Output-Based Emission Control Programs
U.S. Experience
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Paul J. Hibbard and Nancy L. Seidman, Massachusetts Department of Environmental Protection; Barbara Finemore, NRDC; David Moskovitz, RAP

I. Introduction

This paper was prepared for the China Sustainable Energy Program and the WAJF. The purpose of the paper is to briefly describe a new approach to power plant air emission regulation: output-based Generation Performance Standards (GPS). The concept of "generation performance standards", or equivalently "emission performance standards" has evolved in the United States in recent years as state and federal regulators, addressing the consequences of electric industry restructuring, have sought mechanisms for assuring environmental protection in newly competitive electricity markets. Output-based standards are well suited to a competitive electric industry and they provide a mechanism for promoting greater efficiency in the generation of electric power regardless of plant age or historic fuel use.

Thus far, GPS has been implemented in one state in the U.S, Massachusetts, and is under active consideration in many states and at the federal level. GPS has been included in electric utility restructuring legislation in Connecticut and New Jersey, model rules adopted by Northeast States for Coordinated Air Use Management (NESCAUM), an association of air regulators in eleven eastern states), and the approach is included in proposed federal legislation.

This paper describes the rationale, benefits and history of output-based Generation Performance Standards. It then briefly explores a number of general issues involved in establishing and applying GPS. Next, the paper details the Massachusetts power plant nitrogen oxides (NOx) emission control program, which includes GPS in the context of a regional cap and trade program, as well as several innovative features designed to promote end-use efficiency, combined heat and power and clean new energy sources. It also briefly describes proposed regional and national approaches to developing output-based emissions standards.

II. The Development of Generator Performance Standards

A. GPS Rationale and Benefits

Power plant emissions in the US have traditionally been regulated on the basis of pounds of emissions per unit of fuel burned (e.g., lb./mBtu). Historically, this input-based regulatory option was adopted because it could be applied to all sectors being regulated, not just power plants but industrial and commercial sectors. This method was also consistent with the U.S. practice of setting different standards for power plants depending on plant age and fuel use. However, using non-uniform, fuel input-based standards has led to unintended negative consequences. It encourages the construction and operation of plants with higher emissions and lower efficiency, encourages less efficient plants to continue operating, fails to provide incentives for pollution prevention, and is not compatible with competitive markets for generation.

In contrast, output-based standards provide a mechanism for promoting greater efficiency in the generation of electric power regardless of plant age or historic fuel use. Using uniform output-based emission standards is important for electricity markets in the process of evolving to competitive markets since they reward facilities that are efficient in production and promote the development of new and cleaner facilities.

The purposes of shifting to output-based performance standards are:

1. To prevent electric utility restructuring from resulting in a degradation of air quality by providing a mechanism to ensure that disparities in environmental regulation do not create a competitive advantage for more polluting resources (i.e., "leveling the environmental playing field"), and
2. To improve air quality and to reduce the adverse impacts of electricity generation on public health and the environment.
3. To improve economic efficiency by allowing generators to optimize the choice between fuel source and control technology

In the U.S. many states, eager to embrace electric utility restructuring as a means of increasing efficiency and reducing costs, have also been eager to ensure that competition is introduced in a manner that preserves environmental quality. Recognizing the wide disparities in emissions levels that characterize existing power plants throughout the U.S., regulators became concerned that, in the absence of comparable environmental requirements for all suppliers, restructuring could lead to greater reliance on lower cost but more polluting resources. These concerns are particularly acute in the Northeastern United States, where serious air pollution problems are compounded by pollution transport from regions with less stringent environmental regulation.

B. GPS as a Pollution Prevention Strategy

Traditional power plant emission control programs are not typically viewed as pollution prevention (P2) strategies, since they are often met by installing end-of-the-stack emission control technologies. Furthermore, many air control strategies reduce air emissions but increase the solid waste burden associated with plant operations, transferring the environmental burden from one medium to another. Shifting to output-based GPS for even one pollutant can improve a number of other environmental measures as well. As described below, the innovative Massachusetts NOx emission control program has resulted in a number of environmental benefits.

III. Developing and Applying Generation Performance Standards

A. Covered Pollutants

GPS can be set for one or more pollutants. Environmental policy makers in the U.S. have recognized that there are substantial disadvantages to the historical approach of setting standards for one pollutant at a time. Setting a standard for one pollutant today and a second pollutant two or three years from now increases the chances that investments to reduce emissions of the first pollutant causes increased emissions of the second pollutant. It also makes it less likely that investments are made in control strategies that minimizes the cost of controlling both pollutants. As a result Congress is now considering setting standards for four pollutants, SOx, NOx, CO2, and mercury, at the same time.

B. Establishing and Adjusting Output-Based GPS

A common requirement of any GPS is setting the performance standard (emissions per megawatt-hour) to be met. Emission standards in the U.S. and most other countries are the result of a two-step process. The first step is to establish ambient air quality limits for each pollutant at levels that will protect human health and property. The second step is to set emission limits for individual sources at levels low enough to ensure that ambient standards are met. For some pollutants, ambient air quality standards are met by setting a cap on the total amount of emissions. Individual sources of pollution essentially pay for the right to emit a portion of the cap.

Assuming current emission limits or caps are adequate to meet health-based ambient standards, one could just divide current tons of emissions by current kWh output. For example, if current emissions are X tons and existing generation is Y MWh, an output-based standard could just divide X by Y to derive the output GPS. In the Northeastern U.S., the expected average of SO2 emissions from all generation sources would lead to a standard of around 4 lbs./MWh (based on 2000 emissions standards and expected generation in 2000), and a standard of 1.0 lb/MWh for NOx.[1]

Once a standard is set, a decision must be made as to whether and in what manner to adjust an output standard over time in order to encourage further emissions reductions. We believe that at a minimum the standard should be reduced every year or two by the same percentage that electricity production increased. If this is done the total output of pollution remains the same and the performance standard gets predictably more stringent.

C. Applying GPS

GPS is an approach to emission regulation that can take many different forms. For example, GPS can be applied on a facility basis, where each individual facility must meet the standard. GPS can also be applied on a company-wide basis, which will encourage the operation of more efficient units and facilities, or in a scheme which caps emissions on a regional or national basis. The final step includes a cap and trade program, with the allocation of allowances based on electricity output. The recently adopted Massachusetts rule is an example of an output-based allocation of NOx allowances in a regional cap and trade program for nitrogen oxides (NOx) emissions. Output-based standards may also be applied at the level of the retail supplier of electricity. Which option makes most sense in China will depend on a number of factors that have not been explored in this paper

1. Facility-by-Facility GPS

The most stringent way to apply GPS is at the facility level. Each plant would be required to meet the same uniform emissions limit per kWh. Plants that cannot meet the standard would have to shut down, clean up, or pay penalties (if the penalties are less than the costs of cleanup or shutdown, including net revenue loss). Assuming that shutdown or cleanup are the less costly actions, application of the standard will result in emissions reductions, and average emissions will decline. The effect is to reduce pollution from higher-emitting units to levels below the facility standard, without affecting emissions from those units that meet or are cleaner than the standard.

2. Company-Wide GPS

At the next level of aggregation, output-based standards could be applied on a company-wide basis. This allows companies to average the emissions and output at all their facilities to determine whether they can meet the standard. If the standard is applied on a company-wide basis, then emissions, output, and emission rates across more than one facility can be averaged, thus making it easier to comply with the output standard. However, average emissions will not decline at as rapid a pace as in the facility-by-facility approach.

3. Company-Wide Emission Caps

[1] Northeast States for Coordinated Air Use Management "Emission Performance Standards, Model Rule Background Information Document," December 1999. http://www.nescaum.org/workgroups/energy.html.

An alternative to applying output-based standards on a company basis is to set a company-wide cap on total emissions. This could prevent increases in emissions as output increases. For example, companies would need to demonstrate that their annual emissions meet their targeted emission levels. If a shorter averaging time is used (e.g., monthly) then the standard becomes more stringent. This step would use the same monitoring and reporting requirements as those needed for demonstrating that company has meet an output standard without a cap.

4. Regional Cap and Trade Programs

At the next level of aggregation, a regional cap and trade program could be established whereby companies and facilities demonstrate that they hold allowances for every ton of emissions generated during a set time period (usually a year). In this context, allowances could be allocated to facilities based on measured electrical and steam output. If their emissions are lower than their allocated allowances then allowances can be banked or sold to other facilities. This step requires establishing allowances as a currency for trading, and trading mechanisms. The U.S. EPA has successfully established such a program for SO_2 nationally and with states for NO_x on a regional basis. EPA's program[2] requires equivalent monitoring and reporting requirements to ensure that allowances are worth same amount across trading program.

5. Retail sellers

The Emission Performance Standards included in recent state legislation would require that the *seller* of electricity (who may or may not own power plants) ensure that the average emission rates of all the power plants used to meet its customers' electricity needs not exceed specific output-based emission standards. Regardless of their forms, output-based standards can be used in a variety of ways to make the transition from traditional power plant air pollution regulation to methods that encourage efficient generation and pollution prevention.

D. Monitoring and Enforcement

[2] US EPA Draft Design Documents for an SO_2 Trading Program in China; 1999.

Monitoring and enforcement are important parts of any environmental program. Most air emission monitoring in the U.S. is based on continuous emission monitors in power plant stacks. With respect to enforcement, an important principal is the cost of violations should exceed the cost of compliance. Thus, the Massachusetts rule states that if emissions exceed allowances for a given year, allowances for the next year are automatically reduced at the rate of three to one. Experience shows that this approach assures compliance.

IV. The Massachusetts Rule: An Example of Output-Based Allocation within a Regional Cap and Trade Program

A. The Massachusetts Allowance Trading Program

In November 1999, the Massachusetts Department of Environmental Protection (DEP) adopted a new rule [3] to reduce emissions of NO_x from power plants. The rule is part of a multi-state emissions "cap and trade" program.[4] It reduces and caps emissions (at 12,861 tons) from large power plants in Massachusetts during each ozone season (May through September), starting in 2003. In order to track these emissions, a currency, called NO_x “allowances” was created, and is distributed to sources. One NO_x allowance equals one ton of NO_x emissions. Under the cap and trade program, at the end of each ozone season, each power plant must “retire” one allowance for each ton emitted during that ozone season. If a source holds more allowances than it needs to comply, it may bank the excess allowances for future use, or sell them in the allowance market. If a source's emissions exceed the number of allowances held, it needs to purchase allowances commensurate with the shortfall, or face penalty provisions.

The Massachusetts allowance trading program is part of a federal program to limit state NO_x emissions across the affected region, and is necessary to enable states to achieve the national ambient air quality standard for ground-level ozone. Under the federal program, states must achieve an effective cap on NO_x emissions from all sources, but how they do so is left to the states. After carefully reviewing the cost and effectiveness of control strategies available to states, EPA encouraged states to achieve the necessary reductions for state sources through a federally administered cap and trade program. EPA developed a model trading program rule for

[3] Code of Massachusetts Regulations, 310 CMR 7.28. WWW.dep.state.ma.us/dep/bwp/daqc/daqcpubshtm#nox

[4] The Massachusetts NO_x Allowance Trading Program is designed to meet the state’s emission control requirements under the US Environmental Protection Agency “NO_x SIP Call,” which covers over 20 eastern states. 63 FR 61712.

use by states, and recommended the allocation of state budgets under that program using historical data on heat input (input-based allocation).

It is not surprising that EPA recommended that states use an input-based method for allowance allocations. Historically, most environmental regulation at both the national and state level has been written in terms of mass of emissions per unit of heat (or fuel) input – i.e., lbs./mBtu. This was done for several reasons. First, sources of air emissions include a vast array of combustion technologies, from the smallest gasoline engines to the largest coal-fired boilers. Different combustion applications are used for many different purposes, such as power tools, small diesel generators, home heating furnaces, industrial process boilers, and electricity generators. But, though combustion sources may have a wide spectrum of sizes and useful outputs, they share a single, common input: fuel. Fuel input may be easily quantified in terms of quantity, and equivalent heat content. Thus, the easiest way for environmental agencies to regulate emissions across this diverse spectrum of combustion sources was to establish limits on the basis of pounds emitted per unit of fuel (or heat) input. For many sources whose output is not easy to quantify or monitor, this will continue to be the case; for electric generating sources it is not.

Massachusetts decided to distribute, or "allocate" the fixed state NO_x budget of 12,861 tons (or allowances) each year to affected sources on a kWh output basis. In doing so Massachusetts rejected the historical [APPROACH?] used in the SO2 program as well as EPA's proposal to allocated allowances based on historical heat input. Massachusetts chose to allocate allowances to the affected power plants on the basis of net electricity output (output-based allocation), because this method encourages pollution prevention and rewards generation efficiency in the electricity sector.

B. Benefits of Output-Based Allocation

An output-based GPS program will change the relative cost of competing electric generating facilities, favoring those facilities that are more efficient – that is, that need less fuel input (and thus have lower environmental impact) to generate a unit of electricity.

To illustrate this point, Figure 2 presents the relative economic impact of an output-based allocation on two hypothetical 100 megawatt generating facilities – an old coal-fired plant and a new gas-fired plant. Since the allocation is based on electrical output, the two facilities would receive the same allocation.[5] However, based on emission rates typical of similar facilities in Massachusetts, the owner of the coal plant would be a buyer in the allowance market, and the owner of the gas plant a seller.[6] Assuming an allowance price of $1,500/ton, the relative economic impact of compliance with the program would represent an economic advantage to the gas plant of over one million dollars per year, which represents roughly 0.3 cents per kilowatt-hour. This economic advantage could influence (1) which type of facility is built to meet growing electricity demand and (2) which type of facility will be dispatched in the daily energy market. To the extent that this relative economic advantage thus translates into a higher level of generation from gas (and lower from coal), or results in efficiency improvements at the coal facility, the program will result in reductions in emissions of other pollutants, and reduced water and solid waste impacts.

C. Overview of Allowance Allocation

The allocation of the Massachusetts allowance budget can be separated into four pieces, as shown in Figure 1. Each of these items is described more fully below. First, five percent (643 tons) is removed to establish a Public Benefit Set Aside (PBSA). The PBSA was included as an economic incentive for achieving additional emission reductions through the reduction of energy use on the demand side, and through the development and commercialization of zero-emission renewable energy.

Second, another five percent (643 tons) is removed to create a New Unit Set Aside (NUSA). The NUSA was established to remove any disincentive the program might otherwise create for the development of new, cleaner generation facilities in Massachusetts. The NUSA will be used to cover emissions from new units for the first few years of plant operation, at which time they would be included in the allowance allocation program in the same manner as all other affected facilities.

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[5] Under an *input*-based allocation, the less efficient older coal facility would receive significantly more allowances than the gas facility, since it would require more fuel *input* to generate the same level of electrical output as the gas facility.

[6] For the purposes of comparison, it is assumed that both facilities operate the same number of hours over the ozone season. The emission rate assumed for the coal facility is 4 lb/MWh; for the gas facility 0.06 lb/MWh.

Third, the allocation assigns approximately four percent (479 tons) of the budget to affected sources whose useful output is partly or entirely steam for process or heating applications. Massachusetts chose to include an allocation for useful steam output in order to reward the higher efficiencies associated with combined heat and power applications. Finally, the remaining available allowances (approximately 86 percent, or 11,575 tons) are allocated to affected sources based on their useful electrical output.

D. Public Benefit Set Aside

Massachusetts has long supported initiatives to reduce the amount of energy *consumed* in the state, through installation of high-efficiency lighting, heating, cooling, and appliance technologies. In addition, Massachusetts has promulgated laws and policies that encourage the development of new energy generation technologies that use low- or zero-emission renewable fuels. Public-funding support for these energy technologies has been, and continues to be, necessary to overcome economic barriers to their widespread use. In consideration of this market reality, and given the significant non-market environmental benefits that such resources have to offer, Massachusetts designed its Allowance Trading Program allocation to provide additional financial support for the development and installation of energy efficiency measures and renewable power generation.

Specifically, Massachusetts designated 5% of its NOx cap, or 643 allowances, to be awarded to programs or projects that meet specific emission-reducing and/or developmental thresholds. An example of a technology eligible for PBSA allowances would one that avoids emissions of carbon dioxide, sulfur dioxide, mercury, and other pollutants, but whose commercial development or installation is in doubt due to the realities of energy market economics. Income from the sale of allowances awarded from the PBSA could be used to reduce development and/or installation costs.

For example, assuming that allowances from the PBSA are given to qualifying projects at the rate of 1.5 lbs./MWh, a solar (or energy efficiency) project would earn 1 allowance for every 1333 MWh generated (or avoided). Assuming an allowance market value of $1,500/ton, renewable and efficiency projects would receive additional income of over $1/MWh, or 1 mill.

It is important to note that by allocating a portion of the allowances to non-NOx emitting sources NOx emitting sources will have to purchase more allowances. Thus, distribution of PBSA allowances to energy conservation or renewable technologies produces three benefits: it shifts more costs to NOx emitters, it encourages the development of zero emission resources, and it reduces other air, water, and solid waste impacts, of the electricity sector.

E. Combined Heat and Power

The Allowance Trading Program includes several cogeneration facilities that capture and use the steam or heat that otherwise would be wasted in the electricity generation process, in addition to generating electricity. The owners of these combined heat and power (CHP) facilities can either use the heat/steam on site for heating or process applications, or sell it to other industrial, commercial, or residential customers located near the point of generation. In either case, use of this waste heat displaces the need to independently generate the heat through the use of dedicated combustion sources (furnaces, boilers), thereby avoiding additional pollutant emissions. Increased use of CHP technologies will improve overall energy efficiency leading to an overall reduction in pollutant emissions.

Massachusetts designed the Allowance Trading Program to reward the use of CHP. In addition to receiving allowances for useful electrical output, CHP can also be issued allowances for the facility's useful heat or steam output. Additional data needs for this calculation include actual or estimated steam output that is used in heating or process applications. Since the allocations to all sources come from a single capped budget, awarding allowances for CHP rewards these facilities and reduces NOx allocations to non-CHP sources.

F. New Unit Set Aside

Allowances are based on historical generation levels and are allocated three years before they are used. (WHY?) This raises the question of how to address new plant additions, especially new IPP additions. If nothing special were done, a new entrant having had no historical electricity production would be issued no allowances. This means that in addition to the cost of meeting stringent emission limits, clean new sources would face the further financial barrier have to buy credits from existing suppliers. To avoid this problem Massachusetts decided to include includes a set aside of allowances that will be distributed to new sources for the interim period between initial operation and the time when they have sufficient historical operating data to be folded into the general allocation.

G. Annual Allowance Reallocation

Massachusetts reallocates its output-based NOx allowances annually. As a result new sources are quickly incorporated in the system and load growth results in the annual reduction in the allowed emission per kWh.

Figure 3 shows the general effect of the allowance reallocation. The first ("Initial Allocation") represents the allocation for all affected sources in Massachusetts in the first year of the program. This allocation is based on useful output from affected facilities over a historical period. In the first year the six highest emitters (out of 32 sources) receive roughly sixty percent of the state allocation budget.[7]

In the second allocation two facts are assumed to have changed. New generation is built which takes some market share from the existing generators and load grows. In the new year the fixed state NOx budget must be divided by more generation so the allowed emissions per kWh go down. Also, the expected growth in new, clean, and efficient gas fired plants reduces the generation from the older less efficient plants. The combination of factors means the six highest emitters now receive only one third their original allocation and, more important, the allowed NOx emissions per kWh goes down. New clean generation would have sufficient allowances to cover their emissions and higher-emitting generation would face an increasing financial burden associated with purchase of allowances. Thus, the incentive to improve efficiencies and/or install post-combustion control technologies will grow over time for these sources.

[7] The six highest emitters represent nearly 80% of the NO_x emissions from affected sources.

V. Other Examples of Output-Based Emission Control Requirements

A. The NESCAUM Model Rule on Emission Performance Standards for Electricity Suppliers

In late 1996, a Vermont Public Service Board Report Order contained a recommendation for output-based emission performance standards; the idea was also included in proposed state restructuring legislation. At the same time, the U.S. Environmental Protection Agency (EPA) began exploring the idea of using output-based emission limits for the regulation of nitrogen oxides (NO_x). By 1997, northeastern state environment and utility regulators, environmental advocates, and other stakeholders were discussing the potential application of generation performance standards in the context of state restructuring initiatives.

In late 1997, the Massachusetts legislature passed electric utility restructuring legislation that included a provision for the implementation of generation performance standards. In April 1998, the Connecticut legislature likewise passed a restructuring bill that called for the establishment of generation performance standards. Later the same year New Jersey included a provision for generation performance standards in its restructuring legislation.

The NESCAUM Model Rule for Emission Performance Standards (Emission Performance standards is another term for Generation Performance Standards: see footnote 2) was an effort of air regulators in these and neighboring states to provide guidance on a particular approach to GPS. The model rule expands upon the Massachusetts rule in two ways. First, the Model Rule proposes output-based emission performance standards for three pollutants; nitrogen oxides (NOx), sulfur dioxide (SO2), and carbon dioxide (CO2). Second, the requirement of the rule is aimed at retail suppliers of electricity rather than generators. Because many states are moving to retail competition, retail electricity suppliers include electric utilities and competitive suppliers.

Their application to retail suppliers is especially important because it provides a mechanism for limiting the overall environmental impacts of serving retail electricity demand in a particular state, regardless of where the generation used to serve that demand is located.

B. Proposed Federal Legislation with Output-Based Standards for Generating Facilities

An example of potential federal output-based environmental requirements is the Clean Energy Act of 1999 (S.1369), a bill that is now under consideration by the U.S. Senate. This legislation h is important for two reasons. First, it requires implementation of national pollution caps through uniform output-based emission performance standards for all fossil-fueled power plants. Second, the bill simultaneously sets caps on four pollutants; nitrogen oxides, sulfur oxides, mercury and carbon dioxide.

Legislation that controls the four major power plant pollutants in an integrated package would reduce uncertainties for electric generators and would be less costly than separate programs for each pollutant. Integrated control encourages system-wide efficiency improvements and increased utilization of cleaner fuels rather than end-of-pipe controls.

Conclusion

An output-based emissions standard can be viewed as one component of an emission control program, since output-based principles can be incorporated into a number of different emission control strategies. Establishing output-based standards for facilities or companies requires the establishment of mechanisms for documenting and reporting emissions and electricity output (as well as steam output for combined heat and power facilities).

Figure 1
Massachusetts Allowance Allocation
Total: 12,861 Tons

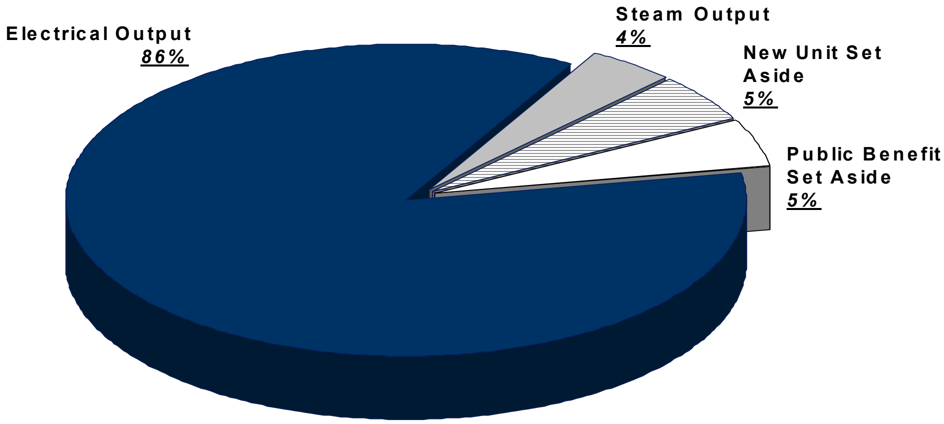

Figure 2
Output-Based Allocation --
Economic impacts on two 100 MW plants

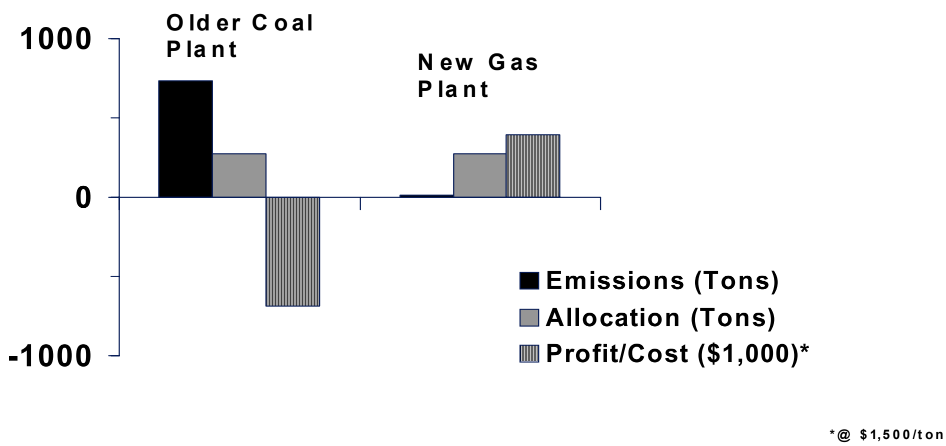

Figure 3
MA Output-Based Allocation --
Increasing Pressure on Highest-Emitting Sources