Evaluating Efficiency and Compliance Options for Large Industrial Boilers in California's Changing Local and State Regulatory Environment

Glen LaPalme, PL Energy, LLC
Eric Koeppel, Enovity, Inc.
Robert Wherritt, Pacific Gas and Electric Company
Gregory W. Stevens, Alternative Energy Systems Consulting, Inc.

ABSTRACT

For industrial facility managers, convincing upper management to invest in boiler upgrades is a difficult task. Some reasons for this dilemma include: the absence of redundant capacity to handle downtime associated with retrofit opportunities; a lack of understanding of the available technologies and energy efficiency retrofit opportunities; a lack of capital funding for energy efficiency projects; and the historically low cost of natural gas relative to electricity. The lack of interest and understanding of these potential investment opportunities by corporate decision makers has severely limited the breadth and depth of technical and cost-effectiveness evaluations. In contrast, performing and presenting a more comprehensive evaluation to decision makers would provide a clearer picture of the numerous benefits and risks of investing or not investing in boiler improvement projects. In California, regulatory changes at the regional and state levels are altering the equation when it comes to investing in industrial boiler upgrades. For example, air districts in the Bay Area and San Joaquin Valley plan to significantly reduce their NOx emissions for boiler systems, and the California Air Resources Board indentified industrial boiler efficiency as one of the most cost effective measures for reducing greenhouse gases in California's industrial sector during their planning for the implementation of the State's Global Warming Solutions Act of 2006 (CARB 2008). The goal of this paper is to present the regulatory changes forthcoming, discuss the potential impacts on operators of large industrial boilers throughout California, and present boiler retrofit options that can achieve environmental compliance while also increasing efficiency, reducing operating costs and/or mitigating a decrease in efficiency due to NOx compliance requirements.

Introduction

The convergence of energy efficiency and environmental regulations has been anticipated by energy professionals for many years. This long awaited event is now upon us. On a national level, the American Counsel for an Energy-Efficient Economy (ACEEE 2009) recently referred to the national legislative environment as an "energy trifecta" with federal funds and efforts being channeled through the stimulus package, energy regulations, and climate change policy. For decades, California has distinguished itself as a leader in the areas of energy efficiency and air quality regulations. Statewide Investor Owned Utilities (IOUs) have been mandated by the California Public Utilities Commission (CPUC) to aggressively pursue energy efficiency. Local air quality management districts throughout the state have been tightening their emissions requirements, mainly to reduce NOx emissions, in a continuous effort to improve regional air quality and/or meet federal air quality attainment pollution levels. In December 2008, the California Air Resources Board (CARB) approved California's plan to reduce the state's greenhouse gas emissions to 1990 levels by 2020, per Assembly Bill 32 (AB 32), Global Warming Solutions Act of 2006. As exciting as these agendas may be, the overlapping and sometimes conflicting administrative and technical requirements imbedded in these "new deals" can confuse and even paralyze the right ideas and best intentions of companies and individuals who must comply and understand these rules and regulations. This paper is a first step at organizing and presenting the impacts these changes have had and will have on industrial boiler operators and the many agencies that will likely be involved in implementing and interpreting the new rules of the game – e.g., state regulators, air quality managers, and energy efficiency program managers. The paper also encourages better coordination between these agencies, particularly with the potentially competing agendas of reducing boiler NOx emissions and increasing boiler energy efficiency. Also, it stresses the need to improve the industry knowledge and understanding of boiler system energy efficiency opportunities, particularly given the increased complexities associated with new NOx regulations and evolving technologies.

Boiler Energy Efficiency Measures and Programs

Typical boiler system energy efficiency measures available to boiler operators include the following: (1) improving combustion efficiency mainly through burner control upgrades (such as electronic parallel positioning/linkage-less controls and O_2 trim) or burner replacements, both aimed at optimizing the combustion excess air; (2) recovering heat through exhaust stack, waste heat recovery economizers (both non-condensing and condensing), steam boiler blow-down heat recovery, condensate recovery, process heat recovery, and combustion air preheating; (3) insulating bare heated surfaces throughout the boiler system; (4) replacing boilers with high-efficiency models, including higher-efficiency technologies such as condensing boilers and direct-contact water heaters for lower inlet temperature applications, converting from steam to hot water heating, and downsizing/right-sizing boilers (e.g., replacing one large boiler with multiple, modulating boilers); (5) using variable frequency drives (VFDs) for combustion fans and boiler pumps, (6) improving water treatment or controls to reduce steam boiler blow-down, such as reverse-osmosis treatment of make-up water and automatic blow-down controls; and (7) repairing and maintaining steam traps and steam and hot water leaks.

The lower NOx requirements will be a driver for future boiler system modifications and replacements, providing new opportunities for energy efficiency programs while at the same time requiring a re-evaluation of baseline efficiencies in order to provide cost-effective incentives and rebates. Therefore, to complement air quality (NOx) emissions regulations, energy efficiency policy makers and program implementers need to understand how and where these air quality requirements impact boiler and system efficiency. With a clear vision of the regulatory horizon, utility programs can offer incentives for direct and indirect energy efficiency measures that offer a co-benefit to compliance or can be packaged with system upgrades such that the potential to make significant improvement in overall system efficiency is realized. Furthermore, air quality regulators need to understand and determine the impact that reducing NOx emissions has on energy efficiency. Ideally, air quality regulators can offer opportunities to reduce NOx emissions through energy efficiency (reduced fuel consumption), coordinated with utility energy efficiency programs and policy makers.

Currently, California's IOUs (Pacific Gas and Electric (PG&E), Southern California Edison, San Diego Gas and Electric, and Southern California Gas) offer a variety of programs. Some programs offer direct rebates while others provide performance based incentives.

Examples of some of these commercial and industrial rebate programs are PG&E's Small Business Program and Southern California Gas's Vendor Participation Program. Examples of performance based utility programs are PG&E's Non-Residential Retrofit (NRR) and Non-Residential New Construction (NRNC) Programs. These programs currently pay an incentive of $1.00 per therm saved for industrial boiler retrofits. Third Party Programs designed specifically for boiler systems include Enovity's Commercial Industrial Boiler Efficiency Program (CIBEP) in PG&E territory. This program offers both incentives and technical services, such as onsite measurements, detailed evaluations, and project development and verification to encourage the implementation of boiler energy efficiency upgrades.

Program Challenges & Lessons Learned

In general, a higher level of technical expertise is needed for evaluating boiler systems and promoting energy efficiency. Historically, employing utility energy efficiency programs to stimulate the implementation of industrial boiler energy efficiency measures has been more challenging than for standard electricity conservation measures. Some of the reasons for this struggle include the higher capital cost of replacing and modifying boiler systems and the historically low cost of natural gas. In addition, utility energy efficiency programs to date have only provided performance based incentives for improvements that exceed standard industry practices or building code requirements. Unfortunately, in many cases, this has afforded customers with only limited opportunity for incentive dollars. The increasing gas reduction targets mandated by the CPUC and new climate change policies have instigated a paradigm shift on this issue. In the past, the utilities have been able to meet their energy efficiency goals by funding projects with California's largest natural gas customers. However, to meet the future gas goals, it will be critical to expend more effort with small and medium sized customers. Since all customers will be required to make changes and upgrade their boilers to meet the new climate change policy and new emissions regulations, energy efficiency should play an important role in accomplishing both objectives. This will require a greater effort to identify and implement an increased number of natural gas saving measures. It should also be noted that one of the (unintended) results of setting more restrictive emission requirements for boilers is that the benchmark for energy efficiency is affected, often establishing a new baseline (industry standard) that could be less efficient than before. This needs to be recognized so that customers can take full advantage of energy efficiency improvements associated with their emissions upgrades and receive incentives for improvements that go beyond the newly established baseline. A challenge moving forward will be to provide clearly defined baselines for boiler energy efficiency measures in an effort to minimum the confusion and inconsistencies surrounding this issue as well as address any changes resulting from new emissions and climate change policies.

One general area of confusion is how boiler efficiency is estimated, referenced, and applied. In general, boiler retrofits savings can be classified as improvements in combustion efficiency, thermal efficiency, or overall system efficiency. It is important to understand these distinctions because minimum boiler standards or premium efficiency requirements are typically expressed in terms of combustion or thermal efficiency and apply only to the boiler unit and not the entire system. Other measures, such as process, condensate, and blow-down heat recovery or steam trap replacements, have nothing to do with the efficiency of generating heat. However, they can significantly contribute to the overall system efficiency and provide a substantial source of future energy savings and emissions reductions.

Past experience shows that boiler replacements generally do not lead to large energy savings and therefore are rarely justified based solely on energy savings. This is due to the typically high costs associated with boiler replacements compared to the relatively low energy cost savings. Based on Enovity's CIBEP field measurement and verification work, it is apparent that the majority of existing boilers in California are operating in the 78% to 85% efficiency range. Other boilers that operate below this range fall into various categories: high pressure boilers (above 150 psig) without economizers can be 1% to 2% or more below 78%; boilers that have been poorly maintained (water-side scaling or flue gas casing leaks) can also be operating in this lower efficiency range; and older boilers that have significant refractory in their casing are usually less efficient. Another class of boilers that operate at less than 78% is "atmospheric" boilers, as opposed to non-atmospheric, forced-draft, sealed combustion boilers. Utility programs to date have focused on rebates/incentives for the installation of new high-efficiency boilers; baselines for incentives are industry standard or minimum code compliant boilers, although codes generally only apply to boilers used for heating buildings and not process boilers. When boilers are replaced at the end-of-life for reliability or conditional issues, or for compliance to new NOx emissions, typical existing boiler baseline efficiencies are 78% to 80% (or higher) with new boiler efficiencies in the 82% to 85% range, and some boiler efficiencies approaching 87%. This efficiency improvement is not generally sufficient to justify replacing the boiler solely based on energy savings. In California, a single policy regarding the determination of baseline boiler efficiencies has not been established and/or made available to most program implementers. There have also been some inconsistencies in setting baselines, primarily when comparing calculated incentives to rebate programs. Also, since the availability of "standard" efficiency boilers is decreasing and the availability of more efficient boilers is increasing (not accounting for lower NOx emissions), it is possible that the baseline for incentives will be raised to a new minimum standard that may be complicated by the impacts of lower NOx emissions. Moving forward, the use of appropriate and accurate baseline efficiencies becomes more important given the newly adopted NOx regulations which will be the driving force for a large number of boiler replacements.

One lesson learned through Enovity's CIBEP is that less gas energy savings are achieved from burner control upgrades, such as upgrading from mechanical-linkage, jack-shaft controls to electronic parallel position and O_2 trim control. Also, many burner manufacturers are now offering these controls as a standard feature on larger ULN burners. This is another example of changes to baselines given the new landscape of reduced NOx emissions. The burner type, design, and condition is the most important aspect in achieving optimized combustion efficiency and in many cases burner constraints may limit an opportunity to reduce the combustion excess air and improve the combustion efficiency.

Also, the adoption of new boiler NOx regulations by the Bay Area Air Quality Management District (BAAQMD) and San Joaquin Valley Air Pollution Control District (SJVAPCD) delayed or canceled the implementation of several boiler control upgrade projects, since the new regulations would potentially require burner or boiler replacements or retrofits. The main energy savings opportunity for burner controls in the BAAQMD and SJVAPCD is the installation of variable frequency drives (VFDs) on the combustion fans for part-load electric energy savings. The boiler industry has generally lagged behind other industries in applying VFD technologies. This is partly due to more sophisticated burner controls and concerns of safe and reliable operation. For instance, there are some boiler manufacturers who currently do not offer VFDs as an optional energy efficiency upgrade to damper control on the combustion fan.

Several manufacturers still use damper control in conjunction with VFD control, reducing efficiency. Also, combustion fan VFDs have generally been applied to the larger boiler systems. For small to medium sized combustion fans, the industry needs to develop a more cost effective controls option for combustion fan VFDs that does not require an O_2 sensor for feedback control since the O_2 sensor is relatively expensive and may not be cost effective for smaller boilers.

Impacts of NOx Reduction on Energy Efficiency

The main method for reducing boiler NOx emissions has been to reduce the formation of NOx in the combustion process by installing ultra-low NOx (ULN) burners. These ULN burners (typically defined as 15 ppm or less) use a combination of increased excess air (lean air/fuel mixture which decreases combustion efficiency), improved fuel/air mixing, staged combustion which increases burner pressure drops and fan electrical requirements, and/or increased flue gas recirculation which decreases combustion efficiency slightly and increases fan electrical requirements. The response time and turn-down ratios of ULN burners are also impacted and negatively affect efficiency - e.g., some industrial boiler systems have to vent live steam in order to provide sufficient load to avoid cycling a boiler off due to reduced burner turn-down. Traditionally, ULN burners have been able to reduce NOx emissions below 9 ppm (adjusted to 3% excess oxygen), with new ULN burners now becoming available to provide NOx emissions below 7 ppm (based on factory testing with limited field testing and demonstrations). Low NOx burners designed to provide NOx emissions just below 30 ppm have less impact on efficiency and are able to operate at optimal excess oxygen levels of 2.5 to 4%. ULN burners operate with excess oxygen levels that can vary from 5 to 9%, depending on the type of burner and its design, and/or higher flue gas recirculation and greater combustion fan electrical consumption (20% to 50% greater compared to 30 ppm NOx burners). They also have lower turn-down ratios of 3 or 4 to 1, compared to 8 or 10 to 1 (for 30 low NOx). New and more efficient ULN burner designs are being developed to provide lower NOx levels below 7 ppm while maintaining or improving burner efficiencies. An example is the stage combustion burner (for the so-called "Super Boiler") being designed and tested by the Gas Technology Institute and leading manufacturers to develop a high-efficiency ULN boiler burner. However, this more efficient, ULN burner design has limited commercial availability (AEE 2008).

The alternative to ULN burners is to treat the exhaust before it enters the atmosphere in order to reduce the NOx emissions. The main exhaust treatment technology is a selective catalytic reduction (SCR) system, of which, the most common SCR system type uses ammonia injection and a catalyst to reduce the NOx emissions. They require sufficient space in the exhaust stack and proper design, installation and control to ensure successful operation and emissions regulations. Also, most current designs require a minimum exhaust temperature of 300°F to 400°F for the chemical reaction to take place. The minimum exhaust temperature requirement and the increased cost compared to ULN burners has limited the technology mainly to large water-tube boilers above 50 MM Btu/hr. However, SCR technology is currently being developed and installed on smaller fire-tube boilers from 20 to 40 MM Btu/hr. For large water-tube boilers, SCR systems will have less impact on the boiler efficiency and energy consumption, as compared to ULN burners, since the combustion process is not impacted (i.e., the excess oxygen and stack temperatures are not impacted) with only a slight increase in auxiliary electrical requirements.

In the SJVAPCD, there have been many successful installations of SCR systems. The facilities that have installed SCRs to meet 9 ppm NOx regulations did not need to replace their existing burners. As discussed later in this paper, the newly adopted NOx regulations in the SJVAPCD are driving NOx emissions below 7 ppm, for which, ULN burner technologies are not readily available. Many larger industrial water-tube boilers that have installed ULN burners instead of SCR systems are now faced with the option of either paying an annual emissions fee for compliance or installing an SCR system. Now, a potential energy efficiency measure involving the replacement of ULN burners with low-NOx (30 ppm) burners in conjunction with the installation of an SCR system exists, which will improve the combustion efficiency, reduce overall electrical requirements and improve the stability and control of the burner, thereby resulting in gas and electric energy savings (baseline ULN burner installation).

On a higher level, there needs to be more coordination between local and state air districts and the utilities in California and other states. Air districts have been mandated to reduce NOx levels at “all feasible” means necessary, which implies that the energy efficiency impacts may be subordinated as secondary effects. Both the air districts and the utilities need to better understand the impacts of lowering boiler NOx emissions on boiler system efficiency. To date, air districts in California have not performed the necessary measurement and verification studies to understand the impacts their regulations have had on reducing pollution through boiler emissions reductions and to compare the trade-offs between reduced emissions and reduced efficiency.

The question is whether local air districts have set lower boiler NOx limits without fully understanding the technology options, their commercially available, and the impacts on energy efficiency, particularly with field testing and measurements. An example is the previous discussion of the options for large water-tube boilers where it may be more appropriate to have regulated lower NOx limits below 9 ppm to drive SCR technology over ULN burners in order to have less of an impact on energy efficiency and boiler operation. The negative impact of lower NOx emissions on energy efficiency was recognized by the BAAQMD when they developed and adopted their new boiler emissions regulations in the summer of 2008 (Rule 9, Regulation 7). This regulation includes two energy efficiency requirements aimed at using energy efficiency as a method of reducing NOx emissions by means of lower fuel consumption. The following section discusses the newly adopted boiler NOx emissions regulations in the BAAQMD and SJVAPCD.

Current (Newly Adopted) Emissions Regulations

For air districts that exceed ozone concentration limits, California requires the following: (1) emissions of ozone precursors, like NOx, must be controlled as expeditiously as possible using all feasible measures; (2) transport of NOx to neighboring air districts that exceed state limits must be reduced; and (3) air districts may consider economic factors, including cost-effectiveness, when adopting control measures.

A comparison of the boiler NOx emissions regulations from all 35 air districts in California would be a significant undertaking. Instead, this paper is limited to a comparative study of the boiler NOx emissions regulations in the BAAQMD and SJVAPCD, where direct experience of boiler energy efficiency and NOx emissions has been obtained by Enovity, through the CIBEP, and new regulations were recently approved in the summer of 2008 for both agencies. These two examples present the regulatory complexities and challenges facing the air districts and utilities, and highlight impacts on boiler operators. Tables 1&2 summarize the newly adopted NOx requirements for industrial boilers in the Bay Area (BAAQMD) and San Joaquin Valley (SJVAPCD).

Table 1: Newly Adopted NOx Emissions Regulations – BAAQMD

Rule #	Rated Heat Input (million BTU/hr)	NOx Limit (ppmv @ 3% O2)	EFFECTIVE DATE 33% of devices at a single facility	66% of devices at a single facility	100% of devices at a single facility
307.1	>2 to 5	30	Later of January 1, 2011 or 10 years after manufacture date if manufactured prior to January 1, 2011	One year after Effective Date	Two years after Effective Date
307.2	>5 to <10	15	Later of January 1, 2012 or 10 years after manufacture date if manufactured prior to January 1, 2012	One year after Effective Date	Two years after Effective Date
307.3	10 to <20	15			
307.4	> 20, load-following unit	15	Later of January 1, 2012 or 5 years after manufacture date if manufactured prior to January 1, 2012	One year after Effective Date	Two years after Effective Date
307.5	20 to <75	9			
307.6	> 75	5			

Table 2: Newly Adopted NOx Emissions Regulations – SJVAPCD

Rated Heat Input (million BTU/hr)	NOx Limit (ppmv @ 3% O2)	Compliance Option / Schedule	Compliance Deadline
≥ 2 to ≤ 5	30	Unless new units installed after January 1, 2010, which are required to meet 9 or 12 ppm Nox	
> 5 to ≤ 20	9	Option A. Standard Schedule	July 1, 2012
	6	Option B. Enhanced Schedule	July 1, 2014
		Option C. Pay an Annual Emissions Fee for compliance	
> 20	7	Option A. Standard Schedule	July 1, 2010
	5	Option B. Enhanced Schedule	July 1, 2014
		Option C. Pay an Annual Emissions Fee for compliance	

Unique to the BAAQMD are boiler efficiency requirements (stack temperature limits and low temperature insulation requirements), partly as a way of recognizing the relationship between NOx reduction and energy efficiency. They also acknowledged current industry trends towards reducing greenhouse gas (GHG) emissions and the need to address greenhouse gas emissions in addition to air quality. The stack temperature limits are fairly aggressive and, if enforced, could force a large number of boiler replacements. As a result, the BAAQMD is reviewing these limits. For example, for hot water boilers with 180˚F hot water supply temperature, the stack temperature limits issued by the BAAQMD result in boiler combustion efficiencies of 83 to 84%, which is above the California Title-20 requirement of 80% combustion efficiency (for space heating boilers). While the stack temperature limits may increase energy efficiency or mitigate a decrease in efficiency due to lower NOx levels, the stack temperature limits will also impact boiler energy efficiency incentives/rebates. For instance, the minimum baseline efficiency may be impacted (i.e., increased to these limits) and/or free-ridership questions may come into play. Specifically, would incentives/rebates be appropriate for new high-efficiency boilers or economizer measures in the BAAQMD, since these measures may be installed because of the air quality regulation and not necessarily energy efficiency? This is an example of where coordination of the regional utility and local air district is needed in establishing air quality regulations and policies for energy efficiency incentives/rebates.

Global Warming Solutions Act of 2006

The Global Warming Solutions Act of 2006 (AB 32), is California's landmark global warming legislation. The goal of the legislation is to reduce California's GHG emissions to 1990 levels by 2020. CARB is the government agency charged with determining how the AB 32 goals will be reached. On June 26, 2008, CARB released its AB 32 draft "scoping plan", which describes the measures that will be used to reach AB 32's GHG reduction goals. The plan aims to reduce California's GHG emissions by 169 million metric tons of carbon dioxide equivalent ($MMTCO_2E$) through a variety of strategies, including sector-specific regulations, market mechanisms, voluntary measures, fees, and incentives (UCS 2009).

On or before January 1, 2011, CARB must officially put into place specific regulations to achieve the global warming emission reductions. These regulations must be in effect by the start of 2012. The bill requires CARB to ensure that regulations to reduce global warming emissions meet several criteria: (1) ensure that global warming emissions reductions are real, permanent, quantifiable, verifiable, enforceable and additional (i.e. new emissions reductions, not those that would otherwise occur); (2) not disproportionately impact low-income communities; (3) complement efforts to achieve and maintain federal and state air quality standards and reduce toxic air pollution emissions; and (4) minimize leakage, where reductions in global warming emissions within California are offset by increases in emissions outside the state. Some "early action measures" will likely be implemented before 2012. Therefore, the layering of local, state and utility mandates and objectives is not only near, it has arrived. Before GHG targets come into play, we should focus on the immediate overlap of energy efficiency and air quality requirements.

Compliance and Retrofit Options

Typical boiler NOx emissions compliance options are as follows: (1) burner retrofits, (2) burner replacements, (3) installation of new boiler and burner, (4) installation of an SCR, or (5) de-rating boilers below size class into a lower NOx emissions limit. In the SJVAPCD, a "Pay the Emissions Fee" option is available. The annual emissions fee option was developed by the SJVAPCD as recognition that for many facilities reducing NOx emissions may not necessarily be cost-effective or feasible. The fee monies will be used by the SJVAPCD to fund more cost effective NOx reduction strategies. This option will be the most cost-effective choice for many customers, particularly since the fee is not that large compared to other compliance option costs. Also, the fee could be used as a cost savings justification for some energy efficiency measures such as replacing an existing ULN burner with a new low excess air, high-efficiency burner in conjunction with a SCR. Table 3 summarizes compliance options by boiler size for the BAAQMD and SJVAPCD.

Table 3: Compliance Options for BAAQMD and SJVAPCD

Rated Heat Input (MMBTUh)	Air District	NOx Limit (ppmv @ 3% O_2)	Compliance Deadline	NOx Reduction Methods & Compliance Options
2 to 5	Bay Area (Rule 9, Reg 7)	30	Jan 1, 2011 to Jan 1, 2013 [1]	1) Burner Retorfit 2) New Burner or Boiler 3) De-rate Boiler
	San Joaquin Valley (Rule 4307)	30 - Existing Units	Jul 1, 2009	1) Burner Retorfit 2) New Burner or Boiler 3) De-rate Boiler
		12 - New Atmospheric Units	Jan 1, 2010	1) New Boiler
		9 - New Non-Atmospheric Units	Jan 1, 2010	1) New Boiler
5 to 20	Bay Area (Rule 9, Reg 7)	15	Jan 1, 2012 to Jan 1, 2014 [1]	1) New Burner or Boiler 2) De-rate Boiler
	San Joaquin Valley (Rule 4320)	9 - Standard Schedule	Jul 1, 2012	1) Burner Retrofit (15 to 9pmm) 2) New Burner or Boiler 3) De-rate Boiler
		Or 6 - Enhanced Schedule	Jul 1, 2014	New burner technology in development (SCR likely not feasible)
		Or pay an annual emissions fee	NA	Pay annnual fee
20 to 75	Bay Area (Rule 9, Reg 7)	9 or 15 [3]	Jan 1, 2012 to Jan 1, 2014 [2]	1) New Burner or Boiler 2) SCR (>30 MM Btu/hr)
	San Joaquin Valley (Rule 4320)	7 - Standard Schedule	Jul 1, 2010	1) Possible Burner Retrofit 2) New Burner or Boiler (depending on technology) 3) SCR (>30 MMBtu/hr)
		Or 5 - Enhanced Schedule	Jul 1, 2014	1) SCR (>30 MM Btu/hr)
		Or pay an annual emissions fee	NA	Pay annnual fee
> 75	Bay Area (Rule 9, Reg 7)	5 or 15 [3]	Jan 1, 2012 to Jan 1, 2014	1) SCR (>30 MM Btu/hr)
	San Joaquin Valley (Rule 4320)	7 - Standard Schedule	Jul 1, 2010	1) Possible Burner Retrofit 2) New Burner or Boiler (depending on technology) 3) SCR (>30 MMBtu/hr)
		Or 5 - Enhanced Schedule	Jul 1, 2014	1) SCR (>30 MM Btu/hr)
		Or pay an annual emissions fee	NA	Pay annnual fee

Table Footnotes: (1) Or 10 years after manufacture date if manufactured prior to the first compliance date, compliance dates are 33% of boilers 1st year, 66% 2nd year and 100% 3rd year; (2) Or 5 years after manufacture date if manufactured prior to the first compliance date, compliance dates are 33% of boilers 1st year, 66% 2nd year and 100% 3rd year; and (3) if a load following unit, the NOx limit is 15 ppm.

There are energy efficiency measures that are directly related to equipment upgrades for NOx emissions reductions and there are measures that are indirectly related to NOx upgrades. The latter can be implemented in conjunction with NOx upgrades as part of a combined project for NOx reduction and energy efficiency. The benefits of combining energy efficiency into NOx reduction upgrades are as follows: (1) mitigate an efficiency decrease and increased operating cost from the NOx reduction; (2) realize energy and utility cost savings; (3) increase efficiency beyond existing (i.e., a 1% to 5% efficiency improvement may be possible in most boiler plants); (4) combine both energy efficiency and NOx reduction as a single project (i.e., reduce downtime and create a payback that otherwise might not exist); (5) reduce greenhouse gas emissions; (6) receive rebates/incentives for the energy efficiency upgrades; (7) increase boiler capacity; (8) improve operations & maintenance; and (9) replace aged, end of life equipment.

Provided below are two lists of energy efficiency measures. The first list is measures directly related to NOx reduction upgrades. The second list is measures indirectly related to NOx upgrades that can be combined with the NOx upgrades for energy efficiency improvements.

List of EEMs directly related to NOx compliance.

- Burner Controls Upgrade (for 30 ppm Low-NOx Burners):
  - Parallel Positioning or Parallel Positioning with O_2 Trim Control (upgrade from jack-shaft linkage control).
  - This measure may not be applicable to ULN burners, since many manufacturers of ULN burners are offering parallel positioning controls as a standard for their ULN burners (i.e., the burners are not sold with mechanical linkage controls).
- Burner Combustion Fan VFD (all burners)
- High-Efficiency Burners with SCR Installation (ULN Burner Replacement):
  - Replace a high excess air, less efficient ULN burner with a new high-efficiency, low excess air 30 ppm NOx burner in conjunction with a SCR for reduced NOx.
  - Or, install a SCR instead of a ULN burner.
  - This measure can result in both potential gas (improved combustion efficiency) and electric savings (reduced fan electrical power).
- High-efficiency ULN Burners:
  - The potential energy efficiency measure will require additional research to compare and evaluate the total efficiency of new ULN burner options from different manufacturers. The total efficiency is a function of excess oxygen, stack temperature, flue gas recirculation (FGR) rate, and the combustion fan horsepower.
  - New ULN burner technologies are being developed to reduce NOx emissions levels while maintaining or improving the total efficiency.
  - New ULN burner efficiencies vary amongst manufactures (5 to 9% excess O2) and may be less than existing, however, manufacturers are now offering ULN burners with reduced excess oxygen levels, FGR rate and fan horsepower, creating a potential class of "high-efficiency" versus "standard-efficiency" ULN burners.
- Boiler Replacements:
  - Install high-efficiency boilers (vs. standard-efficiency) when replacing boilers for compliance.
  - Also, evaluate additional energy savings associated with: (1) condensing technologies for low temperature applications; (2) boiler right-sizing or installing multiple, smaller modulating boilers; and (3) conversion from steam to hot water boilers where the end-use requirement is hot water since it is more efficient to produce the hot water directly than producing steam to make hot water.

List of EEMs In-Directly Related to NOx Compliance

- Heat recovery (i.e., non-condensing economizer, condensing economizers, steam boiler blow-down heat recovery, steam condensate recovery, process heat recovery (thermal regeneration), and combustion air-preheaters)
- Insulation of bare heated surfaces
- VFDs for boiler pumps
- Steam boiler makeup water controls or treatment.

The new NOx regulations and compliance options will offer new energy efficiency measures and will have impacts on the baselines for evaluating any potential incentives and rebates that can be offered through utility programs. Examples of the new measures are replacing existing, inefficient ULN burners with new high-efficiency, low NOx burners and a SCR system for ULN control. In these cases, the baseline will be the existing combustion efficiency and electrical power requirement for the existing burner. For facilities with large water-tube boilers that must meet 9 ppm NOx limits, they will have a choice between installing ULN burners (with varying efficiencies) and SCR (with their existing burner efficiency). In this scenario, for evaluation of the more efficient SCR option, an adjusted baseline associated with the decreased efficiency (gas and electric) of a new standard-efficiency ULN burner will be needed because it would represent the least efficient and inexpensive option to meet the 9 ppm NOx requirement. If new, more efficient ULN burners become commercially available, then utility energy efficiency programs may want to offer incentives for the more expensive and more efficient ULN burners. If so, an evaluation will still need to be performed to determine the incremental cost difference and efficiency improvements and what the appropriate baselines are for the "standard-efficiency" ULN burners. Further research and evaluation of ULN technologies and efficiency impacts for the boiler industry is recommended.

Conclusions

1. Field experience has demonstrated the negative impacts lower NOx emissions requirements have had on boiler efficiency and boiler operations.
2. Boiler emissions compliance is based on a fairly complex set of regulations set by each air district. Further research and field verification of low NOx compliance technologies and their impacts on energy efficiency is needed. What are the correct trade-offs and optimal point of boiler energy efficiency and NOx levels, by size, type and operation of boilers? Are we making the correct decisions on NOx regulations? Additional funding and governmental research and development is needed to advance commercially available high-efficiency, ULN technologies (for 5 to 15 ppm NOx).
3. Since NOx requirements will be the driver for future boiler retrofit projects, utility energy efficiency programs need to rethink boiler incentives and baseline minimum standards.
4. Boiler retrofit baselines should be defined by NOx requirements – i.e., local air district requirements, boiler size, existing burner rating, and available compliance options.
5. There needs to be better coordination of boiler NOx emissions regulations amongst regulating authorities and utilities for improved air quality, energy efficiency and reduced greenhouse gas emissions.

6. Energy efficiency should be promoted as an integral part of NOx compliance. For example, a thermal output based NOx emission limits (i.e., lb NOx/MMBtu output) might better capture both effects.
7. Looking forward, the CPUC and California IOUs should begin to investigate what role rates and incentives will play in a fully matured GHG Cap and Trade Program.
8. Time is of the essence! For example, the new NOx requirements of the BAAQMD and SJVAPCD are in effect. Compliance deadlines depend on the air district, equipment size and age and/or compliance option but they are approaching. Also, on or before January 1, 2011, CARB must officially put into place specific regulations to achieve the global warming emission reductions. These regulations must be in effect by the start of 2012.

References

[ACEEE] American Council for an Energy-Efficient Economy. 2009. *ACEEE's Grapevine Online*. http://aceee.org/about/0902-intro.htm.

[AEE] Association of Energy Engineers, Energy Engineering Journal, "Saving Energy with the High Efficiency Super Boiler." Volume 105, No. 3, 2008.

[CARB] California Air Resources Board. 2008. "Draft AB 32 Scoping Plan Document: Appendix 1 – Modeling Assumptions for Economic Analysis." Sacramento, CA: California Public Utility Commission.

[UCS] Union of Concerned Scientist. 2009. "AB 32: California Global Warming Solutions Act of 2006." http://www.ucsusa.org/assets/documents/global_warming/ab-32-as-signed-fact-sheet-1.pdf, Cambridge, MA: Union of Concerned Scientists.