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Analysis&Perspective

Electric Utility Regulation

Grandfathering, New Source Review, and NO_x—Making Sense of a Flawed System

BY BYRON SWIFT [1]

There are two fundamentally different ways to achieve the reductions in nitrogen oxide (NO_x) emissions required to meet federal and state strategies to reduce urban ozone formation. One is to add end-of-pipe controls such as selective catalytic reduction to existing power plants, which are largely coal-fired and emit not only NO_x but a major portion of the East Coast's total loading of sulfur dioxide, particulates, carbon dioxide, and many air toxics. The other is to achieve the NO_x reductions through investments in new, combined cycle natural gas power plants, cogeneration and efficiency gains. One is an add-on cost that reduces only NOx, while the other is an effective investment that reduces all these pollutants and creates the basis for a sustainable energy future. Unfortunately, current policies for NO_x control in the Clean Air Act may promote the former, rather than more integrated solutions that yield multiple pollutant benefits.

There are major problems with the way NO_x emissions from the electric power industry are regulated under the Clean Air Act. First, lenient standards are applied to older plants, allowing their continued use even though they emit 10 to 40 times more NO_x than new gas-fired technologies. Second, the standards applied to new sources are inflexible and impose high transaction and compliance costs for small marginal NO_x reductions. These combine to discourage investment in far cleaner and more efficient modern technologies, and extends the operating lives of existing inefficient and dirtier plants. The result is greater NO_x pollution, as well as significantly greater ancillary pollutants (SO_2, particulates, and mercury) and greenhouse gases. This is bad for business, bad for the environment, and fundamentally opposed to principles of sustainable development.

Replacing the existing patchwork of old source and new source NO_x standards with consistent and technology-neutral standards, such as emission cap and allowance trading systems, could help solve these problems and promote clean energy sources. Headway is being made by the creation of NO_x emission cap and trading programs in the Northeast and under EPA's planned NO_x SIP call, as well as the four-pollutant bills (H.R. 2569, S. 1369) introduced in the House and Senate that use cap-and-trade approaches to create an integrated regulatory system for power. Moving to these solutions will have major economic and environmental benefits, but will require political will.

This article describes the nature of NO_x regulations for the electric power sector under the Clean Air Act, reviews the results of implementing these regulations in the 1990s, and makes recommendations for improved NO_x regulations that are more effective environmentally and more efficient economically. It shows how reliance on end-of-pipe NO_x rate standards—instead of caps on total emissions combined with emission trading, or other technology-neutral standards—is economically inefficient, and discourages use of new technologies that could achieve multipollutant benefits. Unless NO_x regulation is revamped, environmental and energy policies will continue to be on separate tracks and fail to adequately stimulate the cleaner technologies and technological innovation necessary to bring about efficient and effective environmental improvement.

The Economics of the Utility Industry

Just over half of the electric power in our country is produced by coal-fired power plants, most of which were built between 1950 and 1980 (our remaining power comes largely from nuclear (20 percent), natural gas (14 percent) and hydro (8 percent) sources). These older coal-fired plants are responsible for a very large share of the nation's air pollution, emitting roughly a third or more of the total national loading of sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulates, mercury and other air toxins. Because they attain only 34 percent efficiency, they also produce about a third of national emissions of carbon dioxide (CO_2), a greenhouse gas.

However, economic drivers in many regions favor high utilization of these older coal-fired units as the least expensive means of providing base load electric power generation. A principal reason is that the capital costs of these older plants have been paid off, so they

[1] *Byron Swift directs the Energy and Innovation Center of the Environmental Law Institute (swift@eli.org; www.eli.org).* *Background research for this article was supported in part by The Joyce Foundation and A.W. Mellon Foundation. The author thanks these foundations, as well as Debra Knopman for her excellent advice, and the many others who generously provided advice and comments on this article.* *The views expressed are those of the author, and not necessarily those of the Environmental Law Institute, The Joyce Foundation, or the A.W. Mellon Foundation. This article does not represent an editorial position of BNA., which welcomes other points of view.*

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Figure 1. Differential effects of current law on NO_x reductions from generating technologies (1996-1999):

	Old sources (Title IV "RACT")			New Sources (BACT/LAER)		
	Cyclone coal	Wall-fired coal	T-fired coal	New coal	New gas large*	New gas small*
Uncontrolled NO_x (lb/mmBtu)	1.50	0.95	0.65	0.50	0.05	0.10
Legal standard (lb/mmBtu)	none	0.50	0.45	0.15	0.02+	0.02+
Cost per ton	$0	$150	$400	$565 (SCR)	$2,500	$10,000+

* Uncontrolled NO_x figures are based on the use of dry low NO_x combustor technology.

Sources: EPA 1999b, 1998, 1996; STAPPA/ALAPCO 1996; Chalfin 1999; Witherspoon 1999.

produce electricity only for the cost of fuel, operation, and maintenance. Because coal is also relatively inexpensive, they generate electricity for about 2¢ per kilowatt hour (kWh), which is lower than other sources. As a consequence, there has been relatively little retirement of coal-fired power plants in the 1990s, slowing a transition to a more efficient and cleaner power fleet.

The outlook for new plants is entirely different: over 90 percent of new power plants are expected to be fired by modern natural gas technologies (DOE, 1999). These new gas plants are very clean, emitting no SO_2 or mercury and only 10 percent of the NO_x and particulates emitted by older, coal-fired plants. Because they are almost twice as efficient, they also reduce CO_2 by about 50 percent.

These new gas-fired plants produce electricity at historically low prices, approximately 3-3.5¢/kWh, which is significantly less than new coal-fired plants, so very few new coal-fired plants are being built. However, because the older coal-fired plants have paid off their capital costs, and so generate electricity at around 2¢/kWh, they persist.

Key Problems With the NO_x Regulatory Structure

There are several key problems with the Clean Air Act's regulatory structure for NO_x, and in particular its reliance on specific end-of-pipe emission rate standards. These problems are exacerbated in sectors such as the power sector where capital assets are long-lived, and where there are fundamental differences between technologies that affect their impact on social welfare.

Originally, direct federal regulation of air pollutants under the CAA only applied to new plants. Not until 1990 were most emissions of power plants built before the original 1970 act regulated. In addition to differentiating between old and new plants, the Clean Air Act establishes different emission rate standards for NO_x for major and minor sources, and for each particular energy generation technology.

Further, the 1977 amendments introduced a major difference in standards depending on whether or not a plant is located in an area that has attained the national ambient air quality standard for a particular pollutant.

Finally, these rate-based standards do not require continuous improvement on the part of a plant, but apply at one point in time and are rarely changed. For new plants built after 1971, they apply on the date the plant was built or underwent a major modification, and for existing plants, in 1995 or 2000, depending on which phase of the Title IV acid rain program applies.

This varying quilt of regulatory standards has profoundly influenced how companies design and operate their plants, with some gains, but as this article will point out, also negative consequences for efficiency and the pursuit of comprehensive and integrated answers to our pollution problems.

Problems With Distinction Between Old, New Plants

A major problem with standards under the CAA is that they differentiate between old and new plants, creating a significant bias toward old sources that only need to meet a relatively weak standard, while new sources face a very stringent one. Thus, older largely coal-fired plants emit NO_x at levels of 100-630 parts per million (ppm) of exhaust volume, even though some could reduce NO_x at prices as low as $300 per ton. However, the stringent New Source Review (NSR) standards applied to new and cleaner gas-fired plants require them to reduce their already low NO_x emissions to 9 ppm or in some states 3 ppm, requiring investments that cost from $2,500 to over $10,000 per ton of NO_x reduction. These new source standards are so stringent that they impose significant costs on new sources and discourage investment in newer, cleaner technologies.

Basing a regulatory system on new source standards creates particular problems when capital assets have a long life. One part of this problem has to do with plants that were in operation before the Clean Air Act was passed in 1970, which have never been subjected to new source standards. Many of these grandfathered plants are the subject of a major lawsuit by EPA that asserts they should be subject to new source review because they have made major modifications. However, even if a source has undergone new source review, years or decades may elapse before the plant is subject to the standards again, during which time there is no incentive to improve.

Another problem is that these standards divert research attention away from identifying and developing new, cleaner power sources, to how to achieve pollutant reductions and extend the life of older sources without triggering new source review. This leads to a fundamental lack of alignment of the objectives promoted by CAA and objectives of a sound clean energy policy.

The widely varying NO_x standards applied to different power technologies today are shown above in Figure 1 and described in the following sections. The figure reveals the great disparity between the standards for old and new sources, and also how technology-by-technology standards have imposed the highest costs on the cleanest sources.

Rate Standards for Old Plants Stimulate Minimal Improvement or Technological Innovation

The great majority of NO_x emissions from the power sector come from existing coal-fired plants, many of which were built between 1950 and 1980. Most existing plants are subject only to NO_x standards imposed by Title IV of the 1990 amendments[2], which only requires the installation of low-NO_x boiler technology or the equivalent. The standards were set at 0.45-0.50 pounds per million British thermal units for wall-fired and tangentially fired coal boilers during Phase I of the Title IV program (1996-1999), and from 0.40 to 0.86 lb/mmBtu for a wider group of boilers beginning in 2000. However, because companies are allowed to average the emissions of all their units, and some units are exempt in Phase II (i.e. cyclone units less than 155 MW), some units continue to operate without controls while emitting NO_x at levels as high as 2.0 lb/mmBtu (roughly 630 ppm).

Interviews with power generators and technology vendors indicate that the Title IV standards for NO_x produced minor innovation, because they were set at levels that could be achieved through low-cost boiler modifications. Congress's intent on this issue was quite clear, as the law allows units that could not meet the numerical limit though use of low-NO_x burner technology to meet an alternative emission limit set at the lowest level they could reach using this technology. Since the standard simply required the use of an existing and known technology, the only innovations were to reduce the cost of low-NO_x burner technology for some boiler types.

[2] Title IV created the Acid Rain Program, and established standards for both NO_x and SO_2 emissions, both precursors of acid precipitation. 42 U.S.C. 7651 *et seq.*

Box 1. Technology options available to existing coal-fired plants to meet Title IV standards, by boiler type:

Wall-fired boilers achieved a major cost-reducing innovation that involved simply taking out a row of burners to simulate a low-NO_x burner. This modification allowed many boilers to achieve the Title IV standard at a small fraction of the cost of installing a new low-NO_x burner, although some units experienced a slight loss of capacity in doing so.

Tangentially fired boilers have experienced relatively little innovation. In its Phase II rulemaking, EPA identified that retrofit costs of low-NO_x burners for tangentially fired boilers were $631 a ton during Phase I, whereas they were initially predicted to be $280 (EPA 1996).

Cyclone boilers were completely unregulated during Phase I even though they produce more NO_x than any boiler type, because no combustion control technology was believed available for them when Title IV was passed in 1990. Research was not initiated until 1995, when EPA first indicated it would regulate cyclones in Phase II. A research consortium led by the Electric Power Research Institute formed and rapidly developed an unexpected technological innovation in applying overfire air to cyclones, which had never before been successful, and allows most to meet or potentially exceed the 0.86 lb/mmBtu standard at low cost.

The standards for existing oil and gas-fired plants are significantly more stringent than those for existing coal plants, as most were built after 1971 and were subject to new source standards that establish a minimum NO_x emission limit of 0.20-0.30 lb/mmBtu. 40 CFR 60.44, 60.44a. As described in a subsequent section, new source standards for new gas-fired facilities are even more stringent, in some states as low as 0.02 lb/mmBtu, or an order of magnitude tighter.

There are several major problems with the design of these standards for older plants that limit a sensible NO_x reduction policy. First, they are relatively lenient, requiring only that low-NO_x burners be used at coal-fired plants; this means that relatively inexpensive NO_x reduction technologies are not being used because the plants already meet the minimum standards. Second, rate standards are set on a technology-by-technology basis, and have resulted in more lenient requirements for dirtier technologies. This has created little or no incentive to switch to cleaner processes in the past decades. Thirdly, these standards are input-based, which means they provide no incentive for efficiency within any technology category.

OTC Trading Scheme Forced Improvements at Existing Plants

The most significant strengthening of NO_x standards for existing plants recently occurred in the Ozone Transport Region, which comprises the 12 Northeast states. In 1999, these states instituted a stringent emission cap and allowance trading system that requires electricity generating units to reduce emissions by 55-65 percent from their 1990 baseline. Despite initial expectations that many sources would need to use expensive end-of-pipe controls such as Selective Catalytic Reduction (SCR) to achieve these deep reductions, the flexibility afforded by the cap-and-trade approach led to unexpected results. Chief among these were that most (126) of the 142 affected coal-fired units achieved NO_x reductions up to 30 percent through operational changes alone, without significant capital additions. Bluestein, 1999; GRI 2000. The cap approach allowed compliance through a number of technologies, described in the box below, and not only SCR. As a consequence, compliance costs, after initial volatility at the programs start, in which prices ranged from $3,000 to $7,000 per ton, have settled down to less than $1,000, significantly lower than estimated. This may foreshadow low compliance costs for the EPA NO_x SIP call, which would impose a stringent NO_x emission cap for a broader group of 19 Eastern states. (A SIP call is a directive by EPA for states to rewrite their state implementation plans under the CAA to address an air quality problem.)

New Plant Standards Can Become End-of-the-Pipe Prescriptions That Make Little Sense When Applied to Modern Gas-fired Power Plants

Major new plants built after the CAA Amendments of 1977 must meet significantly more stringent standards in a process called New Source Review. Those built in areas that have attained the ambient ozone standard set

Box 2. Technology options available to existing coal-fired plants to meet stringent NO_x standards

Combustion controls are boiler modifications that minimize the formation of NO_x in the boiler. In addition to the direct burner modifications required for Title IV, advanced combustion controls can include overfire air and computer controls that enhance control of coal and air in the boiler.

Gas Reburn technologies reduce NO_x by injecting natural gas above the coal combustion zone. Gas reburn may achieve up to 55 percent NO_x reduction using 15 percent gas injection, with capital costs of $12-25 per kW and additional fuel costs for the natural gas. Enhanced forms of gas reburn can use reagents such as amine injection to increase NO_x reductions to 60 percent, although these are slightly more expensive. GRI 2000.

Selective Non-Catalytic Reduction (SNCR) injects a urea-based reagent in the upper furnace to reduce NO_x. SNCR achieves about a 35 percent NO_x reduction at a capital cost of $5-20 per kW.

Selective Catalytic Reduction (SCR) injects ammonia into the boiler, which catalytically reduces the NO_x. SCR has the greatest NO_x reducing potential, achieving 70-90 percent reductions, but is also the most expensive, with capital costs of $50-100 per kW. In addition, SCR has substantial operating and catalyst replacement costs, and releases ammonia.

by EPA must prevent significant deterioration of air quality, and install Best Available Control Technology (BACT), defined as the best end-of-pipe technology considering "energy, environmental, and economic impacts and other costs." 42 USC 7475, 7479(3). This stringent standard generally requires a new gas turbine to achieve a 9 ppm NO_x output level (equivalent to 0.04 lb/mmBtu), and may often require use of both combustion controls and end-of-pipe equipment such as Selective Catalytic Reduction (SCR).

New plants in non-attainment areas must install Lowest Achievable Emissions Reduction (LAER) technology for the kind of plant proposed. (42 USC 7503 (a)(2)). This requires end-of-pipe technology to be used that achieve the lowest emissions without considering cost, which can require that SCR or even more expensive technologies be used to reach levels as low as 3 ppm (equivalent to 0.01 lb/mmBtu) in some states. These technologies add significantly to the cost of a new plant, at times as much as 70 percent for smaller plants, and make it more difficult for these new and efficient power plants to compete with older and far dirtier facilities.

These standards are applied primarily to major new sources, but also apply whenever an existing source undergoes a "major modification". The interpretation of the latter phrase is at issue in lawsuits brought by the U.S. Environmental Protection Agency against eight utilities operating 27 large coal-fired facilities, that allege major modifications have been made, and the plants should therefore be subject to new source standards. If new source standards are applied, these plants would need to achieve significant NO_x reductions through the use of technologies such as SCR. Given the very large emissions of NO_x from coal plants, these reductions would be achieved fairly efficiently, typically at a cost of less than $1000 per ton.

The situation is different in applying new source standards to new units, as today over 90 percent of new generation is expected to be natural gas-fired turbines. These are more efficient than coal-fired units and much cleaner, with virtually no SO_2 or mercury emissions, as well as lower NO_x. A research review of modern gas turbines manufactured in the United States and Canada reveals that it is relatively efficient today for large gas turbines to reduce NO_x emissions to the 9-15 ppm level, and small turbines to the 25 ppm level, through the use of dry low-NO_x combustor technology that entails neither a loss of overall efficiency nor the use of add-on controls. However, beyond those levels it becomes exponentially more difficult and less favorable to the environment to decrease NO_x levels, as there is a tradeoff between rising CO levels due to incomplete combustion at lower flame temperatures, and rising NO_x levels with increased temperatures. Chalfin 1999; Schorr 1999; USEPA 1999b.

The improvement in gas-fired power generation technology is a major success in technology development, spurred by the stringency of California standards, new source standards, and research programs such as the Department of Energy's advanced gas turbine program. The levels achieved by modern plants using dry low-NOx combustors are well below historic emissions of over 100 ppm, and an order of magnitude less than uncontrolled emissions of coal plants.

Achieving reductions past the above levels requires installation of end-of-pipe equipment. The principal technology considered today for gas turbines is Selective Catalytic Reduction (SCR), although more recent technologies are emerging such as SCONOX and XONON, described in the box on the next page. However, given the low NO_x levels already reached by dry low-NO_x combusters, adding end-of-pipe controls yields small environmental benefits and becomes very expensive on a per-ton basis, especially for smaller units, as shown above in Figure 1.

Today, many states interpret LAER, and some also BACT, to require that end-of-pipe controls be added to modern gas turbines. This makes little sense environmentally or economically. Low-NO_x combustor technology already achieves emission rates of 0.03-0.06 lb/mmBtu, several times lower than the New Source Performance Standard of 0.15 lb/mmBtu, and 10-40 times lower than the uncontrolled levels of coal-fired units. Forcing reductions beyond this point through add-on controls is very expensive, and as described below has marginal or negative environmental consequences.

The first reason not to require add-on controls to modern gas turbines is that the NO_x reductions achieved by the controls are trivial in comparison to the reductions already achieved by the cleaner process. They do little to solve the regional NO_x problem, which depends instead on reducing emissions from existing coal-fired plants from levels around 0.40 lb/mmBtu to the cap based on 0.15 lb/mmBtu called for in EPA's SIP call. Second, given the very low levels of NO_x emissions already achieved though the cleaner process, the controls themselves, which use toxic catalysts, consume 0.5

Box 3. Technology Options for Reducing NO_x Emissions at New Gas-fired Plants

Dry-Low NO_x Combustor. Modern gas-fired turbines can reach very low levels of NO_x emissions with a dry low-NO_x combustor design that reaches levels of 9-15 ppm NO_x for large turbines (roughly 0.05 lb/mmBtu) and the 25 ppm range for smaller turbines. This technology, funded in part by the Department of Energy's advanced gas turbine program, stages combustion to intimately mix the fuel and air. It is a major advance over older turbines which emitted at historical levels of 99-430 ppm NO_x, and achieves these low emissions without the loss of efficiency or the use of add-on controls. Chalfin 1999; STAPPA-ALAPCO 1994.

Selective Catalytic Reduction (SCR). The SCR process injects ammonia into the gas turbine exhaust as it passes through the heat recovery generator, and the ammonia reacts catalytically with the NO_x to form nitrogen and water. SCR is effective in achieving NO_x reductions at the 90-95 percent level, but uses toxic materials (vanadium and/or titanium) as catalysts, releases ammonia, a problem in urban areas, and also reduces plant efficiency by about 0.5 percent. SCR is also expensive: for larger turbines, retrofitting SCR onto existing gas turbines that may emit over 100 ppm of uncontrolled NO_x results in costs of NO_x reductions around $1000 a ton. However costs are over $2,500 per ton when applying SCR to new large turbines using dry low-NO_x combustors, because they already emit such low NO_x. For smaller industrial gas turbines (4-16 MW) using a dry low-NO_x combustor, the capital cost of an SCR unit is proportionally far higher—capital costs of SCR for a 7 MW turbine are over $1 million, adding 70 percent to the cost of the turbine, and annual costs are $240,000. Together these yield an annualized cost of $423,000 to reduce 25 tons of NO_x emissions a year to 3 tons—a per-ton cost of almost $20,000.

SCONOX and XONON. Emerging technologies such as SCONOX and XONON are even more expensive, but do not use ammonia. SCONOX uses post-combustion catalysts to remove both NO_x and CO from the turbine exhaust, and reduces particulates as well as NO_x; the XONON system combusts fuel through a chemical process that prevents the formation of NO_x. Cost data is available for SCONOX, the more proven of these two technologies. SCONOX is more expensive than SCR, and entails the loss of about 1 percent of plant efficiency. For large units, the combined capital and operating costs add about 2 mills (0.2 cents) to the cost of a kilowatt hour, twice that of SCR. For small industrial 7 MW gas turbines, the capital cost of a SCONOX unit at over $2 million may exceeds the cost of the turbine itself, and annual costs are $310,000. Together these yield an annualized cost of $590,000 to reduce 25 tons of NO_x emissions to 2 tons, or $25,000 a ton (note the cost of reducing the marginal one ton from SCR is $1 million).

to 1 percent of the power of the plant, may emit ammonia, and may create as much or more pollution than they cure (see box). Third, the high costs involved in meeting these very strict NO_x standards for new gas plants, combined with the transaction costs of New Source Review, would appear to limit the number of gas turbines being proposed and installed, especially for smaller units. Any discouragement of these new units must result in greater emissions from older, largely coal-fired units, which emit orders of magnitude more NO_x, and major loadings of SO_2, CO_2 and air toxics.

A final irony is that the Clean Air Act requires any new source in a non-attainment area to fully offset its emissions with matching reductions from existing sources. This means that there are no actual net NO_x reductions due to LAER standards even after the very high costs imposed. In fact, since offsets are required in a ratio greater than 1:1, overall NO_x reductions would be greater if the end-of-pipe controls were not required.

These policies for NO_x reductions lead to a perverse result for all other air pollutants in discouraging clean new gas-fired technologies. This is particularly true for carbon dioxide, the principal greenhouse gas. Since CO_2 is a long-lived gas that lasts for centuries once emitted, it is critical to achieve major carbon reductions in the next decade or two. The only practical way to do so is to invest heavily in efficiency and in modern gas-fired generation, which is needed to substitute for the older coal-fired power plants. Yet our NO_x policies make such new investment considerably more difficult, especially for smaller units that are precisely the ones that are used for cogeneration at industrial sites or to convert methane to power, and are counted on to achieve efficiency gains and major greenhouse gas reductions.

Problems Related to Use of Rate Standards

The second set of major problems with the NO_x standards under the Clean Air Act relates to the use of rate standards. Historically, pollution standards under the CAA have been established as rate standards measuring the concentration or percentage of a pollutant in end-of-pipe emissions. The use of rate standards is appropriate when addressing the local concentration of a pollutant, which was of concern in the early years of the Clean Air Act. However, they become less and less appropriate in addressing total pollutant loadings and regional issues such as urban ozone formation and interstate transport of NO_x. As described below, reliance on traditional end-of-pipe rate standards causes serious problems when addressing these regional issues because they do not create incentives to move to cleaner technologies, create no drivers to exceed the standards, restrict technology choices, and create high transaction costs and conflicts.

Emission rate standards do not promote a move to cleaner technologies

One of the chief problems with emission rate standards under the Clean Air Act is that they are individually set for each specific production technology. Different standards are set depending on the kind of fuel used, as well as the specific boiler or turbine technology used. This method creates major problems when different technologies differ in their environmental effects, as it creates no incentive to move from dirtier to cleaner technologies. Yet in many sectors, particularly the power sector, the fundamental answer to solving pollu-

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tion problems is precisely to move to cleaner, less polluting technologies. Therefore the drivers under the Clean Air Act fail to support the most important need for environmental quality, a shift to cleaner energy generation.

Rate standards apply only once, limiting the technologies able to be used to lower pollution

Another key problem with current rate standard approach is that the standards apply only once: for new plants at the time the plant is built or subsequently undergoes a major modification, and for existing plants at the date Title IV applied. This limits compliance options to capital or process choices made at the time the plant is built or modified, and eliminates the possibility of compliance through changes in management practices, fuels, or any other operational decisions after a plant in built. This harkens back to an older view of pollution, that there is a single known technology "fix" that can be implemented once. The reality is that technology is ever-evolving, and there are numerous technologies and management practices that can reduce pollution; a good regulatory system needs to provides incentives to implement them.

There are three major negative consequences of applying a rate standard only at the time a plant is built or undergoes a major modification. The first is that such a standard provides firms with no incentive to take advantage of future technology advances. A firm does not have to implement anything more after the date it is permitted, even if a technological breakthrough means that it could inexpensively reduce pollution by an additional amount. This is precisely what has happened with cyclone boilers; after the regulatory standard was issued, the industry discovered how to reduce NO_x emissions cheaply in cyclones far below the standard. However, companies had no incentive to do so, and so these high-emitting boilers continued to pour pollution into the air, at rates as high as 500 ppm NO_x.

The second negative consequence is that the CAA's new source standards only promote compliance though decisions about capital equipment, and not though ongoing operational or management decisions after a plant is built. Many NO_x reduction technologies, such as gas reburn and overfire air, are incremental and can be adjusted to achieve various rates of NO_x control depending on the cost of inputs and other parameters. Indeed, the first year of application of the OTC cap-and-trade program for NO_x in the Northeast states revealed that once a market incentive was created to reduce NO_x emissions, companies found ways to lower NO_x by 20-30 percent *at existing units*, and without significant capital additions. Achieving NO_x reductions through operational changes can be highly effective, and may be essential to reduce NO_x to very low levels. Promoting such changes requires that regulatory systems move beyond the current rate-based approach, which provide no incentives to go beyond initially established limits.

A third major but longer-term consequence of requiring compliance only through periodic changes in rates is its chilling effect on research and development. Since the rate standard creates no continuous driver to lower emissions, firms do not invest continuously in research and development to enhance environmental quality, because there is no compliance benefit in doing so. Instead, the periodic effort to lower the rate standards becomes a political issue, with industry battling through its lawyers to make sure the rate standard is as lenient as possible, and then to use existing technologies for compliance. As demonstrated best by the cyclone boiler situation, when the rate standard is then announced, there is then a flurry of research activity on how to reach the standard at least cost, after which the research effort subsides. This is no way to promote innovation or achieve any meaningful relationship between environmental effectiveness and economic efficiency.

Emission rate standards promote end-of-pipe solutions instead of pollution prevention and cleaner processes

A fundamental problem with rate standards is that setting standards focused on end-of-pipe rate reduction inherently favors compliance practices through pollution control devices instead of pollution prevention and cleaner processes. Their structure provides limited incentives to move to cleaner fuels, and to comply through cleaner processes.

The problem here is how the law or the regulatory agency applying a rate standard treats emission reductions achieved by each of the three compliance methods: cleaner fuels, cleaner processes, and end-of-pipe controls. If the law requires a percentage rate reduction, cleaner fuels cannot be used for compliance, as this standard requires additional reductions via end-of-pipe control devices no matter how clean the fuel. The cleaner fuel does not help. This perversely may even lead businesses to use dirtier fuels, as it may be cheaper to reduce pollution by the given percentage with a dirtier fuel compared to the cleaner fuel. A cleaner process also may not count. Over the past decade, major technological advances in natural gas turbines have reduced their uncontrolled NO_x emissions from over 100 ppm to the very low 9-15 ppm range, an order of a magnitude less than a coal-fired technology. This has achieved a 90 percent pollution reduction, yet often may not count when a regulatory body applies a standard like BACT or LAER. Some states applying these standards only recognize reductions achieved though end-of-pipe control equipment such as SCRs. This makes no sense—what matters is the overall cleanliness of a process, not how reductions were achieved.

Most rate standards are not output-based.

A technical concern is that even if rate standards are to be used, they should be output-based and not input-based in order to reward efficiency. Because all power generating units produce an identical commodity—electricity—standards can be expressed as Generation Performance Standards, in units of pollution per kilowatt hour. However, rate standards applied to NO_x are typically expressed in terms of energy inputs—pounds of pollutant allowed per million British thermal units—or as emission factors, such as parts per million of pollutant in exhaust volume. Neither of these rate standards has a great deal of bearing to actual overall pollution levels, and neither rewards efficiency in producing electricity, failing to drive firms towards that goal.

Rate standards create high transaction costs and a culture of conflict between regulators and the regulated industry.

The New Source Review process under the CAA typically takes 1 ½ years or longer, imposing administrative costs on governments and major opportunity costs on companies that may be siting clean new plants. Under this process, the law requires government regulators to make a specific determination of what precise technology is the "best available" or "lowest achievable". EPA 1999b. For BACT, the law requires that these be made "on a case-by-case basis, taking into account energy, environmental, and economic impacts." 42 USC 7479(3). EPA 1990. These standards pit regulators against the applicant on a series of factual issues, creating very high transaction costs that are one of the major issues in siting clean new plants. However there may be no gain to the environment if the plant is a modern gas plant, as NO_x emissions are minimal, and the plant would be expected to create multipollutant benefits by displacing power from dirtier sources.

Regulations do not have to be this way. Major environmental benefits can be achieved with low transaction costs under technology-neutral approaches such as the emission cap and allowance trading system. These eliminate governmental review of technologies, but do require highly credible emission monitoring and reporting standards. Both the Acid Rain Program's SO_2 cap and the OTC NO_x cap achieve major emission reductions and a zero new source standard without any lengthy permitting procedures (transactions take less than 24 hours) or case-by-case conflicts between regulator and regulated. These approaches redirect business effort away from contesting regulatory authority toward competing in the marketplace.

In sum, the combined effect of all these problems acts to discourage investment in new plants, which robs the environment of the efficiency gains made in energy technology between the 1950-1970 era, when many of the existing plants were built, and the present.

Principles for a Results-Oriented Approach

Fortunately, there are solutions for each of the key problems created by the NO_x rate regulations. The best solution would be to develop regulations that are market-based and technology-neutral. The idea is to establish uniform standards that include both old and new plants without placing undue burdens on new efficient plants, promote the use of clean technologies and not dirty ones, and create continuous drivers for innovation. Specific ingredients of the new approach that is needed include systems such as cap-and-trade approach that:

- create a consistent standard applicable to both old and new plants;
- do not discriminate by imposing different standards on different technologies;
- create continuous and not one-time drivers for improvement and innovation;
- allow business flexibility to choose differing compliance approaches;
- have effective monitoring of emissions;
- achieve high levels or 100 percent compliance; and
- minimize transaction costs and conflict.

Steps are being taken in the right directions. These include the Ozone Transport Commission cap-and-trade system for NO_x in the Northeast; EPA's SIP call, which would extend a cap-and-trade system to a total of 19 Eastern states; and proposed four-pollutant bills that would establish stringent national cap-and-trade standards for SO_2, NO_x and CO_2, and address mercury reductions. These help to eliminate the grandfathering problem and create a uniform standard applied to all covered units, while promoting compliance through pollution prevention.

NO_x Cap and Trade. The best and most comprehensive solution would be to replace existing standards with a stringent emission cap and allowance trading system, created on a national or regional basis, that includes all sources.[3] This solution would not only be extremely effective environmentally, but would eliminate virtually all of the problems mentioned above that are caused by the use of rate standards, while promoting innovation and cost reductions. Currently, EPA is proposing a cap-and-trade system as part of the NO_x SIP call regulation, and Congress is also considering cap-and-trade standards in several bills concerning the electricity industry.

The major benefits of a good cap-and-trade system are that it can lead to political acceptance of a very strict limit, which serves society's interest in pollution reductions while allowing the widest possible breadth of compliance options, hence reducing costs. It removes government from case-by-case decisionmaking about technologies, freeing business to experiment without liability. Such a system eliminates all discrimination between old and new plants and between technologies—all face equal incentives to reduce. It performs far better than a rate-based system in regards to both cost and innovation, principally because government no longer needs to predict where innovation may occur as they do in rate system—the cap-and-trade system places this burden on the regulated entities.

A cap-and-trade approach also encourages greater innovation for several reasons. Perhaps the most important is that the uniform standard exerts pressure on all to innovate, as all sources are equally covered under the standard. There are no exceptions, waivers, or lower standards for certain technologies, which characterizes most rate systems. This maximizes the breadth of innovation and allows unexpected innovation. Second, the pressure to innovate is continuous, driven both by the lack of growth in the cap and the opportunity to market allowances. Both give firms reasons to continuously seek to lower emissions, unlike rate systems where there is no incentive to go beyond the rate limit. Third, the opportunity to use allowances softens the risk of failure in experimentation, while the cap assures achievement of environmental goals.

Another key benefit of cap-and-trade programs is their record of effective monitoring and near 100 percent compliance. Sources must report hourly monitoring data on emissions, as well as daily data that confirms that all monitoring equipment is functioning properly. Major penalties are assessed for any violations, and are automatic if emissions exceed allowances. In five years, the Acid Rain Program for SO_2 has achieved 100 percent compliance every year, and in the first year of the OTC NO_x cap-and-trade program, there was only one exceedance of one ton, leading to a swift and automatic penalty. EPA 2000, 1999a.

Yet another benefit of cap-and-trade systems is that they minimize transaction costs. Instead of a protracted dispute between companies and government about what technology is most appropriate, companies must simply comply and be able to show the government that

[3] Although a system of pollution charges or fees may also provide similar benefits if the charges are set high enough, such systems have rarely been implemented in the United States.

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at year end they have enough allowances to cover all emissions. The government role changes dramatically, from choosing technologies to accurately monitoring compliance. Although government is removed from technology choice, the environmental integrity of the program is assured by the overall cap, which never grows.

Disadvantages of the cap-and-trade systems include the accurate monitoring that is required for the program to function, which may make it too expensive to include very small sources. Another potential aspect that some believe may occur is that the trading provisions may shift the locus of emissions, potentially causing areas of higher localized pollution levels. This should not be of concern with a regional pollutant, or if the total reductions are sufficiently great that everyone benefits. In addition, an analysis of the first four years of the Acid Rain Program's SO_2 cap-and-trade program showed that regional movements of allowances were minimal, comprising only 3 percent of all allowances used, and that trading may even have helped cool hot spots. Swift 2000.

Combining a Moderate Rate Standard with Market-based Approaches for Further Reductions. It is possible to combine the rate- and market-based approaches by establishing a moderate rate limit—equivalent to a 70 or 80 percent overall reduction—with a market-based system for further reductions. It would be important to set the rate to be uniform, so as not to discriminate between sources and technologies, and not so stringent that it would preclude competition among several compliance technologies, creating flexibility. The important additional reductions beyond the rate level would then be created through a market-based approach, such as emission charges or a cap-and-trade system.

This hybrid could maintain the traditional use of rates while avoiding the most restrictive aspects of rate standards in dictating technology choices, which increase the higher the rate level is set. Using a cap-and-trade or emission fee system for the added reductions needed above the rate standards allows some of the flexibility and drivers for continuous innovation and reductions created by these mass-based or market systems. One example of this approach is in Sweden, where a rate standard is combined with an incentive fee on NO_x emissions that is redistributed among the utilities based on their power output. It has been credited with generating reductions well below the rate standard. Srivastava, 1996.

Improving the Rate System Approach

Alternative solutions may be considered that improve the existing rate system approach, which are discussed below. However, they do not resolve all or most of the problems identified above, and will not work as well for the economy or the environment as the cap-and-trade system.

More frequent updating of rate standards by government. One option would be for government regulators to update pollution standards more frequently. This is unlikely to work for several reasons. The most important is practical—it now takes five to 10 years between initiation and implementation of a major rulemaking process, which is a far slower pace than the rate of development of technology change. Technology-based rate regulation simply cannot keep up even if one wanted it to. The second reason is that the entire notion of having government regulators attempt to define or divine technology development is flawed. Even the best of regulators cannot do this, as regulatory processes cannot encompass the great variety of base technologies, and much innovation cannot be predicted. Third, all rate standards suffer the inherent defects of providing no incentives to exceed the standard, not promoting continuous innovation, restricting the methods of compliance, and imposing high transaction costs in a permitting process.

Title IV could be considered a laboratory experiment of this approach, as it created a two-phased rate-based rulemaking process for NO_x, with Phase I starting in 1995 and a more stringent Phase II in 2000. However, in retrospect it can be seen that the Phase II standards failed to capture a major opportunity for emission reductions in cyclone boilers, and also did not promote compliance beyond the standards. Only when the OTC cap-and-trade program started did companies' behavior reveal that they could achieve an additional 20-30 percent in NO_x emissions reductions through operational changes at plants. The inflexibility of rate standards therefore is still a major problem under this approach.

Adopt uniform rate standards. Replacing existing provisions with uniform standards would achieve several important goals of a good NO_x regulatory system mentioned above. A uniform rate standard applied to all sources would neither discriminate between old and new sources, nor between technologies, and would reduce transaction costs by creating a simple, objective parameter. Woolf & Biewald, 1999. However, such a standard does not achieve all the goals identified above. It would still suffer from the problems that rate standards experience in restricting technology and compliance choices, not promoting compliance above the limit, and not creating a continuous driver for improvement and innovation. Innovation would therefore suffer, costs would not be as low as they could be, and transaction costs would be higher than in a cap-and-trade system.

Adopt output-based rate standards. Another important goal is to change to output-based standards so that efficiency is rewarded. A breakthrough was made in this regard in EPA's revised New Source Performance Standards adopted in 1998, which for new plants establish a uniform output-based NO_x standard of 1.6 lb per MWh of electricity generated for new plants. Unfortunately, this NSPS is rarely what determines compliance for new gas turbine sources, as New Source Review imposes a more stringent standard under BACT or LAER. Currently, these NSR standards for new plants are based on parts per million, which does not reward efficiency and is a poor indicator of the actual pollution caused by the plant. See EPA RACT, BACT & LAER Clearinghouse (1999). An output-based standard such as NO_x per MWh would be better.

Rationalize BACT and LAER. New source review standards have accelerated technological innovation in both combustion processes and end-of pipe controls. Advances in turbine design over the past 12 years have reduced levels of NO_x produced by gas combustion turbines from historical levels over 100 ppm to the much lower levels (9-25 ppm) mentioned above. The ability of modern gas combined cycle turbines to reach these very low levels of NO_x though combustion advances alone indicates that we have reached the point of diminishing returns when applying NSR to require additional end-of-pipe controls. These NO_x levels for new gas turbines are already several times lower than the NSPS, and the addition of end-of-pipe controls entails very high costs and significant emissions of ancillary pollution for the sake of very small NO_x reductions. BACT and especially LAER should be rationalized to take into account multipollutant consequences of add-on controls, and regulators should permit gas turbines to operate in the 9-25 ppm range without additional end-of-pipe controls.

Sources

Bluestein, Joel, 1999. *OTR NO_x Market: Lessons Learned from 1999*. Energy and Environmental Analysis, Inc., Arlington, Va. (Presented at Emissions Marketing Assoc., October).

Chalfin, Joel, 1999. *Gas Turbine Emissions*. General Electric Power Plants Systems, Schenectady, NY. (Unpublished presentation) (June).

EPRI, 1998. *First Demonstration of Overfire Air on Cyclone Steam Generator Reduces Costs of NO_x Compliance*. EPRI Innovators (October).

Gas Research Institute, 2000. *Low Cost Options for Achieving Deep NO_x Reductions*, Washington, D.C. (March)(posted at www.gri.org).

Kaarsburg, Tina & Gorte, Julie F., 1999. *Promoting Productivity and Clean Air with Innovative Electric Technologies*. Northeast Midwest Economic Review (Nov/Dec).

Schorr, Marvin & Chalfin, Joel, 1999. *Gas Turbine NO_x Emissions Approaching Zero - Is It Worth the Price?* General Electric Power Systems. Presented at Air & Waste Management Association's 92d Annual Meeting, June 1999, St. Louis, Mo.

Srivastava, Ravi and Perrin Quarles, 1996. *Performance of Selective Catalytic Reduction Technology at Electric Utility Boilers in the United States, Germany and Sweden*. Presented at Air & Waste Management Association's Second Conference on Acid Rain And Electric Utilities, Scottsdale, Arizona, January, 1997. (November).

State and Territorial Air Pollution Program Administrators & Association of Local Air Pollution Officials (STAPPA/ALAPCO), 1994. Controlling Nitrogen Oxides Under the Clean Air Act: A Menu of Options, Washington, D.C. (July).

Swift, Byron, 2000. *Allowance Trading and SO2 Hot Spots – Good News from the Acid Rain Program*. 31 Environment Reporter 954 (May 12)(posted at www.epa.gov/acidrain/papers).

U.S. Energy Information Agency, 1998. *Reducing Nitrogen Oxide Emissions: 1996 Compliance with Title IV Limits*. Electric Power Monthly (May).

U.S. Environmental Protection Agency, 2000. 1999 OTC NO_x Budget Program Compliance Report. Clean Air Markets Division (March 27).

United States Environmental Protection Agency, 1999a. 1998 Compliance Report: Acid Rain Program. (EPA-430-R-99-010) (July). [Also 1997, 1996 and 1995 Compliance Reports.]

U.S. Environmental Protection Agency, 1999b. Compilation of Air Pollutant Emission Factors, AP-42. (Each section independently updated).

U.S. Environmental Protection Agency, 1998. RACT/BACT/LAER Clearinghouse Annual Report for 1998: A Compilation of Control Technology Determinations. EPA 456/R-98-004 (June).

U.S. Environmental Protection Agency, 1996. *Acid Rain Program; Nitrogen Oxides Emission Reduction Program - Phase II Final Rule*. 61 Fed. Reg. 67111 (December 19, 1996).

U.S. Environmental Protection Agency, 1990. Draft new Source Review Workshop Manual; Prevention of Significant Deterioration and Nonattainment Area Permitting. (October).

Witherspoon, Leslie & Smith, Ken, 1999. *NO_x Control Technology Options and Development Activity for Mid-range Natural Gas Fired Turbines*. Solar Turbines, San Diego, CA. Presented at Air & Waste Management Association's 92d Annual Meeting, June 1999, St. Louis, Mo.

Woolf, Tim, Bruce Biewald & David White, 1999. *Electricity Market Distortions Associated With Inconsistent Air Quality Regulations*. Synapse Energy Economics (November 18).

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