Source Category: Cement Kilns

INTRODUCTION

The purpose of this document is to provide a forum for public review and comment on the evaluation of candidate control measures that may be considered by the States in the Midwest Regional Planning Organization (MRPO) to develop strategies for ozone, PM2.5, and regional haze State Implementation Plans (SIPs). Additional emission reductions beyond those due to mandatory controls required by the Clean Air Act may be necessary to meet SIP requirements and to demonstrate attainment. This document provides background information on the mandatory control programs and on possible additional control measures.

The candidate control measures identified in this document represent an initial set of possible measures. The MRPO States have not yet determined which measures will be necessary to meet the requirements of the Clean Air Act. As such, the inclusion of a particular measure here should not be interpreted as a commitment or decision by any State to adopt that measure. Other measures will be examined in the near future. Subsequent versions of this document will likely be prepared for evaluation of additional potential control measures.

The evaluation of candidate control measures is presented in a series of "Interim White Papers." Each paper includes a title, summary table, description of the source category, brief regulatory history, discussion of candidate control measures, expected emission reductions, cost effectiveness and basis, timing for implementation, rule development issues, other issues, and a list of supporting references. Table 1 summarizes this information for the cement kiln source category.

SOURCE CATEGORY DESCRIPTION

Portland cement manufacturing is an energy intensive process in which cement is made by grinding and heating a mixture of raw materials such as limestone, clay, sand and iron ore in a rotary kiln. Nationwide, about 82 percent of the kiln's energy requirement is provided by coal, while natural gas contributed about 3 percent of the energy demand, oil about 1 percent, and waste-derived fuels (WDF) such as scrap tires, used motor oils, surplus printing inks, dry-cleaning solvents, paint thinners, sludge from the petroleum industry, provided about 14 percent of the energy. Raw materials are heated in the kiln to temperatures above 2900°F to initiate a chemical reaction that produces cement clinker. The clinker is then cooled, mixed with gypsum and ground to produce cement.

Cement kiln technology consists of three major types of kiln processes: long wet process kilns, long dry process kilns, and most recently, precalciner kilns. The long wet and dry kilns generally have only one combustion zone, whereas the newer precalciner kilns have three separate units – preheater cyclones, a calciner zone, and the rotary kiln. Wet process kilns are older and used where the moisture content of the raw materials mined from nearby quarries is high. Dry process kilns use dry raw materials. To improve the energy efficiency of the dry process, preheaters and precalciners have been introduced on newer kilns.

NOx emissions are generated during fuel combustion by oxidation of chemically-bound nitrogen in the fuel and by thermal fixation of nitrogen in the combustion air. As flame temperature increases, the amount of thermally generated NOx increases. SO2 emissions are generated from sulfur compounds in the raw materials and, to a lesser extent, from sulfur in the fuel. The sulfur and nitrogen contents of the raw materials and fuels used vary by plant. Cement kilns also generate PM emissions, and nearly all kilns are equipped with particulate collection devices to remove cement kiln dust from the kiln exhaust gases.

TABLE 1 – CONTROL MEASURE SUMMARY FOR CEMENT KILNS

Control Measure Summary	**SO2 Emissions (tons/year) in 5-state MRPO Region**	
2002 Existing measures : NSPS; PSD/NSR; State Rules	2002 Base:	38,703
2009 On-the-Books measures: None identified	Reduction: 2009 Remaining:	-0 38,703
Candidate measure ID KILN1: Apply Reasonably Available Controls to All Kilns in Region *Emission Reductions*: 90% from 2002 baseline for all cement kilns in MRPO region *Control Cost*: $2,211/ton to $6,917/ton *Timing of Implementation*: Assumes full reductions achieved in 2009 *Implementation Area*: 5-State MRPO region	2009 Reduction: 2009 Remaining:	-34,833 3,870
Candidate measure ID KILN2: Apply Likely Controls to Kilns subject to the proposed BART requirements *Emission Reductions*: overall reduction of 56% from the cement kiln category, based on 90% reduction in SO2 emissions from kilns identified as possibly being subject to BART *Control Cost*: $2,211/ton to $6,917/ton *Timing of Implementation*: Assumes full reductions achieved in 2013 *Implementation Area*: 5-State MRPO region	2013 Reduction: 2013 Remaining:	-21,637 17,066

Control Measure Summary	**NOx Emissions (tons/year) in 5-state MRPO Region**	
2002 Existing measures : NSPS; PSD/NSR; State RACT Rules	2002 Base:	34,032
2009 On-the-Books measures: NOx SIP Call for cement kilns (30% reduction from uncontrolled levels)	Reduction: 2009 Remaining:	-10,210 23,822
Candidate measure ID KILN1: Apply Reasonably Available Controls to All Kilns in Region *Emission Reductions*: overall reduction of 50% from 2002 Base emissions and 29% reduction from NOx SIP call levels *Control Cost*: $-310/ton to $2,500/ton *Timing of Implementation*: Assumes full reductions achieved in 2009 *Implementation Area*: 5-State MRPO region	2009 Reduction: 2009 Remaining:	-17,016 17,016
Candidate measure ID KILN2: Apply Likely Controls to Kilns subject to the proposed BART requirements *Emission Reductions*: overall reduction of 28% from 2002 emissions category and 40% from NOx SIP Call levels, based on 80% reduction for cement kilns identified as possibly being subject to BART *Control Cost*: $1,500/ton to $2,500/ton *Timing of Implementation*: Assumes full reductions achieved in 2013 *Implementation Area*: 5-State MRPO region	2013 Reduction: 2013 Remaining:	-9,408 14,415

REGULATORY HISTORY

Emission control regulations for cement kilns have historically focused on particulate emissions. Over the past several years, regulations for the control of NOx and hazardous air pollutant (HAP) emissions have also been adopted. Both on-the-books and potential future regulatory programs are briefly discussed in the following paragraphs.

On-the-Books Regulation

Under Title I of the Clean Air Act, EPA has developed New Source Performance Standards (NSPS) for certain specified categories of new and modified large stationary sources. The NSPS for Portland cement plants is contained 40 CFR Part 60 Subpart F and applies to any facility constructed or modified after August 17, 1971. Subpart F specifies emission standards only for particulate matter.

Title I also subjects new and modified large stationary sources that increase their emissions to permitting requirements that impose control technologies of varying levels of stringency (known as New Source Review, or NSR). NSR prescribes control technologies for new plants and for plant modifications that result in a significant increase in emissions, subjecting them to Best Available Control Technology (BACT) in attainment areas and to the Lowest Achievable Emission Rate (LAER) in nonattainment areas. The control strategies that constitute BACT and LAER evolve over time and are reviewed on a case-by-case basis in state permitting proceedings.

EPA finalized the NOx SIP call in 1998 to begin to address interstate transport of air pollution. The final version of the rule called for NOx emission reductions in twenty-two states (including Ohio, Indiana, Illinois, and the southern half of Michigan, but not Wisconsin) that contributed to 1-hour ozone nonattainment in other states. The rule required affected states to amend their SIPs and limit NOx emissions from cement kilns. The first control period was scheduled for the 2004 ozone season. In general, States adopted regulations providing operators of cement kilns several options for complying with emission limits, including use of low-NOx burners or a mid-kiln-firing system that achieves a 30 percent reduction in NOx during the 5-month ozone season.

On June 14, 1999, EPA published a final rule under Title III of the CAA to substantially reduce HAP emissions from Portland cement manufacturing plants. These Maximum Achievable Control Technology (MACT) standards apply to cement kilns located at major sources of HAPs. EPA's rule limits emissions of particulate matter, which contain toxic metals (such as cadmium and chromium), from kilns and clinker coolers. The rule also limits emissions of opacity (a surrogate pollutant for particulate matter and toxic metals) from the kiln, clinker cooler, and materials handling facilities. Finally, the rule places limits on emissions of dioxins/furans and hydrocarbons (a surrogate for toxic organic compounds) from cement kilns.

On-the-Way Regulations

On June 15, 2005, EPA issued final amendments to its July 1999 regional haze rule. These amendments would apply to the provisions of the regional haze rule that require emissions controls known as best available retrofit technology (BART) for industrial facilities emitting air pollutants that reduce visibility. The BART requirements of the regional haze rule apply to facilities built between 1962 and 1977 that have the potential to emit more than 250 tons a year of visibility-impairing pollutants. Those facilities fall into 26 categories, including cement kilns. Some of these facilities previously may not been subject to pollution control requirements for these pollutants. Under the final BART guidelines, states are required to conduct source-by-source BART determinations to identify which facilities must install controls and the type of controls to be used.

Hazardous waste burning kilns emit higher levels of lead and total chlorine than other kilns. Hazardous waste burning cement kilns will be subject to the Hazardous Waste Combustion MACT standard, which will likely include additional standards to control specific metals, total chlorine, and combustion related carbon monoxide and hydrocarbons. On September 30, 1999, EPA promulgated standards to control emissions of hazardous air pollutants from incinerators, cement kilns and lightweight aggregate kilns that burn hazardous wastes. A number of parties sought judicial review of the rule. Our current understanding is that EPA will issue final standards by June 14, 2005.

CANDIDATE CONTROL MEASURES

Most cement kilns already employ fabric filters or electrostatic precipitators for capturing particulate matter. In addition, the MACT standards will also result in additional reductions of PM and VOC emissions. Emissions of PM and VOC are relatively minor on a regional-scale. Therefore, no additional control measures are considered for this White Paper for PM or VOC.

Control techniques for NOx and SO2 may be classified into three broad categories: fuel/raw material substitution, combustion modification, and post-combustion control. Fuel/raw material substitution primarily reduces SO2 by using materials/fuels with low sulfur contents. Combustion modification includes any physical or operational change in the kiln and is applied primarily for NOx control purposes. Post-combustion control employs a device after the combustion of the fuel and is applied to control emissions of NOx and SO2.

There are a wide variety of proven control technologies for reducing NOx emissions from cement kilns. Automated process control has been shown to lower NOx emissions by moderate amounts. Low-NOx burners have been successfully used in the primary burn zone and especially in the precalciner kilns. CemStarSM is a process that involves adding steel slag to the kiln, offering moderate levels of NOx reduction by reducing the required burn zone heat input. Mid-kiln firing of tires provides moderate reductions of NOx emissions while reducing fuel costs and providing an additional revenue stream from receipt of tire tipping fees. SNCR technology has the potential to offer significant reductions on some precalciner kilns. SNCR has been tested on at least one facility in the U.S. However, SNCR is being used in numerous cement kilns in Europe. Many of the control methods can be combined. For example, mid-kiln firing and low-NOx Burners were combined in one case study to provide total NOx reduction of about 50%. SCR has been demonstrated to be successful on a kiln in Europe, but has not been applied to a U.S. cement plant and poses technical challenges. Attachment 1 summarizes information on NOx control options.

SO2 emissions are primarily determined by the content of the volatile sulfur in the raw materials and fuel used. Cement kiln systems have highly alkaline internal environments that can absorb up to 95 percent of potential SO2 emissions. Kilns that use raw materials with little or no volatile sulfur have relatively low SO2 emission levels. However, in systems that have sulfide sulfur (Pyrites) in the kiln feed, the sulfur absorption rate may be as low as 50 percent without unique design changes or changes in raw materials. Sulfur present in the fuel is largely incorporated into the clinker itself and is not normally emitted to the atmosphere. The simplest way to reduce SO2 emissions is using low-sulfur raw materials and fuels. When this is not feasible, emissions can be further controlled using end-of-pipe measures such as dry or wet scrubbers. Wet scrubbers generally reduce SO2 emissions by about 90 percent. Research conducted by the Department of Energy indicates that advanced flue gas desulfization scrubbers can reduce SO2 levels by 95-99 percent. Attachment 2 summarizes information on SO2 control options.

Two specific candidate control measures for NOx and SO2 are discussed below. The first candidate control measure applies to all kilns in the region and is based on reasonably available controls that have been successfully applied to other cement kilns and appear to be feasible for similar equipment and processes in the MRPO region. The second candidate control measure applies likely BART controls for those sources likely to require a BART engineering analysis.

Measure KILN1 – Apply Reasonably Available Controls to All Kilns in Region. Under this approach, all cement kilns in the MRPO region would be required to apply reasonably available controls for NOx and SO2. For NOx, we are assuming that sources could combine mid-kiln firing with low-NOx burners or apply SNCR technologies such as biosolids injection and NOXOUT®. These technologies showed average emission reductions about 50 percent from uncontrolled levels. For SO2, we are assuming that sources could reduce SO2 emissions by 90 percent using wet FGD systems.

Measure KILN2 – Apply Likely Controls to Kilns Subject to BART Requirements. Under this approach, States would develop source-by-source control requirements for those cement kilns subject to a BART engineering analysis. Under a separate task, MACTEC worked with the States to prepare a list of sources likely to be subject to the BART requirements. Many of the 26 kilns in the region are BART-eligible, but only 11 (at four facilities) have been found to be possibly subject to BART (see Table 2). For the purposes of this White Paper, we are assuming that sources potentially requiring BART controls could achieve an 80 percent reduction for NOx (based on SNCR technology used at two kilns in Europe) and a 90 percent reduction for SO2 (based on a wet FGD system).

EMISSION REDUCTIONS

We estimated the emission reductions expected from adoption of the two control measures in the following manner:

1. Obtained 2002 actual emissions from the MRPO's 2002 inventory. Information regarding kilns in the MRPO region operating in 2002 is shown in Table 2.
2. For the on-the-books regulatory scenario (NOx SIP call requirements), calculated future year emissions by applying a 30 percent reduction to 2002 actual NOx emissions for all cement kilns in the MRPO region.
3. For control measure *KILN1*, applied a 50 percent reduction to 2002 NOx emissions and a 90 percent reduction for SO2 emissions for all cement kilns in the MRPO region.
4. For control measure *KILN2*, applied an 80 percent reduction to 2002 NOx emissions and a 90 percent reduction to 2002 SO2 emissions cement kilns identified as being potentially subject to BART.

Table 3 summarizes the actual annual emissions for 2002, the projected emissions in 2009 based on the NOx SIP Call requirements, for measure *KILN1* applying reasonable controls to all kilns, and for measure *KILN2* applying likely controls to cement kilns potentially subject to BART requirements.

Note that these estimated emission reductions are uncertain for two reasons. First, information regarding existing control devices/measures (i.e., low-sulfur raw materials, low-sulfur coal, low-NOx burners, etc.) was missing from the MRPO database for nearly all cement kilns, so we may be overestimating the emission reductions as some sources that may already be controlled or have low emission rates. Second, the feasibility and emission reduction potential of controls at a particular facility are highly dependent on site-specific conditions (type of raw material feed, fuels used, existing equipment configurations, etc.). This uncertainty must ultimately be considered on a plant-by-plant basis to better determine the emission reduction potential of the candidate control measures.

TABLE 2 – 2002 EMISSIONS FROM CEMENT KILNS

Plant Name	Kiln Description	NOx SIP Source?	BART Source?	2002 Annual Emissions (tons/year)			
				SO2	NOx	VOC	PM10
ILLINOIS CEMENT CO Lasalle, IL	Dry Kiln	Yes	No	35	366	23	11
LONE STAR INDUSTRIES Oglesby, IL	Dry Kiln	Yes	No	957	1,281	2	105
LAFARGE MIDWEST INC Grand Chain, IL	Dry Kiln #2 Dry Kiln #1	Yes Yes	No No	283 285	1,938 1,776	8 6	5 14
DIXON-MARQUETTE Dixon, IL	Kilns #1-4	Yes	No	342	1,754	56	526
ESSROC CEMENT CORP. Logansport, IN	Wet Kiln #1 Wet Kiln #2	Yes Yes	No No	949 947	857 855	34 34	75 75
ESSROC CEMENT CORP. Speed, IN	Long Dry #1 Preheat Kiln #2	Yes Yes	Yes Yes	1,727 1,349	911 614	5 54	105 132
LEHIGH CEMENT COMPANY Mitchell, IN	Dry Kiln #1 Dry Kiln #2 Preheat Kiln #3	Yes Yes Yes	Yes Yes Yes	1,056 1,154 1,758	1,596 1,745 838	28 30 33	88 96 104
LONE STAR INDUSTRIES Greencastle, IN	Wet Kiln	Yes	No	267	1,511	0	19
LAFARGE NORTH AMERICA Alpena, MI	Dry Kiln #19 Dry Kiln #20 Dry Kiln #21 Dry Kiln #22 Dry Kiln #23	Yes Yes Yes Yes Yes	Yes Yes Yes Yes Yes	778 948 559 6,418 7,872	1,202 1,239 1,196 3,070 2,975	4 5 5 7 7	19 23 22 56 36
CEMEX, INC. Charlevoix, MI	Precalciner	Yes	No	3,108	3,037	0	18
HOLCIM (US) INC. Dundee, MI	Wet Kiln	Yes	No	7,129	1,455	1,662	32
CEMEX, INC. Xenia, OH	Dry Kiln	Yes	Yes	422	3,429	0	0
LAFARGE/SYSTECH Paulding, OH	Wet Kiln #1 Wet Kiln #21	Yes Yes	No No	112 248	184 203	7 6	5 5
	Totals for MRPO Region			**38,703**	**34,032**	**2,016**	**1,571**

There were no cement kilns operating in Wisconsin in 2002.

TABLE 3
COMPARISON OF ACTUAL, ON-THE-BOOKS, AND CANDIDATE CONTROL MEASURES

		NOx Emissions (tons per year)					
		On-the-Books (NOx SIP Call)		Measure KILN1 NOx SIP Call Plus Reasonable Controls on All Cement Kilns		Measure KILN2 NOx SIP Call Plus Likely Controls for Kilns Subject to BART Requirements	
State	2002 Actual	Reduction from 2002	2009 Remaining	Reduction from 2002	2009 Remaining	Reduction from NOx SIP Levels	2013 Remaining
IL	7,115	2,135	4,981	3,558	3,558	0	4,981
IN	8,927	2,678	6,249	4,464	4,464	2,852	3,397
MI	14,174	4,252	9,922	7,087	7,087	4,841	5,081
OH	3,816	1,145	2,671	1,908	1,908	1,715	957
WI	0	0	0	0	0	0	0
MRPO	**34,032**	**10,210**	**23,822**	**17,016**	**17,016**	**9,408**	**14,415**

		SO2 Emissions (tons per year)					
		On-the-Books (None Identified)		Measure KILN1 NOx SIP Call Plus Reasonable Controls on All Cement Kilns		Measure KILN2 NOx SIP Call Plus Likely Controls for Kilns Subject to BART Requirements	
State	2002 Actual	Reduction from 2002	2009 Remaining	Reduction from 2002	2009 Remaining	Reduction from 2002	2013 Remaining
IL	1,902	0	1,902	1,712	190	0	1,902
IN	9,207	0	9,207	8,286	921	6,340	2,867
MI	26,812	0	26,812	24,131	2,681	14,918	11,895
OH	782	0	782	704	78	380	402
WI	0	0	0	0	0	0	0
MRPO	**38,703**	**0**	**38,703**	**34,833**	**3,870**	**21,637**	**17,066**

Note: the 2009/2013 emission estimates presented here are not growth-adjusted.

COST EFECTIVENESS AND BASIS

Attachments 1 and 2 summarize the cost-effectiveness for various control options. We used the data from the references listed to estimate the range of costs for the two candidate control measures. Costs for a specific unit will vary depending on the kiln type, characteristics of the raw material and fuel, and other source-specific factors. Note that the use of technologies like biosolids injection can result in a cost savings associated with the tipping fees for the biosolids.

Control Measure	Pollutant	% Reduction	Cost Effectiveness ($/ton)
KILN1 – Apply Reasonably Available Controls to All Kilns in Region.	NOx	50	-310 to 2,500
	SO2	90	2,211 to 6,917
KILN2 – Apply Likely Controls to Cement Kilns Subject to BART Requirements	NOx	80	1,500 to 2,000
	SO2	90	2,211 to 6,917

TIMING OF IMPLEMENTATION

Generally, sources are given a 2-4 year phase-in period to comply with new rules. Under the NOx SIP Call for Phase I sources, EPA provided a compliance date of about 3½ years from the SIP submittal date. Most MACT standards allow a 3-year compliance period. Under Phase II of the NOx SIP Call, EPA provided a 2-year period after the SIP submittal date for compliance. States generally provided a 2-year period for compliance with RACT rules. For the purposes of this White Paper, we have assumed that SIP rules would be adopted in early 2007 and that a 2-year period after SIP submittal is adequate for the installation of controls. Thus, emission reductions would occur in 2009 for Measure KILN1.

For the BART control measure, the proposed BART guidelines require states to establish enforceable limits and require compliance with the BART emission limitations no later than 5 years after EPA approves the regional haze SIP. Since the regional haze SIPs are due in 2008, emission reductions would not occur until 2013 if the full 5-year compliance period is used.

RULE DEVELOPMENT ISSUES

Developing emission control regulation for cement kilns will likely require a source-by-source assessment, since the feasibility of controls at a particular site are highly dependent on site-specific conditions (type of raw material feed, fuels used, existing equipment configurations, etc.). MRPO States could require sources to develop source specific RACT analyses implemented through the permitting process. The BART control scenario requires source-by-source control determinations implemented through the permitting process.

GEOGRAPHIC APPLICABILITY

The suggested control measures would apply to all kilns throughout the MRPO region, not just in nonattainment areas.

SEASONAL APPLICABILITY

In addition to emission reductions during the ozone season to attain the ozone NAAQS, reductions are needed throughout the year to address the PM2.5 NAAQS and regional haze. Thus, the candidate control measures are intended to be applied on an annual basis. An alternative scenario could be developed to create separate ozone season and non-ozone season emission control requirements if more stringent control is needed during the ozone season.

AFFECTED SCCs

The primary SCCs affected by this candidate control measure are:

3-05-006-06 Cement Manufacturing Dry Process, Kilns
3-05-006-22 Cement Manufacturing Dry Process, Preheater Kilns
3-05-006-23 Cement Manufacturing Dry Process, Preheater/Precalciner Kilns
3-05-007-06 Cement Manufacturing Wet Process, Kilns

For modeling purposes, we have identified specific sources in the 2002 inventory for which we will develop control factors. For measure KILN1, control factors will be developed for all cement kilns in the MRPO region. For measure KILN2, source-specific control factors will be developed for kilns likely to be subject to BART requirements.

REFERENCES

1. STAPPA/ALAPCO. *Controlling Nitrogen Oxides Under the Clean Air Act: A Menu of Options*. July 1994.
2. U.S. EPA. *Alternative Control Techniques Document – NOx Emissions From Cement Manufacturing*, EPA-453/R-94-004. March 1994.
3. Air & Waste Management Association. *Air Pollution Engineering Manual - Chapter 15 Portland Cement*. 1992.
4. EC/R Incorporated. *NOx Control Technologies for the Cement Industry*. September 19, 2000.
5. NESCAUM. *Status Report on NOx Controls for Gas Turbines, Cement Kilns, Industrial Boilers, and Internal Combustion Engines – Technologies and Cost Effectiveness*. December 2002.
6. Reaction Engineering International, and Energy&Environmental Strategies. *Summary of Emission Controls Available for Large Stationary Sources of NOx and PM*. Prepared for the Western Governor's Association. June 30, 2003.
7. ENVIRON International Corporation. *Evaluation of Potential Control Technologies for Oxides of Nitrogen from Point Sources in Ellis County, Texas*. June 2004.
8. U.S. EPA. *Identification and Discussion of Sources of Regional Point Source NOx and SO2 Emissions Other Than EGUs*. January 2004.
9. European Commission, Integrated Pollution Prevention and Control (IPPC) Bureau. *Reference Document on Best Available Techniques in the Cement and Lime Manufacturing Industries*. December 2001.
10. MACTEC Engineering and Consulting, Inc. *Cement Best Available Retrofit (BART) Engineering Analysis*. March 2005.

Attachment 1 – NOx Control Technologies for Cement Kilns

Technology	**Description**	**Applicability**	**Performance**	**Cost ($/ton)**
Process Control Systems	Process modifications improve fuel efficiency, reduce operating costs, increase capacity and kiln operational stability. Since NOX formation is directly related to the amount of energy consumed in cement-making, improving fuel efficiency and productivity will reduce NOX emissions.	Wet – Yes Long-Dry - Yes Preheater – Yes Precalciner – Yes	<25% reduction	
Changing Feed Composition	Change cement formulation by adding waste iron to lower clinkering temperatures and suppress NOx; the CemStar process is one patented technique. This process can decrease NOx emissions and can also increase production by 15%.	Wet – Yes Long-Dry - Yes Preheater – Yes Precalciner – Yes	23-40% reduction	550
Low-NOx Burners	Low-NOX burners are designed to reduce flame turbulence, delay fuel/air mixing, and establish fuel-rich zones for initial combustion. The longer, less intense flames resulting from the staged combustion lower flame temperatures and reduce thermal NOx formation.	Wet – Yes Long-Dry - Yes Preheater – Yes Precalciner – Yes	4-47% reduction 27% average reduction	300 to 1200
Mid-kiln Firing	Part of the fuel (including tires) is burned at a much lower temperature in a secondary firing zone to complete the preheating and calcination of the raw materials.	Wet – Yes Long-Dry - Yes Preheater – No Precalciner – No	28 to 59% reduction for wet kilns 11 to 55% reduction for dry kilns	-460 to 730
Selective Non-Catalytic Reductions (SNCR)	Injects ammonia-based reagent into upper furnace to reduce NO to N2. One form of SNCR uses the naturally occurring ammonia content of dewatered biosolids as the reagent. The dewatered biosolids are obtained from wastewater treatment plants. Another process using aqueous urea was developed by Electric Power Research Institute (EPRI) and is now marketed by Nalco Fuel Tech, Inc., under the trade name of NOXOUT®.	Wet – No Long-Dry - No Preheater – Yes Precalciner – Yes	Generally 10 to 50% reduction; two European plants have achieved 80% reductions	-310 to 2500
Selective Catalytic Reduction (SCR)	SCR reduces NO and NO2 to N2 with the help of NH3 and a catalyst. Although no SCR systems are currently being used on U.S. cement plants, this control technique has been applied successfully in other industries and pilot plant trials have been conducted in Europe.	Wet – Unkown Long-Dry Yes Preheater – Yes Precalciner – Unknown	70 to 90+% NO_x reduction	1500 – 2000

References:

EC/R Incorporated. *NOx Control Technologies for the Cement Industry*. September 19, 2000.

European Commission, Integrated Pollution Prevention and Control (IPPC) Bureau. *Reference Document on Best Available Techniques in the Cement and Lime Manufacturing Industries*. December 2001.

Attachment 2 – SO2 Control Technologies for Cement Kilns

Technology	Description	Applicability	Performance	Cost ($/ton)
Changing Raw Material and Fuel Composition	Limiting the sulfur content of both raw materials and fuels can reduce releases of SO2. Availability of these materials is high site-specific.	All Kilns	Depends on availability of low-sulfur raw materials	Site-specific
Absorbent Addition	Addition of absorbents such as slaked lime (Ca(OH)2), quicklime (CaO) or activated fly ash with high CaO content to the exhaust gas of the kiln can absorb some of the SO2.	All Kilns	60-80% reduction	2,031 to 7,379
Wet Flue Gas Desulfurization (FGD)	SO2 is absorbed by a liquid/slurry sprayed in a spray tower or is bubbled through the liquid/slurry. Wet scrubbers also significantly reduce the HCl, residual dust, metal and NH3 emissions.	All Kilns	90-99.9% reduction	2,211 to 6,917
Advanced Flue Gas Desulfurization (FGD)	DOE demonstrated a retrofit Passamaquoddy Technology Recovery Scrubber™ using cement kiln dust (CKD), an alkaline-rich (potassium) waste, to react with the acidic flue gas.	All Kilns	95-99.5% reduction	2,187 to 4,028

References:

European Commission, Integrated Pollution Prevention and Control (IPPC) Bureau. *Reference Document on Best Available Techniques in the Cement and Lime Manufacturing Industries*. December 2001.

U.S. DOE, National Energy Technology Laboratory. *Clean Coal Technology Compendium – Cement Kiln Flue Gas Recovery Scrubber*. http://www.netl.doe.gov/cctc/factsheets/pass/cemkilndemo.html

MACTEC Federal Programs, Inc. *Cement Best Available Retrofit Technology (BART) Engineering Analysis*. March 2005.