

## **Optimization Technology and the Clean Air Interstate Rule**

### ***PREPARING FOR CAIR***

The Clean Air Interstate Rule (CAIR) will result in the largest pollution reductions of any air rule in more than a decade. Power generators in the 28 Eastern States and the District of Columbia are making near-term capital investments in order to meet CAIR's 2009-2010 NO<sub>x</sub> and SO<sub>2</sub> reduction deadlines.

Generators can choose from many compliance alternatives including pollution control hardware and software, fuel switching, and buying excess allowances from other companies that have reduced their emissions under cap and trade provisions.

This paper discusses the hardware and software approaches most commonly undertaken, the challenges of each, and the role that optimization can play as the integration engine that manages tradeoffs between goals, processes and systems.

### ***THE CAIR MANDATE***

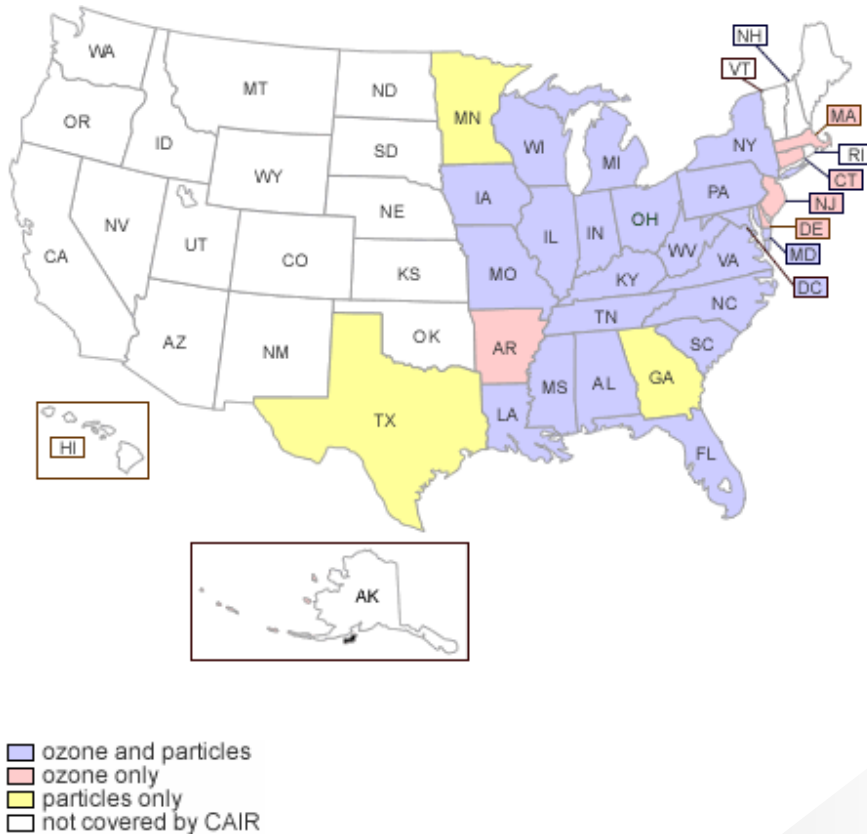
CAIR is a formal Environmental Protection Agency (EPA) Administrative Mandate that codifies into law many provisions first proposed as part of President Bush's Clear Skies legislation. It demands the largest reduction in air pollution since the Clean Air Act Amendments of 1990 (CAAA 1990). CAIR requires the 28 Eastern States and the District of Columbia to reduce, below 2003 levels, emissions of nitrogen oxides (NO<sub>x</sub>) and sulfur dioxides (SO<sub>2</sub>) by 60% and 70%, respectively. Under CAIR, states may achieve the required emissions reductions using one of two compliance options:

- 1) Participate in an EPA-administered interstate cap and trade system, or
- 2) Meet state air emission limits through measures of the state's choosing.

It is expected that most states will implement CAIR through building on the "Cap and Trade" approach used to meet the State Implementation Procedures (SIP) employed for CAAA 1990. The first phase of NO<sub>x</sub> reductions begins in 2009 and the first phase of SO<sub>2</sub> reductions begins in 2010. The second phase of both SO<sub>2</sub> and NO<sub>x</sub> reductions starts in 2015.

The EPA's Office of Air and Radiation (OAR) and the states aim to protect public health and the environment without interfering with the steady flow of affordable energy for American consumers and businesses.

**Diagram 1: States Affected by CAIR**



## ***BEST AVAILABLE CONTROL TECHNOLOGY***

### **Hardware Approaches**

Most CAIR responses will include NO<sub>x</sub> control hardware, ranging from combustion controls to post-combustion selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR) systems. These systems reduce NO<sub>x</sub> emissions, but often do so at the expense of efficiency, combustion degradation and increased complexity of operations.

NO<sub>x</sub> removal hardware solutions are usually considered in the following sequence: low NO<sub>x</sub> burners, overfire air, SNCR and SCR. The ranges of improvements are highly variable since all of these options are dependent on the original boiler design, fuel mix, and how hard a unit is being fired to make load or respond to automatic dispatching.

Low NO<sub>x</sub> burners can reduce NO<sub>x</sub> emissions by 20% to 40%, but they may also have a negative impact on waterwall corrosion, loss on ignition (LOI), steam temperature and efficiency (due to loss of radiant heat transfer in the furnace.)

Overfire air can reduce NO<sub>x</sub> by another 10% to 30% and is often undertaken at the same time as low-NO<sub>x</sub> burners. It can have similar challenges as low-NO<sub>x</sub> burners, and sometimes the boiler design prevents overfire air from being a viable option.

SNCR systems provide 20% to 40% NO<sub>x</sub> reduction and are typically implemented after low NO<sub>x</sub> burners and overfire air have been installed. The challenge is to balance the combustion process (flue gas concentrations as well as temperature) as much as possible throughout the entire load range to maximize SNCR efficiency while minimizing the cost of reagent to meet compliance. There are some concerns about the viability of SNCR technologies for larger units.

SCR systems can provide NO<sub>x</sub> reductions in the range of 75% to 90+%. This ability led many power producers affected by CAAA 1990 regulations to assume that the addition of SCRs would solve their NO<sub>x</sub> compliance issues. However, these systems introduced a whole new set of problems including unacceptable ammonia slip; escalating ammonia costs; ammonium bi-sulfate buildup; and opacity resulting from poorly controlled temperatures and high SO<sub>2</sub>-to-SO<sub>3</sub> conversion rates.

## Combustion Optimization

One of the most cost-effective methods to reduce NO<sub>x</sub> emissions is to optimize the combustion process using neural network software systems, such as NeuCo's CombustionOpt® solution. CombustionOpt streamlines the combustion process given the instrumentation and controls that are already in place, resulting in lower NO<sub>x</sub> emissions by between 10% and 25%.

CombustionOpt manages the tradeoffs between NO<sub>x</sub>, CO and fuel efficiency through closed-loop optimization of the fuel/air and temperature distributions in the furnace while adhering to all applicable measured or modeled operating constraints. The system uses neural networks and other advanced artificial intelligence technologies to extract knowledge about the combustion process and determine the optimal balance of fuel and air flows in the furnace. It optimizes fuel-air ratios in real-time by calculating the changes that should be made to key controllable parameters, such as dampers, feeders, burner tilts and overfire air, to best meet performance goals given current conditions and constraints. These supervisory set-point biases are passed to the DCS continually in closed-loop.

In addition to reducing NO<sub>x</sub> emissions, CombustionOpt improves fuel efficiency, minimizes LOI and opacity, and improves the consistency of operations. Unlike NO<sub>x</sub> control hardware, CombustionOpt can reduce NO<sub>x</sub> emissions while simultaneously improving boiler efficiency,



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which results in fuel cost savings and associated SO<sub>2</sub> and CO<sub>2</sub> benefits. It can also help to manage the complexity of post combustion systems such as SCRs, SNCRs or FGDs by improving the efficiency of reagent usage and/or increasing the amount of NO<sub>x</sub> or SO<sub>2</sub> removed.

Stand alone CombustionOpt Benefits include:

- NO<sub>x</sub> reduction: 10% to 25%
- Heat rate improvement: 0.5% to 2%
- CO reduction: 30% to 50%
- LOI improvement: 20% to 40%
- Opacity control: 10% to 30%
- Improved operating consistency
- Lower reagent costs
- Reduced ammonia slip
- Reduced ammonium bi-sulfate build-up and pluggage

### **Hybrid Hardware / Software Optimization Solution**

The decision about whether to take a hardware or software approach to meet emissions regulations is not a mutually exclusive one. In fact, in many cases the best approach is a hybrid one. This section will discuss the interactions between and benefits of combined hardware and software optimization solutions.

Combustion Optimization software can provide benefits beyond emissions reductions. It can counterbalance the negative impacts of post combustion systems, streamline the operations of combustion controls and post combustion systems, and act as the integration engine that manages tradeoffs between the systems.

By integrating CombustionOpt with low NO<sub>x</sub> burners, NO<sub>x</sub> reductions of up to 50% have been achieved. NeuCo has demonstrated incremental NO<sub>x</sub> reductions relative to low-NO<sub>x</sub> burners going all the way back to its first CombustionOpt installation at Mirant-Canal Unit 2 in 1998, still producing substantial benefits today. The original 1990's low-NO<sub>x</sub> burners increased LOI and more recent versions create high gaseous CO. For the newer low-NO<sub>x</sub> burners, CombustionOpt is able to identify the source of the CO (such as mill performance, primary air transport velocity, individual burner operation and secondary air temperature) and uses available levels to minimize or eliminate the CO excursions. CombustionOpt typically reduces both the average level and variability of LOI regardless of burner type simply as a result of better fuel-air mixing and improved combustion. Where on-line LOI monitoring is available, it can be very effectively addressed by CombustionOpt as either an objective or constraint.

Adding overfire air to low NO<sub>x</sub> burners and CombustionOpt has provided NO<sub>x</sub> reductions up to 60%. For a recent CombustionOpt installation at four 50 MW coal-fired units, for example, a



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one-year payback was achieved by extending the NO<sub>x</sub> reduction – from 0.4 lb/mmBtu to a range between 0.22-0.25 lb/mmBtu – to steady operations below 0.25 lb/mmBtu throughout the operating range of the units.

Overfire air, low NO<sub>x</sub> burners and other NO<sub>x</sub> control retrofits tend to create opacity excursions, particularly on units with older and/or undersized precipitators. On these units CombustionOpt balances the combustion process and fuel-air balance, which helps to maintain or lower the opacity issues as the unit is fired for NO<sub>x</sub> or pushed to respond in a cycling mode.

Integrating low NO<sub>x</sub> burners, overfire air and an SNCR can provide NO<sub>x</sub> reductions by up to 75%; with an SCR, reductions can increase to 90+%, depending of the coal being burned. These ranges assume the original design fuel for the boiler. As the industry experience with the first round of SCR installations has indicated, however, many SCRs exhibit difficulties reaching their design NO<sub>x</sub> removal rates. As required NO<sub>x</sub> removal approaches the design NO<sub>x</sub> reduction level, removal efficiency degrades and slip increases, often exponentially. Much of the difficulty is attributable to high variability in the profile of NO<sub>x</sub> and temperatures at the boiler outlet. CombustionOpt by its nature not only reduces average boiler NO<sub>x</sub>, but also increases the uniformity of both the temperatures and NO<sub>x</sub> in the gasses entering the SCR.

PRB blending will typically increase the NO<sub>x</sub> reductions when combined with low NO<sub>x</sub> burners and overfire air, but may negatively affect the reductions provided by SNCRs and SCRs. Even where SCR reductions are bolstered by a partial or complete PRB conversion, burning PRB can greatly increase the propensity for slagging, given the greater sensitivity of molten slag viscosity to both stoichiometry and temperature. Proving the ability to simultaneously reduce boiler NO<sub>x</sub>, ammonia consumption, and slagging for units with SCRs has been an important focus of NeuCo's four-year, \$19.1 million DOE Clean Coal Power Initiative project at Dynegy's Baldwin Energy Complex. The results at these 600 MW units designed for Illinois Basin coal but converted to 100% PRB and retrofitted with SCRs are compelling.

## **Extending the Solution**

In order to meet the environmental and market challenges, optimization needs to address multiple goals and plant subsystems based on market prices for fuel, reagents, credits and MW hours.

It is no longer sufficient to independently optimize the combustion process for NO<sub>x</sub> regulations, the soot blowing process for opacity and slagging, and steam temperatures for efficiency, especially when fuel blending/switching or spot purchasing of coal is being used as part of the plant's operating strategy. When varying fuel is part of the plant's strategy, many times it is the tradeoff issues such as LOI, low mill/pulverizer outlet temperatures, low air flow (FD, PA and ID), slagging in the furnace and back passes, high or low reheat and superheat steam temperatures, and flue gas temperatures, which need to be balanced as well as possible in order to meet overall plant objectives.



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### **Integrated Optimizers**

CombustionOpt is part of NeuCo's scalable suite of optimization solutions which is designed to manage tradeoffs between interrelated processes. The goal of each Optimizer is to understand current and potential performance, and to take or recommend actions to close the gap. Individual process Optimizers are coordinated and their knowledge and actions are rolled up into successively higher level decision-support interfaces.

Optimizers that can work closely with CombustionOpt to help generators respond to CAIR are SootOpt™ and PerformanceOpt®. SootOpt is a closed-loop optimization application that models heat transfer through the furnace and backpass and dynamically determines the boiler cleaning actions to minimize NO<sub>x</sub>, improve heat rate and reduce the risk of slagging and tube erosion. PerformanceOpt, which is based on a detailed first principles model of the unit, conducts a full mass and energy balance in conjunction with online simulations to identify discrepancies between current and achievable efficiency and capacity and the actions to help improve performance. When used together CombustionOpt, SootOpt and PerformanceOpt provide a comprehensive boiler optimization solution that not only addresses ever-more-stringent emissions challenges, but increases efficiency and availability at the same time.

### **Advanced Instrumentation**

The ability of these systems to optimize is enhanced when they can leverage advanced instrumentation and control to better manage tradeoffs and improve the consistency of operations under all load conditions. Examples of advanced instrumentation and control include heat flux sensors, strain gauges, water lances and cannons, fuel and air measurements for each burner, modulation of individual secondary air dampers, additional analyzers for the flue gas (economizer outlet, ductwork and stack CEMs), Furnace Exit Gas Temperature (FEGT), in-furnace lasers for multiple gas analysis, etc.

As on-line LOI particulate analyzers have been commercialized, they have become available for combustion optimization to explicitly control LOI and the ash sale revenues depending on it. NeuCo has proven the ability to leverage in-site LOI indicators to minimize LOI and reclaim fly ash sales that were not commercially feasible since low-NO<sub>x</sub> burners had been retrofit.

As fuel blending/switching became recognized as an economic NO<sub>x</sub>/SO<sub>2</sub> strategy, additional instrumentation and control was often needed to increase the knowledge of where and when the slagging was occurring and provide more effective means of removing it while the unit is in operation as opposed to taking a de-rate to shed the slag or a forced outage to remove the slag. In today's market most utilities in the earlier compliance areas who practice fuel switching, blending or spot purchase coal have recognized that combustion optimization and soot optimization need to be integrated; therefore, allowing the use of the combustion controls (fuel



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and air) to help minimize the slagging condition from developing rather than waiting to remove it once it has occurred.

## **OPTIMIZATION SOFTWARE AS A STRATEGIC TOOL**

The NO<sub>x</sub> reductions and efficiency improvements achieved with “intelligent” optimization software systems have been well documented, and these systems are playing an increasingly important role in helping generators to comply with emissions regulations such as CAIR. Just as important as the NO<sub>x</sub> reductions achieved by these systems is the role they play in informing compliance strategies and helping to leverage and streamline the operation of instrumentation and hardware investments.

When optimization is deployed early and as part of a comprehensive compliance strategy, it can inform subsequent decisions and allow proactive power producers to minimize the capital associated with meeting compliance requirements. In fact combustion optimization can be used to ascertain a unit’s true baseline NO<sub>x</sub> emissions, i.e., how low NO<sub>x</sub> emissions can go given current unit configuration. This can aid in the evaluation of hardware and control investments.

As instrumentation and control investments are made, optimization can convert the information obtained by advanced instrumentation into actionable knowledge; mitigate the negative impacts of emissions controls; and drive more efficient operations of SCR and SNCR systems.

Other advantages of investing in optimization sooner rather than later are speed and extensibility. NeuCo’s CombustionOpt system can be implemented and producing benefits in as little as 10-14 weeks. Given its inherent ability to work with existing and future data, control and instrumentation investments, the system will not become obsolete. In fact it becomes more powerful as additional instrumentation and control levers are added. CombustionOpt’s ability to integrate with those investments and with other Optimizers toward emissions, efficiency and availability goals, means that a CombustionOpt investment now can be leveraged for years to come.