measurements of air quality indicate that pollutant concentrations are especially high in a given area, the computer program should include additional receptors in that area. Similarly, additional receptors should be included on the windward side of a mountain range because substantial amounts of pollution may be trapped on the side of the range.³⁹⁷

A third course of action would be to program the website automatically to include additional receptors in the immediate vicinity of an existing receptor if the model predicts that the ambient pollutant concentration at this receptor comes within a certain range of the applicable ambient standard. For example, if a standard run of the model for sulfur dioxide concentrations reveals that the predicted annual average ambient concentration at a given receptor will be $79 \mu\text{g}/\text{m}^3$ – within $1 \mu\text{g}/\text{m}^3$ of the applicable NAAQS – the website program could add additional receptors at a relatively small radius around the existing receptor.³⁹⁸

[T]he Clean Air Act requires that the [NAAQS] be met at all locations. But for pollutants with more localized effects (and this includes most of the criteria air pollutants), it is possible for changing locational patterns of emissions to generate "hot spots" that do not coincide with designated receptor points. To prevent the occurrence of localized hot spots for such pollutants, a relatively fine mesh of receptor points will be needed

Krupnick et al., *supra* note 292, at 244; see Westbrook, *supra* note 348, at 550 tbl. 1 ("The reported maximum impact can be sensitive to the [receptor] grid resolution and reference point (origin point).").

394. See I USER'S GUIDE, *supra* note 350, § 2.3, at 2-10.

395. See *id.*; *id.* § 3.4, at 3-59; *id.* § 4.2.2.

396. Unlike the case of environmental degradation markets, see *supra* Section III.C, under our regime additional receptors do not require the formation of additional markets.

397. See Revesz, Note, *supra* note 32, at 810 ("[A] sulfur dioxide emission downwind from a mountain range will have an effect on a far wider area than a similar emission upwind from a physical barrier.").

398. The size of the radius presumably would depend upon the distance between existing receptors. In our working simulation, we placed receptors that were at a minimum 10 kilometers apart. In that situation, one might opt to add receptors at a radius of 1 kilometer around the existing receptor.

B. *New Sources*

The simulation in Part IV dealt only with transfers of allowances among existing sources. The treatment of allowance purchases by new sources would proceed no differently. The website would obtain the location of the new source and temporarily update its emission data to consider whether the proposed emissions increase at that location, combined with the decrease of emissions at the seller's location, would contribute to the violation of an ambient standard. If the proposed transfer would produce a violation, the website would reject it. If not, the website would approve the transfer and save permanently the new emissions data.³⁹⁹

C. *Changes to Existing Sources*

The simulation in Part IV assumed that all sources' relevant specifications – that is, all the specifications that determine the location and extent of damage caused by their emissions – remain constant. In fact, under our proposal, sources would have to seek approval for the continued use of their permits in the event that their relevant specifications changed.

For example, if a source changed its location (i.e., if the owner of a factory moved its production facilities to a new location), then the source would have to seek approval for continued use of the permits it already held. The data the source would submit to the website – and the decision process undertaken by the website – would be exactly the same as if a source located at the old location sought to sell all its permits to a new source located at the new location.

A source that tore down its old smokestack and erected one of different height (whether higher or lower) also would have to seek reapproval. Similarly, the data submitted to the website would be the same as if a source with a smokestack of the old height sought to sell its permits to a source with a smokestack of the new height at the same location.

If the website denied the reconfigured source authorization to continue to use all or some of its permits, then the source would be faced with a choice. First, it might try to sell the permits that it could no longer use. Second, to the extent that it did not want to scale back its production capacity, it could wait in the hope that a subsequent trade of permits by other actors

399. See *supra* Section IV.C.3 for discussion of how this proposal would discourage the placement of new sources in highly polluted areas.

1. Auctions of Allowances

As we explained above, the sulfur dioxide program provides for an annual auction of allowances, in addition to the grandfathering of existing sources.⁴⁰³ The Chicago Board of Trade, operating on EPA's behalf, currently conducts the sulfur dioxide allowance auction. Interested parties submit bids indicating the number of allowances they seek to purchase and the price they are willing to pay. The Chicago Board of Trade determines the price that would lead to the sale of all the available allowances. All bids at or above that price are then accepted, with each successful bidder paying the amount it bid.⁴⁰⁴

Consistent with the logic of our proposed trading regime, before accepting a bid the Chicago Board of Trade could verify that the transfer of the allowance to the successful bidder would not result in the violation of an ambient standard at any receptor point. In light of the current auction structure, it would make sense for bidders placing higher bids to receive priority in determining whether the bidder's purchase would result in an ambient standard violation. In other words, to the extent that two bidders' purchases taken together would result in an ambient standard violation but individually would not, the system would approve the higher bidder's bid and reject the lower bid.

Our approach would have the effect of lowering somewhat the total revenues from the auction. Indeed, because certain high bidders might not be able to purchase permits as a result, the Chicago Board of Trade would need to turn to lower bidders.

2. Retirement of Allowances

Environmentalists and environmental groups sometimes purchase allowances for the purpose of retiring them so as to reduce the total amount of pollution.⁴⁰⁵ Our proposal readily

403. See *supra* text accompanying notes 85-88. In addition, some commentators have advocated the abandonment of the grandfathering-based allocation system in favor of a full-fledged auction distribution system. See, e.g., Nash, *supra* note 21, at 505-09, and the authorities cited therein.

404. See *supra* note 87.

405. See Erik Kriss, *NIMO Gives Away Dirty Air Credits: Environmental Groups Will Retire Credits Which Will Allow Companies to Emit Pollution*, SYRACUSE HERALD-JOURNAL, Apr. 2, 1997, at A12; *Adirondack Group Seeks Bids to Retire Pollution Permits*, BUFF. NEWS, Apr. 2, 1997, at B10; Campbell & Holmes, *supra* note 141. For example, the EPA website helpfully notes:

might change the distribution of permits sufficiently that it could use the permits it held, or it could purchase (with website approval) additional permits that it could in fact use.

D. Variable Ambient Standards

The simulation in Part IV assumed, for expositional convenience, that uniform ambient standards would apply throughout the region. Despite the uniformity of the NAAQS, the Clean Air Act in fact imposes disuniform ambient standards throughout the country. In areas that have ambient air quality levels that are better than the NAAQS, the Prevention of Significant Deterioration (PSD) program imposes a more stringent ambient standard, defined by reference to a baseline plus an increment.⁴⁰⁰ In contrast, areas that have failed to comply with the NAAQS – the nonattainment areas – are subject to a less stringent requirement. Until some time in the future, such areas must make “reasonable further progress” toward attainment, rather than actually achieve attainment.⁴⁰¹

The website could easily be programmed to apply different ambient pollution concentration constraints at different locations. For example, the website might reject trades that would result in annual average ambient concentrations of sulfur dioxide in excess of $80 \mu\text{g}/\text{m}^3$ at some locations, but in excess of $60 \mu\text{g}/\text{m}^3$ at other locations. The website could also be programmed to reject trades that would result in any increases in ambient concentration levels at certain receptor points.⁴⁰²

E. Current Market Practices

We focus here on how our proposal would deal with various practices under the national sulfur dioxide trading program: auctions of allowances, retirement of allowances, purchases of allowances for investment purposes, and banking of allowances.

400. See 42 U.S.C. § 7473(a) (1994); see also *id.* § 7479(4) (defining “baseline concentration”).

401. See *id.* § 7502(c)(2); see also *id.* § 7501(1) (defining “reasonable further progress”).

402. Along these lines, we note that our proposal works well even if the policymaker decides that, because of a concave harm function, it is desirable to concentrate pollution rather than to disperse it. To achieve this goal, one simply would have to apply very stringent ambient standards in most locations and lax ones in the few locations where the pollutant is to be concentrated.

accommodates such transactions. The purchaser simply would indicate that it sought to retire them. The website would then decrease the seller's emissions accordingly, but there would be no corresponding increase in emissions at another location. As a result, the website would never prohibit a retirement transaction.⁴⁰⁶

3. *Purchases of Allowances for Investment Purposes*

Investors might be interested in purchasing pollution allowances for investment purposes, intending to hold them until they can be sold at a profit. Also, brokers may purchase allowances to act as "market-makers," without intending to use the allowances or resell them immediately. As in the case of retirement transactions, the website would credit an emission reduction but not add a corresponding increase in emissions. Again, no such transaction would ever be rejected.

When the holder was ready to sell the allowances, however, it would have to receive permission from the website to proceed with the sale. As in the case of all other transactions, the website would determine whether the increase in emissions would result in violations of ambient standards. Unlike the case of transactions between contemporaneous emitters, there would be no corresponding decrease in emissions, because this decrease would already have been taken into account at the time the investor purchased the allowances.

Our proposal would complicate matters for allowance purchasers with investment motives. Prospective investors would have to take account of the possibility that allowances that they

Environmentally-focused allowance buyers may be interested in contacting an organization that specifically acquires and retires allowances, preventing them from being used to cover SO₂ emissions. For example, The Clean Air Conservancy will purchase allowances for you and provide you with a "Clean Air Certificate," documenting the amount of pollution your contribution has prevented.

EPA, Buying Allowances, at <http://www.epa.gov/airmarkets/trading/buying.html> (last updated April 18, 2001).

406. The retirement system proposed in the text simply assumes that permits purchased for retirement purposes would be deemed by the website as "unused". Another approach would allow an actor purchasing a permit for retirement purposes to specify a location at which the permit is "deemed" to be used. In this way, the purchaser could, in addition to reducing the total amount of pollution emissions throughout the region, also target a particular area for ambient pollution reduction. While this advantage might induce additional actors to purchase permits for retirement purposes, it might also draw criticism from environmental justice advocates on the ground that it would allow communities with more disposable funds to buy their way out of pollution problems.

purchase now may be saleable only to a limited pool of buyers at some point in the future. In that case, the allowances would command a lower price than in a system of unconstrained trading – although, for the same reason, the investor may have bought them at a lower price as well. Moreover, investors might feel pressure to sell allowances earlier out of fear that a delay might preclude (or make less attractive) sales later. At the same time, however, if an investor finds that it cannot sell the allowances at an acceptable price because of a limited pool of buyers, it would have the option of holding them until a later date.⁴⁰⁷

4. *Banking of Allowances*

Some entities obtain allowances with the intent of using them only in the future.⁴⁰⁸ Our proposed trading regime is compatible with such banking of allowances. It simply would require that the website maintain emission input data for multiple years into the future.

A source seeking to bank an allowance for future use would notify the website of the year in which it intended to use the allowance. The website first would test whether the proposed use of the allowance in the future year would result in the violation of an ambient standard in that year, given the existing emission input data for that year, as augmented by the proposed additional emissions. If the model predicted that an ambient standard would be violated, it would reject the proposed banking. If not, the transaction would be approved and the website would update the emissions profile for the future year. It would also modify the emissions date for the current year to reflect the resulting decrease in emissions.⁴⁰⁹

407. Our proposal is also consistent with establishment and maintenance of futures and options markets based upon emissions permits. Specifically, actors still might contract to transact permits in the future at a price agreed upon today. It is true that the website might, at the time of the trade in the future, constrain the buyer's ability to use the permits that it obtains. However, even under that circumstance, the buyer still would be free either to sell the permits (with website approval) or to retain the permits in the hope that subsequent trades might enable the buyer to use the permits. The operation of such markets likely would require development of an appropriate transition rule in the event that EPA changed computer models between the time that a option or futures contract was entered into and the time that it is fulfilled. See *supra* note 391.

408. See Fradette et al., *supra* note 150, at 481 (“[M]any utilities are choosing to overcomply in Phase I and bank the excess emission allowances for Phase II compliance.”).

409. A holder also could choose to take an allowance it previously had elected to bank until one year in the future and change the election either to use the allowance

We acknowledge that our trading regime would impose some limits on the ability of sources to bank their emissions.⁴¹⁰ Moreover, sources would have an incentive to declare their intent to bank sooner, before too many other sources had done so.⁴¹¹ Such constraints, however, are necessary to ensure the attainment of the applicable ambient standards.

CONCLUSION

This Article highlights how traditional tradable pollution permit regimes fail to guard against the violation of ambient standards and the formation of hot spots. The existing regulatory programs that provide for such market transactions all exhibit these problems. Similarly, three alternative design structures advocated by commentators either provide incomplete solutions or give rise to other potentially serious shortcomings.

We propose a new trading regime that might increase the attractiveness of market-based schemes. Under this regime, the government maintains a website containing current emissions data for all the sources of a regulated pollutant. Using an atmospheric dispersion model, the website determines whether a proposed trade leads to a violation of an applicable ambient standard (or the formation of a hot spot), and disapproves trades causing such violations. We demonstrate, by means of a computer simulation, how our trading regime would function, and explain why it performs better than the existing alternatives.

in a different future year, or in the present. The website would consider such a proposal in the same manner. Our proposed regime easily accommodates intertemporal trades.

Similarly, a holder that wanted to bank a permit but was unsure of the year in which it would use the permit could delay that determination. Once it decided on the year in which it would use the permit, it then could seek permission from the website to use the permit in that year. Such a strategy would subject the holder to the risk that the website might withhold permission even though it would have granted permission had the holder sought it earlier.

410. In addition to the constraints discussed in the text, an appropriate transition rule would be required to govern situations where EPA changed computer models between the time at which a holder banked a permit and the subsequent time at which the holder sought to use the banked permit. See *supra* note 391.

411. It is also possible that a holder may now be precluded from banking an allowance, but may nonetheless be able to do so at a future time as a result of intervening transfers.

