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The Origins and Practice of Emissions Trading

An important development in the field of environmental policy has been the growing acceptance and use of emissions trading as a cost-effective means to meet and maintain environmental quality standards. In the first half of the twentieth century, emissions trading programs not only would have been seen as unnecessary; they would have been inconceivable. The legal, bureaucratic, and technological infrastructure necessary to support such systems simply did not exist. Furthermore, most people did not see the release of pollution-causing contaminants into the shared environment as transactions to be measured and monitored. Today, the use of emissions trading programs as a policy tool both reflects and represents the dramatic changes in pollution control policy that have since occurred.

Emissions trading—one option in a suite of economic incentive instruments that economists, regulators, and policymakers have introduced over the last quarter century—refers to the use of transferable rights, allowances, or credits in programs to control emissions.[1] This examination of how emissions trading programs evolved argues that the first emissions trading programs were an unintended consequence of the Clean Air Act of 1970. Despite some early theoretical work by economists, most precedent-setting decisions were made as regulators, firms, environmental groups, and policy analysts struggled to address practical issues of implementation associated with the Clean Air Act. Today, after almost three decades of practice and theory having refined one another, the ability of program designers and policy analysts to anticipate and address the challenges of specific trading applications has significantly improved. However, some early decisions resulted in precedents that have never received the level of deliberation and debate they warrant.

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To date, the major applications of pollution-related trading include: state-level and regional programs to control emissions of air pollutants in local air sheds; national programs to phase out leaded gasoline and to restrict precursors of acid rain; effluent trading in watersheds; and international programs to control chlorofluorocarbons (CFCs) (Table 1). Emissions trading also has a potential role to play in addressing concerns over global warming by limiting greenhouse gases.[2] The trading of transferable permits has also been applied to nonpollution applications such as development rights for land use, fishing quotas, airport landing slots, renewable energy development, and even the electromagnetic spectrum for telecommunications services.[3] The use of transferable water rights in states such as California serves as an important precedent for all such programs.[4]

The first discussions of using tradable credits to manage the release of pollution-causing contaminants occurred in the 1960s. In the first half of the twentieth century, costs associated with damage and nuisance suits and savings generated by using material more efficiently provided firms with some economic incentive to limit their discharges of pollution-causing wastes.[5] However, by the 1960s, with a growing middle class placing more value on environmental amenities, the nation's air and water were becoming more, not less, polluted. Support for additional regulatory mechanisms increased.[6] As federal legislators debated how best to control air and water pollution, economists considered the possibility of using market systems to control emissions. Critics initially feared that such market-based schemes implied that economics, not the public's desire to breathe clean air, would determine the level of air quality in a region. With a tangible resource such as water, one can allocate only so much of that resource before natural limits—such as a river going dry—take effect. Industrial society's ability to emit pollution had no corresponding natural limits, and few people wished to let "economics" establish those limits.

In the 1970s, emissions trading systems moved from the realm of neoclassical economic theory to real-world applications. As it happened, the first uses of emissions trading were an unanticipated consequence of the Clean Air Act of 1970, which established air-quality standards based on health. In metropolitan areas that failed to meet the required standards, various forms of trading emerged to allow increases in emissions when cuts were also made. Designed in an ad hoc manner and involving the most polluted urban areas of the United States, these programs lacked enforceable systems for monitoring and tracking emissions. Many national environmental

Table 1. Major Applications of Emissions Trading

Name of Program	Pollutant Traded	Duration	Participation Rate
EPA Emissions Trading Program	VOCs, CO, NO_x , SO_2, & Particulates	1974–	Low to Moderate
Leaded Gasoline Phasedown	Lead	1979–87	High
Effluent Trading in Watersheds	Phosphorus, Nitrogen, Oil & Grease, Lead, Zinc,Total Suspended Solids, Copper, BOD	1983–	Low
Transfers Among Parties to Montreal Protocol	CFCs	1989 (–95)	Moderate
Acid Rain Program	SO_2	1992–	Moderate
RECLAIM (Regional Clean Air Incentives Market)	NO_x & SO_2	1994–	Moderate
State-level Emissions Trading Programs	VOCs, CO, NO_x SO_2, & Particulates	1993–	Low
NO_x Budget Program	NO_x	1998–	High

Abbreviations:
VOCs—volatile organic compounds
CO—carbon monoxide
SO_2—sulfur dioxide
NO_x—nitrogen oxides
BOD—biochemical oxygen demand
CFCs—chlorfluorocarbons

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groups, most notably the Natural Resources Defense Council (NRDC), opposed these early applications of air emissions trading.

Only later, in the late 1980s, would major environmental groups, such as the Conservation Foundation and the Environmental Defense Fund (now known as Environmental Defense), become major proponents of emissions trading. By that time, regulators had applied trading to a more successful application, the effort to the phase-out of leaded gasoline, and were considering using a similar program to manage cuts in sulfur dioxide emissions from large power plants. Today, the NRDC supports most advanced forms of emissions trading. Groups such as the Sierra Club, Environmental Action, Greenpeace, and Communities for a Better Environment (in California) still voice objections, but their concerns often have to do with issues of design and equity. For example, environmental activists have accused several trading programs of increasing environmental injustices by exacerbating localized air pollution "hot spots" in poor and minority communities, a concern that can be addressed by changes in the design of trading rules.[7] Over the years, similar concerns raised by critics have been addressed by the designers of trading programs.[8] However, some important issues, such as the philosophy governing the allocation of tradable credits, have received little attention because no real challenge emerged. In allocating the right to emit, significant attention has been paid to the details of various schemes, but not to the general philosophy of allocation.

In general, emissions trading—or trading the rights to discharge certain pollutants into the air or into public bodies of water—is a policy tool in which theory and practice have refined each other over the last several decades. This article outlines the abrupt move from theory to practice in the early 1970s and examines the changes in application and program design that have occurred since. Although this evolution is far from over, an examination of how such programs have evolved up to this point provides insight into the strengths and limits of emissions trading as a policy tool.

Theoretical Foundations: 1960–1974

While economists did not formally explore the theoretical foundations of emissions control systems and their rules until the late 1960s, the groundwork was laid by a seminal article published by Ronald Coase in 1960.[9] Coase's article, which helped win him the Nobel Prize in economics in 1991, considered the problem of social cost and how to solve it in the best interests of society. In sharp contrast to previous work in welfare economics, Coase argued that it does not always make sense to tax a polluting factory based on the damage it causes to its neighbor, such as a laundry. He emphasized that one must consider the alternatives available to the neighbor, such as moving to another location, along with the costs to the polluting factory in determining what option is best. Ideally, Coase argued, participants should be left to their own devices to negotiate the best possible solution. Needless to say, such an outcome was more likely to occur if participants could trade various rights to use the air, which was not seriously considered at the time.

It was not until the late 1960s that more concrete, yet still theoretical, arguments were made for the establishment and structuring of "pollution" markets and thus emissions trading systems. This early work was published independently by Thomas Crocker in the United States for air pollution and John Dales in Canada for water pollution.[10] These authors emphasized the benefits of auctioning off pollution rights to the highest bidder, the results of which would presumably reflect the correct social value to place on the pollution at the desired total quantity. They argued that such auctions could result in the same economically "optimal" level of pollution as would a carefully chosen pollution tax. These early papers touched off debates by economists such as William Baumol, Wallace Oates, Thomas Tietenberg, Terry Ferrar, and Andrew Whinston over the pros and cons of pollution taxes versus emissions trading.[11]

The purpose of establishing a market in "pollution rights" was not always clear in this exploratory work. Was the goal to arrive at a level and distribution of pollution-causing emissions that optimized some measure of happiness or social utility, with consumers of clean air competing with industrial facilities for the right to use that valuable resource? If so, the future of emissions trading—or, in general, pollution trading—looked dim, both to those exploring the topic and to anyone interested in serious changes in environmental quality. Numerous problems undermined any hope that market forces alone could determine an appropriate level and distribution of emissions.[12]

Or was the purpose to help achieve a predetermined environmental objective in an efficient (i.e., cost-effective) manner? That is, was the purpose to allocate a fixed quantity of emissions among firms that desired some portion of the total emissions? In that case, emissions trading looked more promising. By starting with a fixed number of emissions credits, the most important decision—the de-

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sired level of air quality—had already been made by the polity instead of by the market. The market would only be used to allocate the distribution of those emissions credits. It eventually became apparent that emissions trading had a future in this role. In 1972, David Montgomery, who was at Cal Tech at the time, provided the first mathematical argument that the overall cost of achieving an environmental standard could be minimized through marketable permits being traded among firms attempting to minimize their total production costs.[13]

To Montgomery and those who pursued this line of thought, several things appeared necessary:

- Government-enforced limits on the total amount of a certain contaminant that could be emitted in a certain geographic area.
- A mechanism for allocating portions of the total emissions rights to individual firms operating in that area.
- Rules for trading discrete units of those allowances between firms.

These economists did not have much to say on the specifics of what limits to set, how to allocate the initial pool of trading units by mechanisms other than auctions, or how to measure, monitor, and track emissions. However, they did consider problems associated with treating emissions as a commodity. For example, they discussed what constraints might be necessary to avoid emissions from being concentrated in a certain location. Some economists even proposed trading schemes to address specific pollution concerns, such as using biological oxygen demand (BOD) bonds to control discharges of effluent high in BOD into the Delaware estuary.[14] Even so, by the early 1970s consideration of emissions trading schemes had only occurred at a theoretical level among academic economists. This was about to change as the recently established U.S. Environmental Protection Agency (EPA) began to seriously implement the nation's new air-quality legislation.

Offsets, Netting, Bubbles, and Banking: A Move Toward Practice, 1974–1979

The actual move from theory to practice happened unexpectedly. With the Clean Air Act Amendments of 1970 and the creation of

National Ambient Air Quality Standards for "criteria" air pollutants such as sulfur dioxide, nitrogen oxides, and carbon monoxide, the notion of trading emissions soon became a practical issue. That Act required states to meet ambient air-quality standards established by the EPA within three years of those standards being promulgated (i.e., by 1975). For areas not in attainment after that deadline, theoretical issues associated with emissions trading suddenly became real.[15]

Conceptually, the issue was simple. What if an industrial facility that emitted sulfur dioxide desired to expand production in an area that was already out of attainment for sulfur dioxide? Or what if a new sulfur-emitting facility desired to locate in the region? Clearly, if the region was not in attainment for the sulfur dioxide standard, state-level pollution control agencies could not allow increases in emissions. After all, the new emissions would add to whatever problem existed. Although the law required new industrial sources of air contaminants to meet strict emissions limits, any increase in emissions represented a step in the wrong direction. A provision in the Clean Air Act Amendments of 1977 also prohibited any significant deterioration in the air quality of regions that already met ambient standards, which raised similar questions about emissions increases in those regions.[16]

Here then was a practical dilemma faced by heavily industrialized states in the mid-1970s that had to be addressed in a creative way. Simply deciding that a firm could not expand by constructing new facilities or move into a newly designated nonattainment area was not a politically acceptable alternative. Compensating for new emissions by incrementally reducing the emissions of all other emission sources in the regional air shed was not an option either. Even if a mechanism for making such reductions existed, a central regulatory agency could not be expected to reallocate emissions throughout the region in response to each request for new emissions.

In 1976, the Regional Administrator in EPA's San Francisco Office, Paul DeFalco, responded to this dilemma by passing the Offset Interpretative Ruling for California. This ruling specified that new stationary sources of emissions in nonattainment areas (such as Los Angeles) must meet the lowest achievable emission rate and offset their emissions with a greater than one-to-one trade-off rate elsewhere within the air shed.[17] The EPA codified this strategy in the 1977 amendments to the Clean Air Act, which allowed industrial expansion when the added pollution load met all permitting requirements *and* was offset by reductions elsewhere in the region.[18]

This use of tradable offsets thus provided some level of flexibility in allowing new sources of emissions, first in California and then elsewhere in the nation.

In practice, most firms that installed new sources secured their offsets by replacing older, less efficient equipment. In effect, facilities were allowed to offset their own increased emissions with reductions elsewhere in their facility. Given that new equipment had to meet strict emissions standards, securing these offsets usually was not too difficult.[19]

Firms desiring to construct entirely new facilities faced a more difficult challenge than firms wishing to expand or modify their plants. Companies constructing new facilities had to secure their offsets—technically, emissions reduction credits—from existing facilities. For example, when the Hampton Roads Energy Company planned to build a new oil refinery near Virginia's Dismal Swamp, which gives off about 100 tons of hydrocarbons per day, the president of the company, Jack Evans, was informed that he would have to secure offsets for the hydrocarbons that his refinery would emit. Officials with the EPA suggested that Evans secure the necessary offsets by paying the owner of a competing refinery to reduce its emissions of hydrocarbons. To Evans, the notion of paying to clean up a competitor's refinery seemed absurd, especially since his company's new refinery would be cleaner than the other.[20]

This policy of encouraging offsets established a precedent. In effect, it said that anybody who was already emitting a pollutant in an nonattainment area owned a license to release those emissions. Furthermore, this policy suggested that firms could trade that license as if it were a commodity. In many ways, this policy ran parallel to the assignment of water rights in western states. If all water withdrawals from a particular river are assigned, then anybody desiring additional water must purchase their rights from somebody else. In the case of emissions in a nonattainment area, the good being sought is not a physical resource, such as water, but a license to emit pollutants into a common emissions sink. Both goods, though, represent something scarce that must be allocated by one method or another.

The need to obtain offsets for new sources in nonattainment areas also raised the possibility that a market for offsets could be created. Theoretically, firms that reduced emissions of a criteria pollutant in an nonattainment area could offer offsets to the highest bidder, thereby establishing a supply of offsets at a price that reflected their demand. In the late 1970s, though, such a market for offsets was not practical, which was confirmed by some of the earliest instances of offset trades in the Long Beach and San Francisco Bay areas.[21] First, no significant demand for tradable offsets existed. Firms that needed offsets usually secured their offsets internally. Second, far better monitoring, record keeping, and tracking were needed before firms could be allowed to generate tradable offsets without a careful review of their emissions. Economists would later attribute the poor development of an interfirm market for offsets to high transaction costs of negotiation between firms and regulators.[22] Finally, the precise rules for generating and trading emissions credits still had to be systematized.

At this time, most environmental groups looked upon emission trading programs with suspicion, partly because of another program that developed in parallel with offsets. According to the Clean Air Act of 1970, firms that constructed new emission sources had to meet stringent New Source Performance Standards, regardless of whether their facility was located in a nonattainment zone. Significant modifications to an existing piece of equipment could also trigger these new standards. But what if a firm that planned to modify equipment agreed to reduce emissions elsewhere at the same site so that the net result would not be large enough to trigger the "new source" requirement? The policy of "netting," introduced in 1974, allowed firms to do this, to avoid the "new source" requirement for modified equipment if they reduced emissions elsewhere in their facility. Critics pointed out that the program not only allowed firms to avoid meeting stringent standards but also slightly increased emissions. One analysis showed that the widespread use of netting in Southern California resulted in an increase in hydrocarbon emissions of 173,000 pounds per day between 1976 and 1986.[23] Given that the netting program was a form of internal trading that had to be approved and monitored by state regulators, environmental groups at the time treated all emissions trading schemes with suspicion.[24]

The EPA announced two more components of a general emissions trading policy on 11 December 1979: bubbles and banking.[25] Bubbles, or emissions averaging, allowed firms to receive credit for reducing emissions beyond state-required levels at emission points where they could do so inexpensively. They could then apply those credits in efforts to meet emissions limits at other points, presumably where controlling emissions cost more. In effect, firms could place an imaginary bubble over multiple emission sources and treat those emissions as exiting through a single stack. Regulators hoped that the policy would induce firms to develop creative pollution prevention techniques and to deploy more effective pollution control technology. To further increase the incentive of firms to reduce emissions where they could do so inexpensively, the EPA also allowed facilities to bank their emissions reductions as credits for future netting, offsets, and bubbling uses.[26]

An example of a facility that made use of bubbles in the 1980s was a 3M plant in Bristol, Pennsylvania. State regulations required 3M to make a 74 percent reduction in the emission of volatile organic compounds (VOCs) from each of the site's seven tape coaters and three tape treaters. However, by reducing production at two lines and replacing a solvent-based coater with one that used no solvents, engineers generated enough credits to continue operating the remaining lines with no changes. In the end, 3M cut their VOC emissions by the required amount, but did so at a savings of several million dollars.[27]

Like netting and offsets, bubbles and banking also raised numerous policy questions.[28] Among other issues, environmental groups expressed serious concern with the ability of regulatory agencies to verify that all emissions credits generated by facilities were real and permanent. For example, if a firm shut down a facility, should it get credit for the resulting cut in emissions and be able to use that credit to offset new sources sometime in the future? Or, could a facility generate credits needed to offset an increase in more creative ways—such as by putting a service vehicle on the highway to help reduce traffic jams? After all, fewer traffic jams would translate into fewer emissions of hydrocarbons and nitrogen oxides. Could that decrease in emissions be applied to offset increases elsewhere?[29] In an attempt to address these and similar questions, the EPA consolidated the four elements of its emissions trading policy—offsets, netting, bubbles, and banking—in an interim guidance document issued on 7 April 1982.[30] Soon after, controversy over the ability of firms to bubble emissions in nonattainment areas, allowing some firms to avoid requirements for additional emissions reductions, resulted in litigation by the Natural Resources Defense Council that went all the way to the U.S. Supreme Court.[31] The case was decided in 1984, upholding the EPA's policy innovation. The EPA finalized its emissions trading policy on 4 December 1986.

Part of the problem lay with the existing system of permitting. Under that system, permits were required only for major new and modified sources of emissions. Existing processes, even if they were

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major emissions sources, required no permit as preexisting emissions levels were sanctioned through so-called "grandfathering." Even in nonattainment areas, regulators placed only the weakest of controls on existing sources. Furthermore, documenting emissions credits—which could affect two or more permits—was difficult. In most airsheds, then, no baseline of actual emissions had ever been established, and nobody knew for sure whether the transfer of emissions credits actually resulted in fewer total emissions.

To what extent was the equivalent of emissions trading—effluent trading—used in water pollution control? In general, regulators had little incentive to develop such policies in the 1970s and early 1980s. Offsets, for example, only make sense when regulators are expected to sustain strict ambient standards. While the Federal Water Pollution Control Act Amendments of 1972 reinforced the call for ambient water-quality standards expressed in the Water Quality Act of 1965, the legislation focused on the application of uniform, technology-based discharge standards.[32] The hope was that strict technology-based controls would eventually solve water pollution problems by reducing the discharge of contaminants to near zero. In addition, bubbling generally was not applicable because effluent discharge permits already treated most complex facilities as a single source, with all waste water flowing from a single treatment system.

Only in the mid-1980s, as it became obvious that technology-based controls would not be enough, did state regulators start paying more attention to the total quantity of contaminants entering a watershed. In watersheds where Total Maximum Daily Loads (TMDLs) are now enforced, some mechanisms for generating effluent credits and trading them have emerged.[33] Still, even at present there have been fewer than a few dozen such effluent trades.[34]

Lessons Learned in the Phase-Down of Leaded Gasoline, 1979–1987

As questions involving netting, offsets, and bubbling were being addressed, another practical experience with emissions trading emerged unexpectedly: the phase down (and eventual elimination) of leaded gasoline. Although this program involved emissions only in an indirect way, air-quality regulators at the EPA designed the program and took the lessons they learned to heart. Among other things, this program demonstrated the power of using trading systems to reduce the number of "command and control" decisions necessary when trying to coordinate a major change.

The need to phase out leaded gas emerged when General Motors announced that it would reduce emissions from its automobiles by installing catalytic converters on all new cars manufactured after 1975, with that year corresponding to a deadline in the Clean Air Act for cutting certain emissions by 90 percent. This decision by General Motors—and, later, by other automobile manufacturers—to install catalytic converters doomed the domestic market for leaded gasoline.[35] These pollution-control devices work by exposing hot exhaust gases to a platinum catalyst, which oxidizes carbon monoxide and unburned hydrocarbons to carbon dioxide and water. Given that any lead in the exhaust stream would render the platinum catalyst ineffective, cars with catalytic converters required unleaded fuel. Oil refiners, of course, had been adding tetraethyl lead to their products since the 1920s, which inexpensively increased the octane rating of their gasolines.[36]

To ensure that unleaded gasoline would be available for cars with catalytic converters, the EPA used its authority under the Clean Air Act to phase out leaded gasoline. As automobile manufacturers sold more cars with catalytic converters, refiners were expected to produce more unleaded gasoline with octane ratings sufficient to avoid knocking and pinging. From the perspective of refiners, the phaseout of leaded gasoline was not a pollution-control issue as much as a change in product specification.[37] To reduce their dependency on octane-boosting tetraethyl lead, they needed to install expensive new equipment—reformers—to convert low-octane, straight-chained gasoline molecules into high-octane, cyclic ones. Not only did this equipment represent a major capital investment, but it also consumed significant quantities of energy.[38]

Some refineries moved quickly in responding to the demand for unleaded gasoline. In 1971, even before the EPA officially set July 1974 as the date by which all major service stations had to start offering unleaded gasoline, the Cities Service refinery in Lake Charles, Louisiana, announced plans to construct a thirty thousand barrel-per-day reformer. Similar announcements from several other oil companies followed. Judging from the speed at which these oil companies moved to increase their capacity for producing unleaded gasoline, they saw being suppliers of lead-free gasoline as a marketing opportunity.[39]

Other oil companies moved more slowly. Firms that designed and constructed refinery equipment, such as the Fluor Corporation, took out full-page advertisements in trade journals, encouraging these companies to plan ahead. In one advertisement, Fluor noted that although talking about the subject of lead reduction "tends to make us look as though we were rubbing our hands gleefully . . . we think the conversion program will hit our industry like a tidal wave."[40]

To ensure that the supply of unleaded gasoline kept pace with demand, the EPA required refiners to meet specific milestones. In 1975, with lead levels averaging about 2 grams per gallon, the EPA set the target for 1978 at 0.8 grams per gallon (averaged over all gasoline produced by the refiner), dropping to 0.5 grams per gallon by the end of 1979. In managing this reduction, though, the EPA faced two dilemmas. First, economies of scale made producing unleaded gasoline more expensive for small refineries. As a result, the EPA gave smaller refineries favorable treatment through relaxed standards. Second, forcing all large refineries to meet the same limits and deadlines was not particularly efficient. Refiners that already installed the necessary equipment could easily meet their targets. Refiners without the necessary equipment faced challenges, and they often sought temporary exemptions, which were granted if the refiner showed good faith toward meeting its goals.[41]

A small step toward the application of trading principles came in 1979. Because continuous monitoring of each refinery's output was not practical, the EPA allowed refiners to average their lead levels in gasoline produced over a three-month period.[42] A larger step came three years later. In late 1982, with favorable treatment to small refineries scheduled to be eliminated, few of those refineries had invested in the equipment necessary to produce higher-octane gasoline.[43] Expecting those refineries to install that equipment on time simply was not realistic. Yet extending the favorable treatment only rewarded those facilities for not taking action. To manage the phaseout in a way that recognized the distribution of available equipment, yet penalized and rewarded the appropriate parties, the EPA allowed inter-refinery averaging of leaded gasoline. For the purpose of meeting the lead limits imposed by the EPA, a refinery not capable of meeting its targets could secure the right to use additional lead from a refinery that exceeded its targets. As long as the combined average met the target, the EPA considered both refineries in compliance.[44]

In essence, then, a market for lead credits had been created. A refinery that met its target could now sell its excess credit to any other refinery. With this system of trading in place, the EPA could steadily cut the lead limit without having to be concerned with the specific constraints facing each refinery. Refiners who could exceed their targets efficiently did so—and sold their extra credits to refiners who found it costly to install the necessary equipment. The trading program also allowed the EPA to eliminate the favorable treatment given to small refiners without placing too large a burden on them. In 1985, the EPA extended the program to allow refiners to bank credits through the end of 1987.[45] At the peak of the phasedown activity in 1985, more than half of all refineries participated in the program, though only 15 percent of the total lead rights were actually traded. In the end, the largest rate of participation in the lead trading program was through the banking provision, with 35 percent of the total lead rights being banked.[46]

In practice, of course, refiners were trading the right to use lead in their products, not the right to emit leaded exhaust. The EPA put a cap on the production and use of tetraethyl lead, not emissions of lead. However, all the lead added to gasoline eventually ended up as emissions. Furthermore, the initiative had been motivated by the Clean Air Act and the program had been designed by the EPA's office of mobile emission sources.[47] Therefore, with a slight twist in perspective, one could certainly frame the trading of lead credits as an emissions trading program, complete with: a government-enforced limit on total emissions; discrete rights to emit that could be bought and sold; and rules for owning, trading, and using those rights. Furthermore, the trading program allowed the EPA to secure the reductions it needed without forcing all refineries to meet the same goal regardless of practical constraints. Theoretically, with trading, reductions could be made in the most efficient way possible, with each firm following the strategy best for it.

While the phasedown of leaded gasoline is generally considered a success, officials uncovered enforcement problems. Loopholes allowed a few oil refiners to violate the spirit as well as the letter of the law of this program. Still, significant auditing and enforcement was possible. The EPA checked reports of lead input against the records of lead manufacturers, cross-referenced reports of banking and trading transactions, and occasionally conducted site audits. Several companies were found to have exaggerated gasoline sales in order to artificially comply with their averaged lead targets. One company was fined $40 million in 1986 for spiking 800 gallons of gasoline with 135 grams of excess lead. In some cases, violators were identified by competing refineries.[48]

While this experience with violators underscored the need for better monitoring systems, the success of the lead phase-down program increased the confidence of air-quality regulators who hoped to use trading as a tool for managing emissions reductions in nonattainment areas. Indeed, the "Emissions Trading Policy Statement" that the EPA released in December 1986 reflected this interest.

The use of credit trading in the phaseout of leaded gasoline also served as a model for another program: the phaseout of CFCs and other ozone-depleting chemicals. The need to cut world production of CFCs came with the signing of the Montreal Protocol on Substances that Deplete the Ozone Layer on 16 September 1987. The protocol—originally designed to cut the production of CFCs by 50 percent but later amended to be a phaseout—allowed for the trading of production rights similar to that in the lead-trading program.[49] Allowance trading of CFCs, which began in 1989, was allowed between and within nations, and continued largely until 1996, when the production of CFCs in developed nations was phased out.[50] Given that different types of CFCs have different ozone-depletion capabilities, inter-pollutant trading was allowed at predetermined ratios proportional to their ozone-depletion capability. Trading in this market was modest because of the limited number of CFC producers, with the most activity taking place from 1991 to 1995, especially between the U.S. and Canadian plants of DuPont and Dow Chemical.[51]

In the leaded-gasoline program, the question of how to allocate credits never arose. Nobody, for example, asked why the Exxon corporation initially had the right to use more tetraethyl lead than the Murphy Oil Corporation. The answer was simple. Larger firms produced and sold more gasoline than smaller firms. Neither did anyone ask why corporations were granted the right to use tetraethyl lead at no cost. After all, refineries had never paid a fee before and there was no reason even to think in those terms. As with the right to emit air pollutants in nonattainment areas, past use served as a baseline by default. In the CFC program, however, the issue of allocation did arise but was diffused by treating industrial nations and developing nations differently. In addition, inexpensive substitutes for CFCs made the issue less contentious than it could have become, as did DuPont dropping its opposition to the program as its patents on major CFC products were about to expire.

The Emergence of "Cap and Trade" Programs

The first major nationwide experience with emissions trading—as opposed to the trading of production rights—came not, as regulators had expected, in the effort to manage nonattainment areas but in the effort to control acid rain. By the 1980s, scientists had reached consensus on the ability of sulfur-emitting coal- and oil-fired electric generating plants in one region to increase the pH levels of precipitation in another region. Scientists studying the problem argued that the amount of sulfur entering the atmosphere from such sources had to be reduced, either by encouraging plants to burn expensive low-sulfur fuel or by having them install devices capable of scrubbing sulfur dioxide from their emissions.[52]

The issue of how to control acid rain was hotly debated by politicians for much of the 1980s, with coal interests in the Midwest and Appalachian states pitted against proponents of controls in the Northeast and Canada. Indeed, partly due to the contentious issue of acid rain control, several efforts to amend the Clean Air Act ended in stalemate. Meanwhile, in the late 1980s, U.S. Senators Timothy Wirth of Colorado and John Heinz of Pennsylvania released a bipartisan report recommending the use of emissions trading as a policy instrument. Leaders in environmental groups, such as Dan Dudek and Robert Stavins of the Environmental Defense Fund (EDF), also started supporting the use of well-designed trading programs. (Stavins is now a professor at the John F. Kennedy School of Government of Harvard University.) The EDF adopted its promarket policy perspective at this time based both on emissions trading and its successful promotion of a water conservation and transfer scheme in Southern California. Strong interest in the use of emissions trading was also being expressed from within the Executive Office of President George H. W. Bush, with White House Counsel C. Boyden Gray, Richard Schmalensee of the Council of Economic Advisers, and Schmalensee's senior staff economist, Robert Hahn, being notable supporters.[53]

In July 1989, the Bush administration released its recommended overhaul of the Clean Air Act. The proposal included significant cuts in emissions in sulfur dioxide. After prolonged debate and a filibuster by Senator Robert Byrd of West Virginia, Congress finally approved a version of that bill. Among other things, Title IV of the legislation required the EPA to cut emissions of sulfur dioxide by 10 million tons below 1980 levels.[54] The legislation also authorized the EPA to use a trading program to manage the necessary cuts. Previous proposals simply would have mandated the addition of flue gas desulfurization equipment at affected coal-fired power plants, an available but often expensive technology.[55]

In the first phase of the emission cuts (1995–99), the EPA capped the total quantity of sulfur dioxide that 263 large, coal-fired power plants could release, and gradually reduced that cap. To accomplish this task, the EPA first created a baseline of actual emissions. Next, the agency created enough "allowances" to match those emissions, with each allowance representing a ton of sulfur dioxide. Each power plant received enough allowances to cover its existing emissions. Then, to achieve the necessary cuts, the EPA incrementally reduced the available emission allowances. In a second phase (2000–2009), the EPA initiated deeper cuts and integrated into the program power plants over a minimal size that had not been included in Phase One. While regulators intended to reduce the number of allowances going to each power plant by a fixed percentage, various exceptions, special provisions, and bonus allowances enacted by Congress resulted in a more complicated formula.[56]

In response to each cut in allowances, the operators of the affected facilities had several compliance options. To reduce emissions, their main options were to install scrubbers or switch to lower sulfur fuel. Alternatively, to continue emitting at a constant level, they could purchase additional allowances from facilities that reduced emissions more than needed. Facilities with extra allowances could also bank those unused allowances to meet future cuts, which created an incentive to reduce emissions faster than required.[57]

Enforcement was (and is) based on a system of annual reconciliation. By February of each year, all power plants in the Acid Rain Program were (and are) required to submit paperwork demonstrating that they possessed enough allowances to cover their emissions from the previous year. For example, if a plant received allowances to emit 1,200 tons of sulfur dioxide but actually emitted 1,500 tons over the course of the year, then that facility had to secure an additional 300 allowances from the market. Otherwise, the company had to pay a significant penalty ($2,000 per ton, escalated for inflation since 1990) *and* offset the excess emissions. Regulators could also audit the records of each power plant to verify that a company's record of purchasing fuel and the data recorded from monitoring instruments were consistent with what was reported.[58]

Whereas the program to phase out leaded gasoline was only temporary—mainly because refiners had to stop producing leaded gasoline—the sulfur dioxide program is permanent. Some method of allocating the right to emit sulfur dioxide will continue to be necessary. Hence, in addition to providing firms with as much flexibility as possible in achieving the required emissions cuts, the trading program also helps to allocate emissions on an ongoing basis. For most of the past decade, the price of sulfur dioxide allowances has remained relatively low ($70–220 per ton) because most midwestern and eastern power plants have easily met their targets through the use of inexpensive, low-sulfur coal.[59] However, a significant increase in the demand for electricity could quickly raise the value of sulfur dioxide emissions. After all, any new fossil-fueled generating plant that comes on line must secure all of its allowances from the market. Sharp rises in transportation costs, which would affect the cost of hauling low-sulfur coal long distances, could also have an effect; indeed, a major factor in lowering compliance costs was the lowering of rates for shipping coal eastward. In such cases, managing the allocation of a fixed pool of emissions would be far more complex and expensive without a trading program in place.

In the acid rain program, as in the phaseout of leaded gasoline, the purpose of establishing a market was not to ascertain what level of environmental quality firms could economically sustain. The environmental objectives were already set. In many ways, the emissions "cap" established by Congress was the most significant part of the acid rain program. The market for allowances was mainly a mechanism to achieve those cuts in an efficient and flexible manner—and to manage the resulting pool of emissions on an ongoing basis. At the same time, the program reinforced the notion that the initial allocation of allowances should be based on prior use.

The Spread of Emissions Trading Programs

More recently, some states and regional air pollution control agencies have set up "cap and trade" programs to manage emissions reductions in nonattainment areas. In part, these programs came in response to provisions in the Clean Air Act Amendments of 1990 that set milestones for bringing areas with poor air quality into attainment with National Ambient Air Quality Standards. Title I of that legislation specifically encouraged states to develop economic-incentive programs in making the necessary emissions reductions. Furthermore, since April 1994, the EPA has required such programs in areas not in attainment for carbon monoxide and smog-causing ozone.[60]

As in the 1970s, in most nonattainment areas coordinating cuts to stationary sources by "command and control" posed a significant challenge. Although the 1990 amendments required state agencies to implement more sophisticated permitting systems, using those permits to achieve the desired cuts would have been difficult. Not only would each permit need to be adjusted on a case-by-case basis, but most industrial facilities already operated below their permitted levels. Therefore, cuts to permitted levels would not even have translated into fewer emissions. In addition, some facilities could make significant cuts relatively inexpensively. Encouraging those firms to make as large of a reduction in emissions as they could while getting all firms to share in the costs would have been virtually impossible without some program of emissions trading.

To make the necessary reductions while providing firms with the flexibility to make cuts in an efficient manner, some states turned to emissions trading programs. For example, in 1994, California's South Coast Air Quality Management District (SCAQMD) initiated a program known as the Regional Clean Air Incentives Market (RECLAIM) that issues RECLAIM Trading Credits (RTCs) for nitrogen dioxide and sulfur dioxide emissions. The SCAQMD is managing the mandated cuts by slowly reducing the number of RTCs available to industrial firms operating in the greater Los Angeles air basin.[61] In Illinois, regulators later designed a similar program to reduce emissions of smog-causing volatile organic compounds in the Chicago area.[62] In the late 1990s, eight states in the Northeast corridor organized an interstate trading program to cut dramatically emissions of nitrogen oxides so as to control the formation of ozone-causing smog in the region.[63] In addition, modest emissions trading and banking programs now exist in more than half a dozen individual states of the Northeast.[64]

Although regulators put these programs in place as a way to distribute cuts in nonattainment areas required by the CAA, these programs also can be used to manage offsets on an ongoing basis. Any firm that wishes to expand or construct new facilities in an area

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hovering near attainment can secure the necessary offsets through these same emissions trading markets. As these programs mature, regulators will increasingly play the role of auditors, verifying that firms balance actual emissions with emissions allowances. Private firms will also play an increasingly important role as auditors and brokers, with one of the first having been the Washington, D.C.–based firm AER*X, which an EPA official founded in 1984 to serve as an air emissions reduction exchange.

Emissions trading programs, of course, are still in their youth. Most industrial facilities currently do not participate in any emissions or (effluent trading) program and probably will not for some time to come. Furthermore, individual programs require significant effort to develop. Numerous design concerns must be considered. For example, emissions trading programs that do not place explicit caps on the pollutants being managed are less likely to be effective. Neither are programs that fail to establish clear rules for allocating allowances, monitoring emissions, retiring and banking allowances, generating credits, and demonstrating compliance—all in a way that is appropriate for that pollutant. The size of the region associated with a trading program also matters, with a higher geographic scale of administration being better; any pollutants able to drift in from outside the trading zone clearly complicate matters.[65] Finally, trading programs cannot be expected to cover all emissions sources for a pollutant. Natural, nonpoint, and mobile sources often require different strategies. Good program design, proponents argue, can address such concerns.

Some issues are more problematic. Although some critics have attacked the practice of allocating allowances based on a firm's history of emissions, the challenge has not been significant. By precedent, the assumption is that the status quo should be used as a baseline, with facilities initially having the right to emit whatever they have been emitting in the past. This assumption is generally consistent with the allocation of water rights in western states. In effect, the policy implies that firms have been putting a resource—whether it is water or the right to emit a contaminant—to productive purposes, and therefore deserved to inherit those rights. However, on equity grounds, economists and others have criticized trading programs for this "free" distribution of emissions allowances to existing facilities, while new facilities must purchase all their allowances from the market.[66]

Alternative strategies certainly exist. For example, emissions trading programs could be designed to require that all allowances be

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purchased from the market. Or regulators could require firms to pay a fee for each allowance used. Currently, firms already pay a fee proportional to the size of their emissions when submitting an application for an air permit, with that fee covering the administrative expenses associated with permitting. In any case, the issue did not present itself when the first decisions concerning the right to emit contaminants were made in the 1970s. Only after participants gained experience in program design and implementation, such as with the acid rain program, did such issues come to the fore.

Critically rethinking the various aspects of an emissions trading program, including the philosophy governing the initial allocation of credits, will be especially important as policymakers look toward using such programs to manage emissions of carbon dioxide (CO_2). Emissions of CO_2, which come mainly from the burning of fossil fuel, contribute to the possibility of global climate change by increasing the amount of heat absorbed by the atmosphere. At a general level, the strengths of emissions trading systems appear to match the task at hand: emissions of CO_2 can be treated as a tradable commodity with few or no geographical constraints; a cap on emissions is desirable; target reductions have been agreed upon under international treaty (the Framework Convention on Climate Change of 1992 and the Kyoto Protocol of 1997); and those reductions can be managed by shrinking the pool of allowances. Although carbon-related trading programs will inevitably raise questions specific to the release of greenhouse gases—such as how to reward actions that take carbon out of the atmosphere through tree planting, improved forest management, or the pumping of CO_2 emissions into brine formations—reaching consensus on those questions would not be a major problem if governments decide to pursue the issue seriously.

The more difficult policy questions will revolve around issues never seriously debated in the United States or resolved in ways not possible internationally. Two important issues involve the philosophy of allocation (especially if deep cuts in CO_2 emissions are called for) and the philosophy of enforcement. Given that a nation's economic well-being correlates with energy consumption, placing a cap on CO_2 emissions could be akin to restricting the ability of developing nations to improve their material standard of living. Any initial allocation based on current emissions of CO_2—that is, prior use—would be politically untenable at the international level. Enforcement would also raise a host of complex issues that have not emerged in the design of U.S. programs. Such issues, linked to issues of equity and sovereignty rather than effectiveness and efficiency, will require that program designers and policymakers revisit assumptions that have worked in U.S. programs.[67]

Summary

In the 1960s and early 1970s, the notion of using emissions trading to help manage air quality often met with skepticism. Air quality, critics feared, would be subject to the vagaries of supply and demand. However, over the last quarter century, regulators in the United States have gained considerable experience with emissions trading programs. In each case, market incentives were used to reach environmental objectives, not determine them.

Despite early theoretical work on the possibility of using market-based schemes to control pollution, the first practical programs were not highly influenced by that research. As it happened, the Clean Air Act Amendment of 1970 unexpectedly forced regulators to develop various types of trading programs. First, in urban areas that did not meet air-quality standards established by the Clean Air Act, the right to emit pollutants suddenly became a scare resource that had to be allocated among industrial firms. If the EPA took the new law seriously, which environmental groups made sure that the agency did, firms could not expand their industrial operations unless they balanced any increases in emissions with decreases elsewhere in the region. Hence, by the mid-1970s, regulators recognized that a mechanism that allowed firms to generate "emission reduction credits" and to use those credits to balance emissions increases was necessary. However, the appropriate monitoring systems, administrative rules, and regulatory culture simply did not exist.

Air-quality regulators also found themselves faced with another challenge that could be traced back to the Clean Air Act of 1970: the phaseout of leaded gasoline. In this case, the EPA discovered that not all oil refineries could meet milestones set by the agency. Hence, the agency allowed refineries to generate credits for exceeding expectations and then trade those credits with refineries that could not meet their assigned targets. This program served as a model for allowance trading of production rights in the phaseout of CFCs.

Both the need to manage offsets in nonattainment areas and the program to phase out leaded gasoline made clear that trading programs could be used to meet, not set, environmental objectives.

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Hence, as Congress set new objectives, such as cutting sulfur dioxide emissions below 1980 levels and requiring state agencies to meet a specific schedule in controlling troublesome emissions in nonattainment areas, regulators turned to emissions trading as a way to allocate the available pool of emissions. Therefore, while in their youth, trading programs are now a legitimate policy tool, and a regulatory infrastructure and culture is emerging that allows regulators to use this tool to accomplish several goals:

- To reduce the need for "command and control" decisions and compliance when significant cuts in emissions are called for
- To provide for flexibility in determining how reductions are distributed among firms, with facilities able to make reductions inexpensively, doing so while other firms indirectly share in the costs
- To help regulators allocate a fixed pool of emission allowances on an ongoing basis

The designers of emissions trading programs have had to address numerous practical issues, such as how to measure the baselines on which the initial allocations of credits are based, how best to monitor and enforce program rules, how to reconcile the desired geographic scale of administration with political boundaries, how to broker and record trades, how to educate participants and the public, and how to address issues of environmental justice.[68] Similar issues also have to be addressed in programs designed to distribute the discharge of various contaminants into certain water bodies. In general, though, well-designed programs have demonstrated their usefulness in helping to achieve and sustain specific environmental objectives.

With an emissions trading program likely to be part of any effective global effort to reduce and manage the release of greenhouse gases, many issues now have to be addressed in an international context, which poses new questions of equity and sovereignty. In the case of global warming, CO_2 emissions are tightly coupled to the burning of inexpensive fossil fuels and, therefore, to a population's material standard of living. Hence, the design of a trading program for the emission of greenhouse gases has significant consequences, with the allocation of tradable credits being a potentially contentious issue. The philosophy of allocating the right to emit based on past use, which has not been particularly controversial in the United

States, has not gone unquestioned at the international level. Furthermore, at the international level, the monitoring and accounting systems that must be put into place involve issues of sovereignty never faced by regulators in the United States. Precedent-setting assumptions and choices that have been acceptable in the United States will not necessarily be so at the international level.

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Notes

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68. For more details on the lessons from sulfur dioxide allowance trading, see, in general, Stavins, "What Can We Learn from the Grand Policy Experiment?" 77–82; Barry D. Solomon, "Global CO_2 Emissions Trading: Early Lessons from the U.S. Acid Rain Program," *Climatic Change* 30 (May 1995): 83–85; Solomon and Lee, "Emissions Trading Systems and Environmental Justice."

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