Appendix G

Indiana RH SIP for the Second Implementation Period
Nitrogen Oxides and Sulfur Dioxide Four-Factor Analysis For Cement Kilns

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INDIANA

REGIONAL HAZE

STATE IMPLEMENTATION PLAN

FOR THE

SECOND IMPLEMENTATION PERIOD

Nitrogen Oxides and Sulfur Dioxide
Four-Factor Analysis
For
Cement Kilns

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May 18, 2021

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF GRAPHS

LIST OF APPENDICES

ACRONYMS/ABBREVIATIONS LIST

AFGD	Advanced Flue Gas Desulfurization
AP-42	Air Pollution Factors Reference
BART	Best Available Retrofit Technology
^{o}C	Celsius
CAA	Clean Air Act
CaO	Lime
CaSO3	Calcium Sulfate
CaSO4	Calcium Sulfate
CFR	Code of Federal Regulations
CO	Carbon Monoxide
CPI	Consumer Price Index
D.C.	District of Columbia
DSI	Dry Sorbent Injection
EPA	Environmental Protection Agency
ESP	Electric Static Precipitator
FGD	Flue Gas Desulfurization
FLMs	Federal Land Managers
HAPs	Hazardous Air Pollutants
ID	Identification
IDEM	Indiana Department of Environmental Management
LADCO	Lake Michigan Air Directors Consortium
lbs/hr	Pounds Per Hour
LHWF	Liquid Hazardous Waste Fuel
LNB	Low NO_x Burners
MACT	Maximum Achievable Control Technology
MANE-VU	Mid-Atlantic/Northeast Visibility Union
MARAMA	Mid-Atlantic Regional Air Management Association
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NH3	Ammonia
NO_x	Nitrogen Oxides
NSPS	New Source Performance Standards and
Petcoke	Petroleum Derived Coke
PM	Particulate Matter
PSD	Prevention of Significant Deterioration
RCRA	Resource Conservation and Recovery Act
RH	Regional Haze
RPGs	Reasonable Progress Goals
SCR	Selective Catalytic Reduction
SDA	Spray Dryer Absorption
SSM	Significant Source Modification
SO_2	Sulfur Dioxide
tons/yr	Tons Per Year

1.0 INTRODUCTION

The Regional Haze (RH) Rule requires each state to develop a long-term strategy that includes the control measures necessary to make reasonable progress at each Class I area outside the state "that may be affected by emissions from the state." The Clean Air Act (CAA) and RH Rule provides for states to determine what emission control measures for its own sources, groups of sources, and/or source categories are necessary to make reasonable progress in Class I areas. Section 169A(g)(1) of the CAA lists four factors that must be taken into consideration in determining reasonable progress. Potential pollution control technologies available to achieve reasonable progress goals (RPGs) are evaluated with respect to the following four factors listed in the CAA:

- Cost,
- Compliance timeframe,
- Energy and non-air quality environmental impacts, and
- Remaining useful life for affected sources.

The "four-factor" analysis conducted in this document includes identifying which nitrogen oxides (NO_x) and sulfur dioxide (SO_2) emission control measures to consider, evaluating the four factors to be characterized for the NO_x and SO_2 control options considered, and evaluating the cost effectiveness of the emission control measures identified for the cement kiln source category and Indiana's two Portland cement manufacturing facilities selected in accordance with 40 CFR 51.308(f)(2) of the RH Rule. This four-factor analysis will also include selecting NO_x and SO_2 emissions information for characterizing emissions-related factors and identifying applicable Federal regulations that contribute NO_x and SO_2 emissions control benefits in reducing regional haze by 2028 and beyond.

2.0 BACKGROUND

The emissions inventory and contribution assessment performed by the Lake Michigan Air Directors Consortium (LADCO) for member states, Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin demonstrated that NO_x and SO_2 emissions were key contributors to visibility impairment at Class I areas in the Northern Midwest region. In anticipation for RH State Implementation Plan (SIP) development, LADCO procured the services of Amec Foster Wheeler Environment & Infrastructure, Inc. to develop a four-factor analysis document for LADCO States. Based on information from the contribution assessment, LADCO states agreed to include cement plants as one of the four source categories identified as large contributors of NO_x and SO_2 emissions for four-factor analysis.

This effort was undertaken in support of establishing RPGs for Northern Midwestern States for the implementation period ending 2028. The results of the cement kiln analysis were detailed in LADCO's "Four-Factor Analysis for Regional Haze in the Northern Midwest Class I Areas, Methodology for Source Selection, Evaluation of Control Options, and Four-Factor Analysis," document dated October 27, 2015. The source category description, the NO_x and SO_2 emissions and control measures descriptions and tables and the four statutory factors descriptions for the cement kiln source category outlined in Section 3 below were taken from this document which can be found at the following link: https://www.ladco.org/wp-content/uploads/Documents/Reports/Regional_Haze/Round2/2015_LADCO-4-Factor-Analysis-Regional-Haze.pdf. See references at the end of this document. This excludes the entire section except for subsection 3.5 and 3.6 with minor changes to the language for clarification consistency throughout this document.

In Indiana, two Portland cement manufacturing facilities met the Indiana Department of Environmental Management's (IDEM's) source selection criteria for the RH SIP second implementation period four-factor analysis. IDEM will evaluate the two Portland cement manufacturing facilities in terms of their cement kilns as a source category for the four-factor analysis. By focusing on cement kilns as a source category, IDEM can identify and describe all appropriate NO_x and SO_2 control measures for cement kilns and reference cement kiln best available retrofit technology (BART) analyses for other facilities in the Midwest region collected by EPA Region 8 and shared by the National Park Service, Federal Land Managers to provide for a more robust analysis of potential NO_x and SO_2 control measures for the cement kilns at Indiana's two Portland cement manufacturing facilities selected for the RH SIP second implementation period four-factor analysis.

3.0 SOURCE CATEGORY DESCRIPTION FOR CEMENT KILNS

Portland cement is a main ingredient for concrete and other common building materials. Portland cement is mainly composed of clinker, a material formed by heating limestone and other ingredients to temperatures over 1,400 ºC (2,650 ºF). High combustion temperatures require large amounts of fuel and can result in significant emissions of NO_x and SO_2; crushing of ingredients and finished clinker can release dust and particles; and ammonia is sometimes produced during the heating of limestone. Figure 3.1 in Appendix A shows a process flow diagram of a Portland cement facility. The process flow diagram (taken from AP-42) shows both wet and dry Portland cement processes.

The pyroprocessing step is the predominant source of gaseous pollutant emissions. In general, there are five different processes used in the Portland cement industry to accomplish the pyroprocessing step: the wet process, the dry process (long dry process), the semidry process, the dry process with a preheater, and the dry process with a preheater/precalciner.

The kiln is a long cylinder rotating about its axis once every, one to two minutes. The axis is inclined at a slight angle, the end where fuel combustion occurs being lower. The rotation causes the ground limestone, silica, alumina, and iron (raw meal or kiln feed) to gradually pass along from where it enters at the cool end, to the hot end where it eventually drops out and cools. As the raw materials travel the length of the kiln, they are heated by the combustion of fuel at the discharge end of the kiln. In the long dry process, all the pyroprocessing activity occurs in the rotary kiln. The rotary kiln produces temperatures sufficient to heat the raw meal to sintering temperature (up to 1450 °C).

Dry process pyroprocessing systems have been improved in thermal efficiency and productive capacity through the addition of one or more cyclone-type preheater vessels in the gas stream exiting the rotary kiln. This system is called the preheater process. The vessels are arranged vertically, in series, and are supported by a structure known as the preheater tower. Hot exhaust gases from the rotary kiln pass counter currently through the downward-moving raw materials in the preheater vessels. Compared to the simple rotary kiln (long dry process), the heat transfer rate is significantly increased, the degree of heat utilization is greater, and the process time is markedly reduced by the intimate contact of the solid particles with the hot gases. The improved heat transfer allows the length of the rotary kiln to be reduced. An added benefit of the preheater operation is that hot gases from the preheater tower are used to help dry raw materials in the raw mill. Because the catch from the mechanical collectors, fabric filters, and/or electrostatic precipitators that follow the raw mill is returned to the process, these devices are considered production units as well as pollution control devices.

Additional thermal efficiencies and productivity gains have been achieved by diverting some of the fuel to a precalciner vessel (or calciner) at the base of the preheater tower. This system is called the preheater/precalciner process. A calciner vessel is a specially designed combustion chamber at the base of the preheater, into which a portion of the fuel needed for clinker production is injected. Typically, 60-75% of the fuel required for clinker formation is burned in the calciner. In the calciner, the raw materials are heated to approximately 650-1050°C. this temperature, the decomposition of calcium carbonate occurs. The degree of calcination of feed entering the kiln is up to 90-95%.

The final component of the pyroprocessing system is the clinker cooler. The clinker cooler serves three main purposes.

- recoups up to 30% of the heat input to the kiln system,
- locks in desirable product qualities by freezing mineralogy, and
- makes it possible to handle the cooled clinker with conventional conveying equipment.

The more common types of clinker coolers are reciprocating grate, planetary, and rotary. In these coolers, the clinker is cooled from about 1,100°C to 90°C (2000°F to 200°F) by ambient air that passes through the clinker and into the rotary kiln for use as combustion air. However, in the reciprocating grate cooler, lower clinker discharge temperatures are achieved by passing an additional quantity of air through the clinker. Because this additional air cannot be used in the kiln for efficient combustion, it is vented to the atmosphere, used for drying coal or raw materials, or used as a combustion air source for the precalciner.

Cement kilns are generally a counter flow process in which the feed is dumped into the high end of the kiln and the heat source is entered into the other. Coal is the fuel of choice in cement kilns, primarily because of its low cost, but also because the coal ash contributes to the product. In addition to conventional fuels, many Portland cement facilities are employing the use of petroleum derived coke (petcoke) blended with coal to fire kilns. The analysis of facilities in the LADCO states showed use of petcoke along with coal, liquid hazardous waste, and other fuels. Heat and feed are flowing in opposite directions within the kiln chamber so that the feed is constantly increasing in temperature from start to finish. As the feed passes through the kiln, gasses and byproducts are generated and collected. The resulting clinker, an intermediate product, is ground to make cement.

In the second portion of the cement manufacturing process, a series of blending and grinding operations completes the transformation of clinker into finished cement. Up to 5% gypsum or natural anhydrite is added to the clinker during grinding to control the cement setting time, and other specialty chemicals are added as needed to impart specific product properties. This finish milling is accomplished almost exclusively in ball or tube mills. Typically, finishing is conducted in a closed-circuit system, with product sizing by air separation.

3.1 Source Category NO_x Emissions and Potential Control Options

Kilns emit a mixture of fuel and thermal NO_x with a small portion coming from feed and prompt NO_x. Predominance of thermal and fuel NO_x in cement kiln combustion depends on the fuel being used and kiln design. Nitrogen content in fuel, fuel efficiency, and combustion temperatures impact NO_x creation.

Due to multiple factors affecting NO_x formation from combustion, there are different methods of reducing or controlling NO_x emissions from kilns. The potential control types can be categorized into the following three categories: pre-combustion NO_x controls, combustion modifications, and post-combustion NO_x controls. Pre-combustion NO_x controls include fuel substitution. This assessment does not analyze fuel switching as the costs are highly variable, and feasibility is dependent on individual kiln characteristics and functions. Combustion modifications in kilns are changes to one or more controllable variables in the combustion process itself, such as restriction of oxygen, flame temperature and/or residence time. Post-combustion NO_x controls utilize add-on control technologies to decrease the amount of formed NO_x before the combustion air is released to the atmosphere. It should be noted that certain physical or operational changes to a source may require analysis under the Prevention of Significant Deterioration (PSD) Program. It should also be noted that the potentially applicable controls for any one source are highly dependent on the type of kiln, fuel(s) used, heat input capacity, and mode of operation.

For cement kilns, control technology options identified for NO_x include tuning/optimization, low-NO_x burners (LNB), indirect firing, mid-kiln firing, selective catalytic reduction (SCR), and selective non-catalytic reduction (SNCR). Table 3-1 on the following page summarizes appropriate NO_x control options for cement manufacturing kilns.

Table 3-1 Source Category Potential NO_x Control Options for Cement Kilns

Technology	Description	Applicability	Performance
Tuning/Optimization[3]	Process optimizing such as flame shaping and temperature profile	Potential control measure for all cement manufacturing kilns	Varies
LNB[1]	Advanced burner design that controls oxygen, flame temperature, and/or residence time with controlled fuel feed	Potential control measure for all cement manufacturing kilns	10-20% reduction in NO_x
LNB + Indirect Firing[1,2]	Advanced burner design that controls oxygen, flame temperature, and/or residence time with controlled fuel feed	Potential control measure for all cement kilns. Dependent on fuels burned, kiln use, and kiln configuration.	10-40% reduction in NO_x
Mid-Kiln Firing[3]	Injecting solid fuel (usually tire derived fuel) into midpoint of kiln system	Potential control measure for all cement kilns. Dependent on fuels burned, kiln use, and kiln configuration.	10-55% reduction in NO_x
LNB + Mid-Kiln Firing[1]	Advanced burner design that controls oxygen, flame temperature, and/or residence time with fuel injection at mid-point of kiln system	Potential control measure for all cement kilns. Dependent on fuels burned, kiln use, and kiln configuration.	45% reduction in NO_x
SNCR[4]	A reducing agent such as ammonia is introduced into the flue gas stream to form nitrogen gas	Potential control measure for all cement kilns. Dependent on fuels burned, kiln use, and kiln configuration.	45% reduction in NO_x
SCR[1,2,4,5]	A reducing agent such as ammonia is introduced into the flue gas stream to form nitrogen gas in the presence of a catalyst	Potential control measure for all preheater and preheater/precalciner cement kilns. Dependent on fuels burned, kiln use, and kiln configuration.	70-90% reduction in NO_x

Note: EPA Air Pollution Control Manual cites 12-77% reduction with NH3 based SNCR (2019), with BART application achieving 35-58% reduction, with a median of 40%.

Table references:

1. *Midwest Regional Planning Organization Cement BART Engineering Analysis*, LADCO, March 2005.
2. *BART Determination Support Document for Lafarge North America Seattle Plant*, Washington State Department of Ecology, October 2008.
3. *Supplementary Information for Four-Factor Analyses by WRAP States*, WRAP and WGQ, May 2009.
4. *Control Technology Analysis for Carolinas Cement Company LLC*. Environmental Quality Management, Inc., Feb 2008.
5. *Attachment to Letter, RE: National Association of Clean Air Agencies*. Docket ID No. EPA-HQ-OAR-2007-0877, Sep 2008.

3.1.1 Source Category Potential Combustion NO_x Control Options

Kiln Tuning/Optimization

Kiln tuning and optimization is a baseline NO_x control that applies to cement manufacturing. This pre-combustion control includes improving fuel efficiency and modifications to the kiln design to reduce NO_x emissions. Efficiency and cost effectiveness of this pre-combustion NO_x control is difficult to quantify as designs and processes are highly variable.

Low NO_x Burners /Indirect Firing

LNB reduces NO_x formation by controlling oxygen, flame temperature, and/or residence time. Cement kilns utilize staged air low-NO_x burners. Central air and swirl air generate an optimum internal recirculation, with a correspondingly high residence time for the combustion of solid fuels. Staged air LNB increases residence time and thus is more effective for fuel oil kilns which produce higher fuel NO_x emissions. Furthermore, by internal recirculation of the combustion gases the spontaneous formation of NO_x decreases. In addition, by reducing the peak flame temperature, significantly less NO_x is formed in the process. LNB can be used on all types of cement manufacturing kilns.

Indirect firing systems are a type of combustion modification that utilizes pulverized fuel and transports the fuel to the burner via a dense phase conveying system which reduces air volume. This process creates a fuel rich flame which in turn decreases oxygen that is necessary in NO_x formation. LNB can be used in collaboration with indirect firing and has control efficiencies of 10 to 40 percent. When only LNB is applied to cement kilns, a reduction in 10-20 percent is observed (LADCO, 2005). Indirect firing with LNB can be used on all systems in cement production.

Staged Combustion

Staged combustion of fuel includes the use of precalciners and mid-kiln firing. In mid-kiln firing, fuel is injected near the mid-point of the kiln using a feed fork, pivoting doors, and a drop tube that extends into the kiln wall. Fuel injection occurs once in a revolution. Typically, fuel with low fuel NO_x is used. This combustion modification reduces the heat needed thus leading to a reduction in thermal NO_x formation. Mid-kiln firing has been used in long wet and dry kilns but can also be used in preheater and preheater/precalciner systems.

Preheater/precalciner kilns are inherently a form of staged combustion. Up to 70% of the total fuel consumption in a preheater/precalciner kiln is combusted in the calciner. The operating temperature in the calciner is significantly lower than in the kiln. The ideal temperature range is approximately 900°C while the kiln temperature is between 1500°C and 1700°C. Since most of the fuel is combusted at a lower temperature, less thermal NO_x is formed. In addition, combustion in the calciner can occur with less excess oxygen resulting in slightly reducing conditions which also reduces NO_x formation.

With preheater and preheater/precalciner systems, fuel can also be introduced into the riser duct using a drop chute with an airlock which causes combustion to be initiated in the riser duct which is located between the calciner and rotary kiln. Combustion continues within the rotary kiln section away from the high temperatures of the main kiln burner.

Mid-kiln firing on its own can reduce NO_x from 11 to 55 percent depending on fuel used and kiln design (EC/R Incorporated, 2009). Paired with a LNB, up to a 45 percent reduction has been noted (LADCO, 2005).

Water Injection

Water injection is a well-established mechanism for controlling thermal NO_x emissions. To control the formation of thermal NO_x, water is injected with the fuel to reduce flame temperature. For cyclone boilers that generate high levels of thermal NO_x, reductions of 22% have been demonstrated and higher reductions are possible. Industry experience has shown up to a 50% control efficiency for water injection into the burning zone of a cement kiln. Liquid Hazardous Waste Fuel (LHWF) typically contains up to 18% moisture and has the same effect as water injection on the formation of thermal NO_x. Inherent moisture of the LHWF injected into the kiln or the calciner has the effect of cooling the flame and reducing NO_x emissions. The use of waste derived fuel is recognized as a NO_x control on Kilns #1 and #2 at the Lafarge North America Paulding, Ohio plant and at the Lehigh Cement Waco, Texas plant (see Summary table in Appendix C).

3.1.2 Source Category Post-Combustion Potential NO_x Control Options

Selective Non-Catalytic Reduction

SNCR is another control option that is dependent on kiln type. An ammonia containing solution (e.g., anhydrous ammonia, aqueous ammonia, or urea) is injected into the preheater tower for NO_x reduction. The ammonia reacts with the NO_x to form nitrogen and water. Optimum temperature ranges from 1600° - 2000°F which must be maintained for the reaction to occur. At lower temperatures, the reaction rates slow and increases the chance of ammonia slip, although it is noted that a minimum of 5 parts per million ammonia slip may still occur during normal SNCR processes (Environmental Quality Management, Inc., 2008). If temperatures exceed the optimal range, the reactions do not occur; and ammonia or urea reagent will oxidize and result in even greater NO_x emissions. SNCR secondary reactions can form precipitate which can foul the preheater and interrupt kiln processes. Exercising caution with ammonia input quantity and adding wet scrubbing can help reduce ammonia emissions. As is the case with SCR, SNCR works best when applied with preheater and preheater/precalciner kilns with NO_x reductions of 45 percent (Environmental Quality Management, Inc., 2008).

Selective Catalytic Reduction

In SCR, anhydrous ammonia is injected into NO_x containing exhaust gas and directed through a catalyst bed to reduce NO_x to nitrogen and water. Catalysts typically used include vanadium pentoxide, zeolite, or titanium dioxide. To complete the reaction, a temperature range of 480° - 800°F is required. Due to this temperature requirement, SCR application would theoretically work best for preheater and/or precalciner kilns but has limited application on cement kilns for NO_x control in the united states. The catalyst bed can be placed after the preheater tower or before or after the particulate matter (PM) control device. SCR placement is important and leads to control design decisions. If the SCR is placed at the preheater tower, temperature requirements are met but the catalyst is subject to fouling by particulate, alkalis, lime, and sulfur dioxide in cement kiln gases. Fouling can cause the catalyst to become unreactive, thus allowing injected ammonia to escape through the system which is known as ammonia slip. There are sulfur tolerant SCR catalysts available that can limit SO_2 oxidation to less than 1 percent (LADCO, 2005). Particulate accumulation can be reduced with soot blowers. If the SCR is placed after the PM control device, reheating of exhaust gases will be required for the catalyst reaction. SCR NO_x reduction observed ranges from 70 to 90 percent.

3.2 Source Category Four-Factor Analysis of Potential NO_x Control Options

The four-factor analysis approach has been utilized to analyze the potential NO_x control options presented in Table 3-1 on page 5. The four factors that must be taken into consideration for potential NO_x control options in determining reasonable progress for the cement kiln source category are outlined below.

3.2.1 Source Category Cost of Compliance for Potential NO_x Control Options

To compare the various control options, information has been compiled on the cost effectiveness of retrofitting controls. As a rule of thumb, cost effectiveness increases with the amount of cement produced by the facility.

For this assessment, cost effectiveness was pulled from various sources, compiled into a general range, and converted into 2015 dollars. This information is summarized in Table 3-2 on page 10. Please note that the ranges will vary less than what is shown depending on the size and type of kiln.

Factors contributing to capital costs include installation costs, control hardware, and additional add-ons required due to site-specific conditions. LNB with mid-kiln/indirect firing generally will be more cost effective than the current post-combustion control options. When LNB is applied to preheater/precalciner kilns, costs are generally lower than long dry kilns. However due to less pollutants emitted from preheater/precalciner kilns than dry kilns, the cost values are slightly higher for the former type when comparing similar sized facilities. Site-specific factors can impose additional costs.

For preheater/precalciner kilns, an SNCR system may be considered. An SNCR system consists of an ammonia storage tank, blower or compressor, and various valves, indicators, and controls; the ammonia injection grid; and a continuous emissions monitoring system. No reactor is required for SNCR as the urea or other reducing agent can be injected directly into the gas stream. This reduces capital costs for the system; however, operating costs are higher due to lower efficiency and more reagents use and NO_x reduction efficiency is greatly increased.

An SCR system includes catalyst materials; the ammonia system including a vaporizer, storage tank, blower or compressor, and various valves, indicators, and controls; the ammonia injection grid; the SCR reactor housing (which contains the catalyst); transition ductwork; and a continuous emissions monitoring system. The decision to use aqua ammonia or urea instead of anhydrous ammonia can play a small role in affecting costs because aqua ammonia and urea have higher capital and operating costs. SCR systems are generally designed for use in combustion systems with a much lower dust loading (e.g., power plants, boilers). The high dust loading contributes to catalyst deactivation mechanisms including plugging, masking, encrustations, and poisoning. To function in a cement kiln, the SCR system may require additional particulate removal equipment and associating ductwork depending on site specific factors. If the exhaust gas temperature range entering the SCR does not meet the optimal catalyst temperature requirements, modifications may have to be made to increase/decrease the temperature. Additional gas cleaning may be required to maintain the SCR as well as a bypass installation to protect the SCR during startup, shutdown, and malfunction which could potentially foul the catalyst. A preheater/precalciner kiln is generally more cost effective when compared to a dry kiln.

Table 3-2 Source Category Cost Effectiveness of Potential NO_x Control Options

Control Option	Specific Design Parameters Identified	Cost Effectiveness (2015 $/ton)[a]	Factors Affecting Cost	Potential Applicability to Specific Facilities (Unit ID)
Tuning/Optimization[3]	None	Low	Engineering and contractor costs	05-01[b]
LNB[1]	None	No Data	Equipment, installation, and engineering	05-01
LNB + Indirect Firing[1,2]	Specific temperature range, oxygen levels, and flame length	$200-$21,100	Equipment, installation, and engineering	05-01
Mid-Kiln Firing[3]	Specific fuel injection location	$600-$3,600	Equipment, installation, and engineering	05-01
LNB + Mid-Kiln Firing[1]	Specific temperature range, specific fuel injection, oxygen levels, and flame length	No Data	Equipment, installation, and engineering	05-01
SNCR[4]	Specific temperature range; PM reduction, ammonia injection, preheater kiln	$1,400	Equipment, installation, engineering, energy use, waste removal, and reduction agent	None
SCR[1,2,4,5]	Specific temperature range; PM reduction, ammonia injection, catalyst bed	$600-$17,700	Equipment, installation, engineering, energy use, waste removal, reduction agent, and catalyst	05-01

[a] Costs have been converted into 2015 dollars using Consumer Price Index (CPI) data through August 2015.
[b] Table 6-1 Point Source NO_x Information Collected for Select Cement and Lime Kilns in the LADCO Region, *Four-Factor Analysis for Regional Haze in the Northern Midwest Class I Area,* LADCO, 2015, page 6-2.

Table references:
1. *Midwest Regional Planning Organization Cement BART Engineering Analysis*, LADCO, March 2005.
2. *BART Determination Support Document for Lafarge North America Seattle Plant*, Washington State Department of Ecology, October 2008.
3. *Supplementary Information for Four Factor Analyses by WRAP States*, WRAP and WGQ, May 2009.
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5. *Attachment to Letter, RE: National Association of Clean Air Agencies.* Docket ID No. EPA-HQ-OAR-2007-0877, Sep 2008.

3.2.2 Source Category Time Necessary for Potential NO_x Control Options Compliance

Sources are generally given between two and five years to implement changes for compliance with new regulations. Maximum achievable control technology (MACT) standards typically allow three years for compliance and BART emission limitations require compliance no more than five years after regional haze SIP approval by the EPA. Under the NO_x SIP Call for Phases I and II, EPA allowed for three and a half and two years, respectively, after the SIP submittal date for compliance. Combustion modifications and post-combustion NO_x controls require significant time for engineering, construction, and facility preparedness. After SIP submittal, a two-year period is assumed to be adequate for pre-combustion controls and a three-year period for post-combustion control installation. Substantially less time would be required for boiler optimization and tuning which can be implemented within a few months to a year.

3.2.3 Source Category Energy and Non-Air Impacts of Potential NO_x Control Options

With LNB, flame efficiency can be impacted thus increasing fuel consumption. Vendors claim that new LNB designs do not lower fuel efficiency so a small increase in fuel consumption may occur. If catalyst bed or reaction temperatures are not met for post-combustion controls, additional fuel or electrical power may be required to heat or cool the gas stream.

When SNCR, SCR, and RNCR conditions are not met (e.g., temperature range), the required reactions to promote NO_x reduction do not occur thus leading to ammonia slip or an increase in particulate emissions. In the presence of a catalyst, the increase in particulate emissions can potentially foul the catalyst. With ammonia slip, ammonia is permitted through the stack to react with sulfur and nitrogen oxides to form particulate, thus, contributing to regional haze. Ammonia slip can also contaminate surface waters by deposition. For SNCR, SCR, and RNCR, storage of anhydrous ammonia is accompanied with more environmental and safety risk than with aqueous ammonia or urea storage. Additionally, spent catalyst beds will need to be changed periodically resulting in an increase in waste disposal.

3.2.4 Source Category Remaining Useful Life of Potential NO_x Control Options

According to MARAMA's Assessment of Reasonable Progress for Regional Haze in MANE-VU Class I areas, the remaining useful life of each emission unit is a minimum of at least 10 years. With proper maintenance and upkeep, some units can operate for 20-30 years more.

3.3 Source Category SO_2 Emissions and Potential Control Options

Sulfur dioxide is formed primarily from sulfur in the raw materials. Sulfur content in fuels and raw materials can vary according to geographic location. In contrast to industrial boilers, SO_2 emissions from cement kilns are not strongly dependent on fuel sulfur content but rather the amount of sulfide (e.g., pyrite) in kiln feedstocks and the molar ratio of total sulfur to total alkali input to the system. Oxidizing or reducing conditions and their location within the kiln as well as temperature profile in the kiln system can impact SO_2 emissions. Additionally, inherent reduction of SO_2 emissions occurs in cement production due to the alkaline nature of cement which promotes direct absorption of SO_2 into the product.

Potential control types can be categorized into the following three categories: pre-combustion SO_2 controls, combustion modifications, and post-combustion SO_2 controls. Pre-combustion SO_2 controls include fuel substitution. This assessment does not analyze the cost effectiveness of fuel switching because costs are highly variable and SO_2 emissions are not strongly dependent on sulfur content in fuel but rather on the sulfur content in kiln feedstock. Combustion modifications are changes to one or more controllable variables in the combustion process itself. Retrofit combustion modifications exist but are very invasive and may be possible for only a small number of existing kilns. For this reason, these modifications are not assessed in this report. Post-combustion SO_2 controls utilize add-on control technologies to decrease the amount of formed SO_2 before the combustion air is release to the atmosphere. It should be noted that certain physical or operational changes to a source may require analysis under the PSD program. It should also be noted that the potentially applicable controls for any one source are highly dependent on the type of kiln, fuel(s) used, heat input capacity, and mode of operation.

Table 3-3 on the following page summarizes appropriate SO_2 control options for cement manufacturing kilns.

Table 3-3 Source Category Potential SO_2 Control Technologies for Cement Kilns

Technology	Description	Applicability	Performance
Conventional Dry Flue Gas Desulfurization (FGD) - Dry Sorbent Injection[1,2,3,4]	An absorbent reagent such as lime slurry is introduced into the flue gas stream through direct injection to absorb SO_2, creating a dry solid which is caught in a downstream fabric filter or ESP	Potential control measure for all cement kilns; dependent on fuels burned, kiln use, and kiln configuration	25-50% reduction in SO_2
Conventional Dry Flue Gas Desulfurization (FGD) - Spray Dryer[1,5,6]	An absorbent reagent such as lime, calcium hydrate, limestone or soda ash is introduced into the flue gas stream through spray in an absorption tower to absorb SO_2, creating a dry solid which is caught in a downstream fabric filter or ESP	Potential control measure for all cement manufacturing kilns; dependent on fuels burned, kiln use, and kiln configuration	90-95% reduction in SO_2
Advanced Flue Gas Desulfurization (FGD)[1]	A slurry reagent is sprayed onto cooled/humidified flue gas to absorb SO2, creating calcium sulfate that is oxidized to create wallboard-grade gypsum	Potential control measure for all cement kilns; dependent on fuels burned, kiln use, and kiln configuration	95-99.5% reduction in SO_2
Wet Flue Gas Desulfurization (FGD)[1,2,3,4,5,6]	A scrubbing reagent such as caustic, crushed limestone, or lime is introduced into the flue gas stream to absorb SO2, creating liquid or sludge waste	Potential control measure for all cement and lime manufacturing kilns; dependent on fuels burned, kiln use, and kiln configuration	40-99% reduction in SO_2

Table references:

1. *Midwest Regional Planning Organization Cement BART Engineering Analysis*, LADCO, March 2005.
2. *BART Determination Support Document for Lafarge North America Seattle Plant*, Washington State Department of Ecology, October 2008.
3. *Prevention of Significant Air Quality Deterioration Review Preliminary Determination - CEMEX Southeast, LLC,* Georgia EPD, December 2008.
4. *Control Technology Analysis for Carolinas Cement Company LLC*, Environmental Quality Management, Inc., February 2008.
5. *Technical Evaluation & Preliminary Determination - Jacksonville Lime LLC*, Florida DEP, December 2013.
6. *Subject: Engineering Evaluation of Prevention of Significant Deterioration Permit Application Submitted by Carmeuse Lime & Stone for its Winchester Facility (Registration No. 80504)*. VA DEQ, April 2014.

3.3.1 Source Category Pre-Combustion Potential SO_2 Control Options

Flue Gas Desulfurization

For cement kilns, control technology options identified for SO_2 include conventional dry flue gas desulfurization (FGD), wet FGD, and advanced flue gas desulfurization (AFGD). Descriptions of each of these technologies are provided below and a summary of these controls is provided in Table 3-3 on the previous page.

Conventional Dry Flue Gas Desulfurization

There are two types of conventional dry FGD controls: dry sorbent injection (DSI) and spray dryer absorption (SDA) systems.

In DSI, lime, calcium hydrate, limestone or soda ash is injected into the flue gas stream producing solid particles of calcium sulfite and calcium sulfate (CaSO3 or CaSO4). These particles and excess reagent are removed from the gas stream using a particulate control device. SO_2 removal efficiency typically ranges from 25-50 percent and depends on absorbent injection location, temperature, degree of mixing, retention time, kiln type, and additional add-ons. Depending on site-specific processes, DSI systems can and have been applied to cement kilns.

In an SDA system, lime slurry is sprayed into an absorption tower where SO_2 is absorbed into the slurry, forming a mixture of calcium sulfite and calcium sulfate. The water evaporates before the droplets reach the bottom of the tower due to the liquid-to-gas ratio. The dry solids created due to the evaporation are collected with a fabric filter or ESP. When applied to cement kilns, spray dryers are expected to reduce SO_2 emissions by 90 to 95 percent (LADCO, 2005).

According to MARAMA's Assessment of Reasonable Progress for Regional Haze in MANE-VU Class I areas, SDA systems are typically applied to preheater or preheater/precalciner kilns in the cement industry. In long dry kilns, two methods are used to cool down exhaust gases. Spray water is introduced into the feed end of the kiln or by dilution air-cooling once the gases leave the kiln. An SDA equivalent application for long dry kilns is to use a conditioning tower to replace the method of cooling and pair with an alkaline slurry system to reduce SO_2 emissions. For long wet kilns, an SDA system should be applied with care because the addition of the lime slurry may drop the exhaust gases temperature below acid adiabatic saturation temperatures, plugging and causing corrosion problems in the downstream particulate control device, duct work, and induced draft fan (LADCO, 2005).

It must be noted that exhaust gases that exit at or near the adiabatic saturation temperatures can create problems with dry FGD by causing the baghouse filter cake to become saturated with moisture and plug both the filters and the dust removal system. In addition, the lime slurry would not dry properly and would plug up the dust collection system. However, some argue that SO_2 removal, actually, occurs on the filter cake. Ultimately, it is important that exit gas temperatures are above the adiabatic saturation temperatures (LADCO, 2005).

Advanced Flue Gas Desulfurization

AFGD utilizes a single absorber to accomplish three actions at once. Before entering the absorber, incoming flue gas is cooled and humidified with process wet suppression. As the quenched flue gas enters the absorber, reagent slurry is distributed via two tiers of fountain like sprays and onto a polymer grid packing that promotes gas/liquid contact. This is where SO_2 absorption, neutralization, and partial oxidation begins. The products formed are calcium sulfite and calcium sulfate. Slurry and absorbed SO_2 fall into the slurry reservoir where unreacted acids are neutralized further by injected dry limestone powder.

Meanwhile, air is injected into the slurry through mixing with the use of an air rotary sparger which oxidizes the primary product, calcium sulfite, into gypsum. Fixed air spargers are also used to supplement complete oxidation. Slurry is recycled back to the absorber grid while the gypsum is drawn from the reservoir, dewatered, and washed to remove chlorides. The liquid generated by dewatering is returned to the reservoir with a slipstream headed to the wastewater evaporation system to be injected into the hot flue gas prior to the ESP which is placed before the absorber. The gypsum created wallboard quality gypsum which can be added in the final grinding process to regulate concrete setting time. Particulate collected in the ESP consist of water evaporates and dissolved solids that can be collected for disposal or sale.

After going through the polymer grid packing, the flue gas continues onto a large gas/liquid disengagement zone above the slurry reservoir where the SO_2 has been absorbed and finally exiting through a horizontal mist eliminator.

AFGD has not been used in cement kilns before. In the Assessment of Reasonable Progress for Regional Haze in MANE-VU Class I areas, MACTEC recommends the use of an AFGD system because it is similar to wet FGD and can produce commercial grade gypsum. AFGD control efficiency ranges from 95 to 99.5 percent (LADCO, 2005). AFGD is not generally considered technically feasible for cement kilns.

Wet Flue Gas Desulfurization

Caustic, crushed limestone, and lime are used as scrubbing agents in wet FGD. In the presence of these agents, SO_2 from the exhaust gases is absorbed into the contact liquid. When lime or limestone is used, additional steps and equipment are required to stabilize the watery calcium sulfite or calcium sulfate sludge produced.

Calcium sulfate sludge can be dewatered but in order to create the calcium sulfate, an air injection blower is needed to supply oxygen necessary for the reaction to occur. In cement kilns, SO_2 reduction efficiency ranges from 40 to 99 percent.

When directly applied to the exhaust gas stream, calcium sulfate scaling and cementitious buildup can occur when used for acid gas control. To prevent these issues from happening, a particulate control device can be installed. However, if the particulate control device fails this could impact the downstream wet scrubber.

3.4 Source Category Four-Factor Analysis of Potential SO_2 Control Options

The four-factor analysis approach has been utilized to analyze the potential SO_2 control options presented in Table 3-3 page 13. The four factors that must be taken into consideration for potential SO_2 control options in determining reasonable progress for the cement kiln source category are outlined below.

3.4.1 Source Category Cost of Compliance for Potential SO_2 Control Options

Information on cost effectiveness of retrofitting controls onto kilns has been compiled from various sources. It is important to note that the values provided are estimated and actual retrofit control costs may be higher or lower depending on the utilization and production scale of the kiln as well as specific capital costs associated with the design.

Pre-combustion (e.g., fuel substitution) and combustion modifications were not discussed in detail in this assessment due to highly variable costs determined by individual kiln characteristics and functions.

Post-combustion SO_2 control costs can be impacted by scrubbing agent used, additional equipment required for promoting SO_2 reduction reactions, and the associated energy costs. Lime is generally less expensive and readily available. However, if other scrubbing agents are used this could increase costs. For the AFGD process, spargers and blowers are necessary to oxidize the waste product and additional equipment are required to dewater the gypsum hydrate. In order to keep the flue gas above adiabatic saturation in dry FGD, equipment like an evaporative cooler, a heat exchanger, or a heat recovery boiler will be needed. These additions will run up the costs with purchase, installation, and associated energy costs. However, costs may be offset with the sale of gypsum generated by AFGD. Wet FGD systems also provide another level of particulate control.

In assessing cost effectiveness of SO_2 controls for lime plants, PSD evaluations of two lime plants, Jacksonville Lime LLC (Florida) and Carmeuse Lime & Stone (Virginia), were found. In each PSD analysis, both the state and the facility agreed that application of SO_2 controls may not be cost effective due to inherent scrubbing of SO_2 within the process.

Table 3-4 on the following page summarizes the cost effectiveness and factors affecting the cost of each control option addressed in this analysis, as well as potential applicability to the specific facilities analyzed as part of this report. Costs have been converted into 2015 dollars using Consumer Price Index (CPI) data through August 2015. Please note that some costs may have decreased since the original analyses; however, this analysis has only used past data available. A confidential key to the unit IDs is provided on the informational disc included with this report. It must be pointed out that the cost-effective ranges for cement kilns vary greatly. This range includes both long dry kilns and preheater/precalciner kilns, the latter of which exhibits higher cost per ton of SO_2.

Table 3-4 Source Category Cost Effectiveness of Potential SO_2 Control Options

Control Option	Specific Design Parameters Identified	Cost Effectiveness (2015 $/ton)[a]	Factors Affecting Cost
Conventional Dry Flue Gas Desulfurization (FGD) - Dry Sorbent Injection[1,2,3,4]	Direct flue gas application, lime/calcium hydrate/limestone/soda ash injection, PM control device	$2,400-$9,000 (cement)	Equipment, installation, engineering, reagent, and waste removal
Conventional Dry Flue Gas Desulfurization (FGD) - Spray Dryer[1,5,6]	An absorbent reagent such as lime, calcium hydrate, limestone or soda ash is introduced into the flue gas stream through spray in an absorption tower to absorb SO_2, creating a dry solid which is caught in a downstream fabric filter or ESP	$2,300-$88,800 (cement)	Equipment, installation, engineering, reagent, and waste removal
Advanced Flue Gas Desulfurization (FGD)[1]	Lime slurry injection, PM control device	$2,400-$47,100 (cement)	Equipment, installation, engineering, reagent, energy use, waste removal, and byproduct resale
Wet Flue Gas Desulfurization (FGD)[1,2,3,4,5,6]	Caustic/crushed limestone/lime slurry, scrubber vessel pressure drop, air injection blower, PM control device	$1,500-$78,800 (cement)	Equipment, installation, engineering, reagent, energy use, and waste removal

[a] Costs have been converted into 2015 dollars using Consumer Price Index (CPI) data through August 2015.

Table references:

1. *Midwest Regional Planning Organization Cement BART Engineering Analysis*, LADCO, March 2005.
2. *BART Determination Support Document for Lafarge North America Seattle Plant*, Washington State Department of Ecology, October 2008.
3. *Prevention of Significant Air Quality Deterioration Review Preliminary Determination - CEMEX Southeast, LLC,* Georgia EPD, December 2008.
4. *Control Technology Analysis for Carolinas Cement Company LLC*, Environmental Quality Management, Inc., February 2008.

3.4.2 Source Category Time Necessary for Potential SO_2 Control Options Compliance

Sources are generally given between two and five years to implement changes for compliance with new regulations. MACT standards typically allow three years for compliance and BART emission limitations require compliance no more than five years after regional haze SIP approval by the EPA. Combustion modifications and post-combustion controls require significant time for engineering, construction, and facility preparedness. Two to five years would typically be appropriate, depending on the size of the unit and control options selected.

3.4.3 Source Category Energy and Non-Air Impacts of Potential SO_2 Control Options

Post-combustion SO_2 controls can impact energy use and the environment in forms other than air quality. Non-air environmental impacts include solid, liquid, and/or hazardous waste generation and deposition of atmospheric pollutants on land or water. Dry FGD generates particulate that is collected by PM control devices that will need to be disposed. Wet FGD generates wastewater and sludge that increases a facility's wastewater treatment and solid waste management burdens. Even though AFGD generally creates commercial grade gypsum, gypsum that does not meet industry standards can be created due to fuels used.

Post-combustion SO_2 controls may also impact energy use for kilns. Wet FGD tends to consume more energy due to an operational pressure drop in the scrubber vessel. When systems utilize more reagent for the associated process, more energy consumption occurs. For some technologies, a flue gas reheater may be essential to the system thus increasing energy use.

3.4.4 Source Category Remaining Useful Life for SO_2 Control Options

According to MARAMA's Assessment of Reasonable Progress for Regional Haze in MANE-VU Class I areas, the remaining useful life of each emission unit is a minimum of at least 10 years. With proper maintenance and upkeep, some units can operate for 20-30 years more.

3.5 Clean Air Act Regulations Controlling Cement Kilns

3.5.1 National Emission Standards for Hazardous Air Pollutants (NESHAPs) for the Portland Cement Manufacturing 40 CFR 63, Subpart LLL and New Source Performance Standards (NSPS) for Portland Cement Plants

The Portland cement manufacturing industry is governed by the revised amendments to the National Emission Standards for Hazardous Air Pollutants (NESHAPs) for the Portland Cement Manufacturing 40 CFR 63, Subpart LLL and New Source Performance Standards (NSPS) for Portland Cement Plants, 40 CFR 60, Subpart F. The EPA originally established the NESHAPs for the Portland cement manufacturing industry and NSPS for Portland cement plants in 1999 under sections 112(d) and 111(b) of the CAA.

On September 9, 2010, EPA finalized amendments to the NESHAPs for the Portland Cement Manufacturing Industry and New Source Performance Standards for Portland Cement Plants. The final 2010 NSPS for Portland cement plants revised and added, as applicable, emission limits for PM, opacity, NO_x, and SO_2 for facilities that commence construction, modification, or reconstruction after June 16, 2008 and included additional testing and monitoring requirements for affected sources.

On July 18, 2012, the EPA proposed amendments to the NESHAPs for the Portland cement source category and NSPS for Portland cement plants in response to petitions for reconsideration filed by the Portland cement industry and a federal court decision by the United States Court of Appeals for the District of Columbia Circuit to remand the 2010 amendments. The most significant amendment was to the NESHAP and NSPS for PM, which was the only change to the NSPS rule.

The NSPS emission limits for NO_x and SO_2 established in the 2010 amendments remained the same and the final rule was effective on February 12, 2013. Subsequently, on November 19, 2014, the EPA issued a proposal to amend the two rules issued in February 2013 after the agency became aware of certain minor technical errors in those amendments. The final amendments to correct these errors became effective on July 1, 2015 and remains in effect at this time.

3.5.2 National Emission Standards for Hazardous Air Pollutants from Hazardous Waste Combustors 40 CFR 63, Subpart EEE

Hazardous waste-burning cement kilns are governed by the NESHAP for Hazardous Waste Combustors, 40 CFR 63, Subpart EEE. The original amendments were proposed on April 19, 1996 under the joint authority the CAA and the Resource Conservation and Recovery Act. The NESHAP limits emissions of chlorinated dioxins and furans, other toxic organic compounds, toxic metals, hydrochloric acid, chlorine gas, and particulate matter. These standards reflect the performance of Maximum Achievable Control Technologies (MACT) as specified by the Clean Air Act.

On June 19, 1998, the NESHAPs for hazardous waste combustors was published in the FR. There were numerous actions taken between 1998 when the first NESHAPs amendments were finalized and 2008 when the current amendments became effective. On October 12, 2005, the NESHAP for new and existing sources at hazardous waste combustion facilities was finalized. Four petitions for reconsideration of the final rule were filed. On March 23, 2006 and September 6, 2006, EPA granted reconsideration with respect to issues raised by the petitions. EPA also re-opened the rule to consider comments relating to a post-promulgation decision of the United States Court of Appeals for the D.C. Circuit. As a result of this reconsideration process, EPA revised the new source standard for particulate matter, the particulate matter detection system provisions, and revisions to the health-based compliance alternative for total chlorine. Several corrections and clarifications were also made to the final NESHAP amendments which were finalized on October 28, 2008.

3.6 Source Category Selected Best Available Retrofit Technology

3.6.1 Source Category Reasonable Level of Control for NO_x Emissions

The largest contributor to overall NO_x emissions from cement kilns is thermal NO_x which results from high temperature combustion as described in Section 3.1 on page 4. Combustion modifications are an efficient way to reduce the formation of thermal NO_x by modifying the way oxygen or fuel is provided for combustion.

Low-NO_x burner systems are available for all kilns for NO_x emissions control. Table 3-1 on page 5 reports potential NO_x reduction rates of 10-55 percent with the installation of low-NO_x burners depending on fuel used, type of kiln, type of low-NO_x burner, and operating conditions. When only LNB is applied to cement kilns, a reduction of 10-20 percent is observed (LADCO, 2005), however LNB can be used in collaboration with indirect firing for improved control efficiencies that range from 20 to 40 percent.

According to Table 3-1 on page 5, SNCR systems are also available for all kiln types and has the NO_x reduction potential of 45 percent. The NO_x reduction efficiency of SNCR depends upon the temperature, residence time, and ammonia and NO_x concentrations in the flue gas. The injection of ammonia (NH3) or urea reduce NO_x emissions by 40 to 80 percent depending on the reagent and molar ratio of the reagent and product. This is a significant difference compared to LNB only and LNB with indirect firing.

IDEM selects SNCR as NO_x BART for the cement kiln source category. This includes cement kilns with no add-on NO_x controls and those with LNB. Although LNB are the next best retrofit technology for cement kilns with no add-on NO_x controls, these devices have been rejected as BART by the EPA as shown in the BART evaluations collected by Region 8 in Appendix C and replaced by the cement manufacturing industry as the standard NO_x emissions reduction control measure for all cement kiln designs. This is demonstrated by the number of new preheater/precalciner cement kiln designs with SNCR for NO_x control (LADCO 2015).

The advantages of using SNCR are the following for most cement kiln designs:

- Reduced NO_x, and
- Possibility to use petroleum coke with current NO_x limits.

The disadvantages of using SNCR are the following for most cement kiln designs:

- Higher than average CO,
- Ammonia emissions observed during raw mill offline periods, and
- Ammonia emissions may occur over longer periods of time when the raw mill system is operational.

3.6.2 Source Category Reasonable Level of Control for SO_2 Emissions

Sulfur dioxide emissions from cement kilns are primarily derived from sulfur in the kiln feed as described in Section 3.3 on page 12. The form of the sulfur dictates the location in the kiln where the SO_2 generation takes place. SO_2

scrubbing technologies are an efficient way to reduce SO_2. DSI systems are mechanically simple and consist of much fewer moving parts and ancillary systems compared to other scrubbing technologies such as wet scrubbers and spray dryer absorbers.

DSI systems are available for all kiln types. Table 3-3 on page 13 reports a 25-50 percent SO_2 reduction potential for DSI, dependent on fuels burned, kiln use, and kiln configuration. DSI technology was originally designed to reduce the amount of sulfur trioxide and acid gas emissions at sources such as coal-fired boilers. Since the amount of SO_2 removal achieved by DSI has always been less than other, more effective means of SO_2 removal (such as, wet or dry FGD systems specifically designed for sulfur dioxide removal), the technology was not previously marketed for SO_2 removal. However, recent regulatory drivers, such as the EPA Mercury and Air Toxics Rule for EGUs, have created renewed interest in DSI as a means of SO_2 removal due to the considerably lower capital costs of DSI compared to the more conventional wet or dry FGD systems. For this reason, SO_2 removal efficiency for these devices have improved.

IDEM selects DSI as SO_2 BART for the cement kiln source category because it is the next best retrofit technology for cement kilns with no add-on controls. With the installation of a DSI system, there is a high potential that footprint/physical space would be significantly impacted and inclusion of a baghouse in addition to the DSI system may be necessary.

4.0 SOURCES SELECTED FOR CEMENT KILN FOUR-FACTOR ANALYSIS

Cement is manufactured through a closely controlled chemical combination of calcium, silicon, aluminum, iron, and other ingredients. Common materials used to manufacture cement is limestone, clay, slag, shale, silica sand, and iron ore. These ingredients, when heated at high temperatures in a cement kiln form a rock-like structure called clinker, which is subsequently ground to a fine powder, and thoroughly intermixed to form a homogeneous mixture commonly thought of as cement. The rotary kilns, where clinker is chemically formed, are long, steel, cylindrical shells lined with a special refractory brick to withstand the severe effects of abrasion and high temperatures. Cement kilns are slightly inclined, so the kiln feed introduced in the back end of the kiln ("cold" end) is able to travel to the front end ("hot" end) and be transformed chemically along the path. The kiln length serves as the calcining zone where at the lower end of the kiln, the decomposition reactions of the carbonates occur.

4.1 Lehigh Cement Company, LLC

At the Mitchell plant, Lehigh Cement Company operates three long dry rotary kilns to produce Portland cement. Kilns #1 and #2 were constructed in 1959 as long dry kilns and modified to one-stage preheater kilns in July 2003 with a heat input rate of 118 million Btu per hour and a nominal production rate of 38 tons per hour. Kiln #3 was constructed in 1974 as a one-stage preheater kiln with a heat input rate of 118 million Btu per hour and nominal production rate of 43 tons per hour.

The front end of the cement kiln is where the fuel is introduced, which for the cases of the three cement kilns at Mitchell, is a combination of pulverized coal and/or natural gas. Heat from the firing of fuel is carried by the air stream being drawn through the process and used to heat the kiln feed. For Mitchell's kilns, the one-stage cyclone-type preheater improves the kiln's thermal efficiency and productive capacity, allowing for some counter-current heat transfer to occur between the gas stream and the fresh kiln feed before it reaches the front end of the kiln. Compared to the simple rotary kiln (long dry process) without preheater vessels, the heat transfer rate is higher, the degree of heat utilization is greater, and the process time is reduced in the Mitchell kilns due to the intimate contact of the solid particles with the hot gases in the preheater vessels.

Oxygen levels are monitored in the kiln system as an indication of complete combustion and to ensure fuel efficiency. Typical oxygen levels and temperatures at the kiln inlets and outlets are provided in Table 4-1 below.

Table 4-1 Lehigh Cement Company Kilns Operations Design Parameters

Location	Oxygen (%)	Temperature (ºF)
Kiln #1, #2, and #3 Inlets	Not Measured	1000-1400
Kiln #1, #2, and #3 Outlets	2-4	2700-3000

4.1.1 NO_x Emissions and Controls at the Mitchell Plant

The largest contributor to overall NO_x emissions is thermal NO_x which results from high temperature combustion. The three Mitchell kilns each have a single cyclone through which raw feed is processed before being introduced to the kiln. While a very small amount of heat transfer occurs in the cyclone, the cyclones do not allow the process to behave like a cement kiln with traditional preheater technology. In reality, the three Mitchell kilns behave like a long dry kiln in terms of fuel efficiency and NO_x formation. None of the three kilns have add-on NO_x control technology installed. To reduce NO_x emissions, the facility relies on good combustion practices and, more recently, reliance on a higher percentage of natural gas in the annual fuel mix.

4.1.2 SO_2 Emissions and Controls at the Mitchell Plant

The three Mitchell kilns have minimal add-on SO_2 control devices. All three kilns have dry sorbent injection DSI systems through which lime is processed and introduced to the kiln systems. The DSI systems are used minimally and were installed for the purposes of reducing HCl emissions at times. However, introduction of lime to the kiln process also has the co-benefit of reducing SO_2 emissions.

There are mechanisms inherent to the cement manufacturing process, in particular the calcination processing the production of clinker, which act to control SO_2 emissions. The calcination process in a cement kiln is designed to convert calcium carbonate $CaCO_3$ into lime CaO. This produces a lime-rich environment that is ideal for the scrubbing of any SO_2 present in the combustion gases by allowing the SO_2 to react to form $CaSO_3$ and $CaSO_4$ that, in turn are incorporated into the clinker. $CaSO_4$ is very stable as a solid, thus the majority of SO_2 formed from combustion in the kiln process exits the kiln in the clinker as $CaSO_4$ rather than in the exhaust gas as SO_2.

4.1.3 NO_x and SO_2 Emissions Trends at the Mitchell Plant

NO_x and SO_2 emissions from Mitchell's three kilns follow the same trend as the throughput for the 11-year period from 2008 to 2018. Reported annual NO_x and SO_2 emissions and throughputs for the Mitchell kilns are combined in Table 4-2 on the following page. The bar graphs in Graphs 4-1 and 4-2 on page 24 and 25, respectively, were developed using the emissions and throughput information in Table 4-2.

The first graph in Graph 4-1 shows a similar trend for NO_x and SO_2 emissions as the trend for throughput in the second graph in Graph 4-2 for the Michell kilns. This indicates that NO_x and SO_2 emissions for the cement kilns are driven by cement production and are a direct result of the type and amount of fuel and raw meal used for cement production. The bar graphs in Graphs 4-1 and 4-2 show that NO_x and SO_2 emissions increased in 2010 while throughput decreased. Then in 2011, NO_x and SO_2 emissions decreased while throughput increased.

The Mitchell kiln units are subject to the Standards of Performance for Portland Cement Plants, 40 CFR 60, Subpart F for facilities that commenced construction or modification after August 17, 1971, but on or before June 16, 2008 but the NO_x and SO_2 emission limitations in Subpart F apply to kiln units that commenced construction or modification after 2008. There are no NO_x or SO_2 emission limitations applicable to the existing three kilns in the NESHAPs or NSPS for Portland cement plants, therefore, the anomalies in 2010 and 2011 cannot be attributed to these regulations.

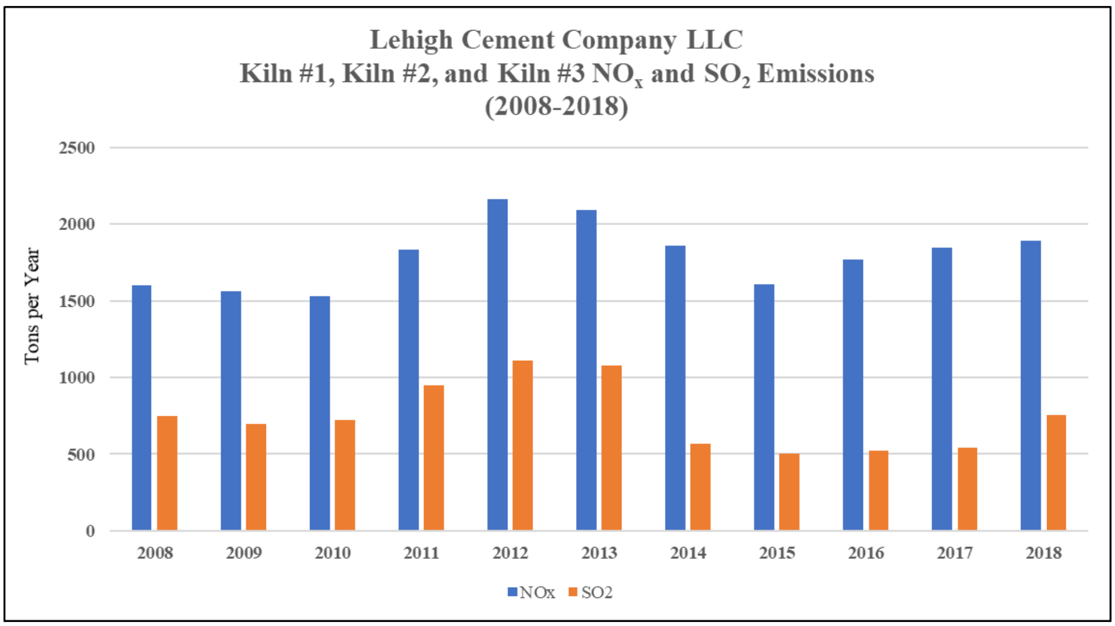
A review of the source's Part 70, Title V Operating permits revealed that in 2008 the Lehigh Cement Company submitted a letter informing IDEM of its intention to conduct a temporary operation and experimental trial. In 2008, the source was issued a Title V Temporary Operation permit and an extension permit in 2009, related to the use of engineered fuel in kiln #1. The temporary operation was conducted in two phases over an approximate two-year period that began in 2010, which suggests that the anomalies in 2010 and 2011 can be attributed to the temporary operation and experimental trial. In 2013, the company was issued a Title V Administrative Amendment permit to allow all three kilns at Mitchell to use additional alternative fuels. NO_x or SO_2 emission are not regulated under the NESHAPs for Hazardous Waste Combustors, 40 CFR 63, Subpart EEE.

Table 4-2 Lehigh and Lone Star Kilns NO_x and SO_2 Emissions and Throughput

Inventory Year	LEHIGH CEMENT COMPANY, LLC			LONE STAR INDUSTRY, INC DBA BUZZI UNICEM		
	Actual Throughput	NO_x Emissions (ton/yr)	SO_2 Emissions (ton/yr)	Actual Throughput	NO_x Emissions (ton/yr)	SO_2 Emissions (ton/yr)
2008	616064	1603.62	745.97	1274148	1726.36	500.46
2009	577076	1563.28	698.58	1318451	2012.33	410.76
2010	610039	1527.39	719.56	1122421	1763.10	208.76
2011	563803	1833.23	949.57	1083141	1746.21	167.76
2012	676583	2162.70	1108.30	1090071	2118.19	158.82
2013	655246	2089.94	1075.41	934789	1409.51	138.29
2014	636948	1859.00	569.02	1024609	1317.91	174.63
2015	541656	1609.14	501.92	1230046	1397.32	148.75
2016	665975	1767.30	519.38	1219236	1580.96	138.86
2017	696917	1847.29	540.42	1159966	1686.35	168.69
2018	599142	1889.19	753.27	1091362	1713.20	104.30

Note: Reported emissions from the sources' emission statements in accordance with Title V reporting requirements (328-IAC-2-6)

Graph 4-1 Lehigh Cement Company Kilns NO_x and SO_2 Emissions



Graph 4-2 Lehigh Cement Company Kilns Throughput

4.2 Lone Star Industries, Inc. dba Buzzi Unicem USA

At the Greencastle plant, Lone Star Industries operates one semi-dry kiln. This cement kiln type is unique in its design and operation and is one of only two semi-dry kilns in operation in the United States. Like a traditional long wet cement kiln, raw materials are ground and blended with water to form a slurry for feed to the kiln. However, unlike a traditional wet plant, in a semi-dry process like Greencastle's, the slurry is injected into a crusher/drier that flashes off the water content of the slurry and renders a dried material that is then transported to a preheater/precalciner. Typical oxygen levels and temperatures for various locations in the process are provided in Table 4-3.

Table 4-3 Lone Star Kiln Operations Design Parameters

Location	Oxygen (%)	Temperature (ºF)
Calciner Outlet/ First Stage Inlet	Not Measured	1550-1650
First Stage Outlet/ Crusher-Dryer Inlet	Not Measured	1600-1700
Crusher-Dryer Outlet	3-4	400-500

The pre-heater/pre-calciner Portland cement kiln was originally constructed in 1966 and modified to the semi-dry system in 2000. The semi-dry kiln system includes a calciner tower with staged combustion and a rotary kiln with a combined nominal rated clinker capacity of 208 tons per hour. The semi-dry kiln system, uses coal and the following supplemental fuels:

- Liquid and solid hazardous waste fuel at a maximum rate allowed by the NESHAP for Hazardous Waste Combustors, 40 CFR 63, Subpart EEE,
- plastic chips, carpet fibers, paper products, wood chips, chipped tires, toner, cosmetics, seed corn, and oil absorbent material including oil filter fluff,
- petroleum coke, and
- distillate fuel for burner startup activities,

4.2.1 NO_x Emissions and Controls at the Greencastle Plant

The largest contributor to overall NO_x emissions is thermal NO_x which results from high temperature combustion. To reduce NO_x emissions, the facility utilizes staged combustion and is equipped with multi-channel low-NO_x burners in both the kiln and calciner. Staged combustion is accomplished by introducing fuel into an expanded portion of the kiln riser duct. Since the kiln exit gas has a relatively low oxygen content available for combustion, a high temperature reducing zone is created in the riser duct. These conditions render less oxygen available for chemical reaction with the nitrogen present and the potential for NO_x formation is reduced as a result.

The Greencastle plant also uses liquid hazardous waste to provide a considerable portion of the heat requirement to produce clinker. The use of liquid hazardous waste fuel (LHWF) as a substitute for traditional fossil fuels in both the kiln and the calciner also has a substantial effect of lowering NO_x emissions, due to the water content of the LHWF. Water injection is a well-established mechanism for controlling thermal NO_x emissions. LHWF typically contains approximately up to 18% moisture. The LHWF is injected into both the kiln and calciner burner systems, where the inherent moisture has the effect of cooling the flame and reducing the formation of thermal NO_x. For cyclone boilers that generate high levels of thermal NO_x, reductions of 22% have been demonstrated and higher reductions are possible. Industry experience has shown up to a 50% control efficiency for water injection into the burning zone of a cement kiln.

4.2.2 SO_2 Emissions and Controls at the Greencastle Plant

The Greencastle kiln has no add-on control devices for the control of SO_2. However, there are mechanisms inherent to the cement manufacturing process, in particular the calcination processing in the production of clinker, which act to control SO_2 emissions. The calcination process in a cement kiln is designed to convert calcium carbonate ($CaCO_3$) into lime (CaO). This produces a lime-rich environment that is ideal for the scrubbing of any SO_2 present in the combustion gases by allowing the SO_2 to react to form $CaSO_3$ and $CaSO_4$ that, in turn are incorporated into the clinker. $CaSO_4$ is very stable as a solid, thus the majority of SO_2 formed from combustion in the kiln process exits the kiln in the clinker as $CaSO_4$ rather than in the exhaust gas as SO_2. An additional scrubbing mechanism occurs in the flash drier where hot gases from the top of the tower are used to flash dry the slurry in the crusher/dryer making calcium in the raw materials available to absorb SO_2, comparable to in-line raw mills which AP-42 indicates have absorption capabilities up to 95%. The overall effect of these inherent mechanisms in the Greencastle kiln system is evidenced by the low annual SO_2 emissions from the Greencastle plant.

4.2.3 NO_x and SO_2 Emissions Trends at the Greencastle Plant

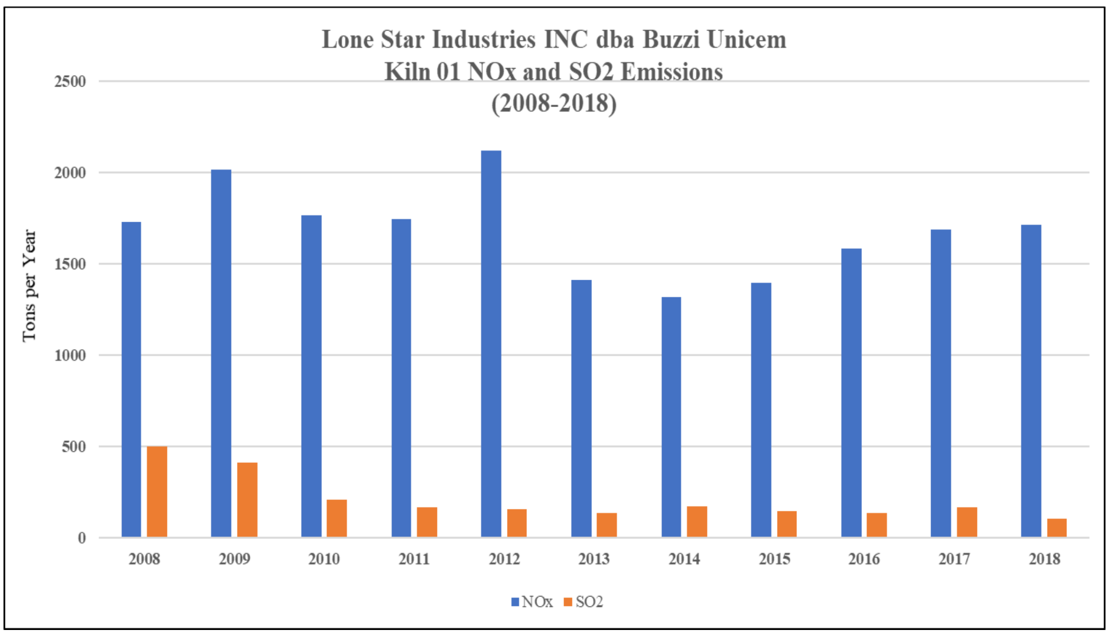
The bar graphs in 4-3 and 4-4 on pages 27 and 28, respectively, show the emissions and throughput trends for the Greencastle cement kiln over the 11-year period from 2008 to 2018. Reported annual NO_x and SO_2 emissions and throughputs for the Greencastle kiln are listed in Table 4-2 on page 24. The bar graphs in Graphs 4-3 and 4-4 were developed using the emissions and throughput information in Table 4-2.

NO_x and SO_2 emissions from the Greencastle kiln shown on the bar graph in Graph 4-3 mostly follow the same trend as the kiln's throughput in Graph 4-4. This indicates that NO_x and SO_2 emissions from the Greencastle kiln are influenced by clinker production. Since SO_2 emissions are primarily driven by the amount of sulfur in the kiln feed, emissions correlate to the amount of kiln feed used.

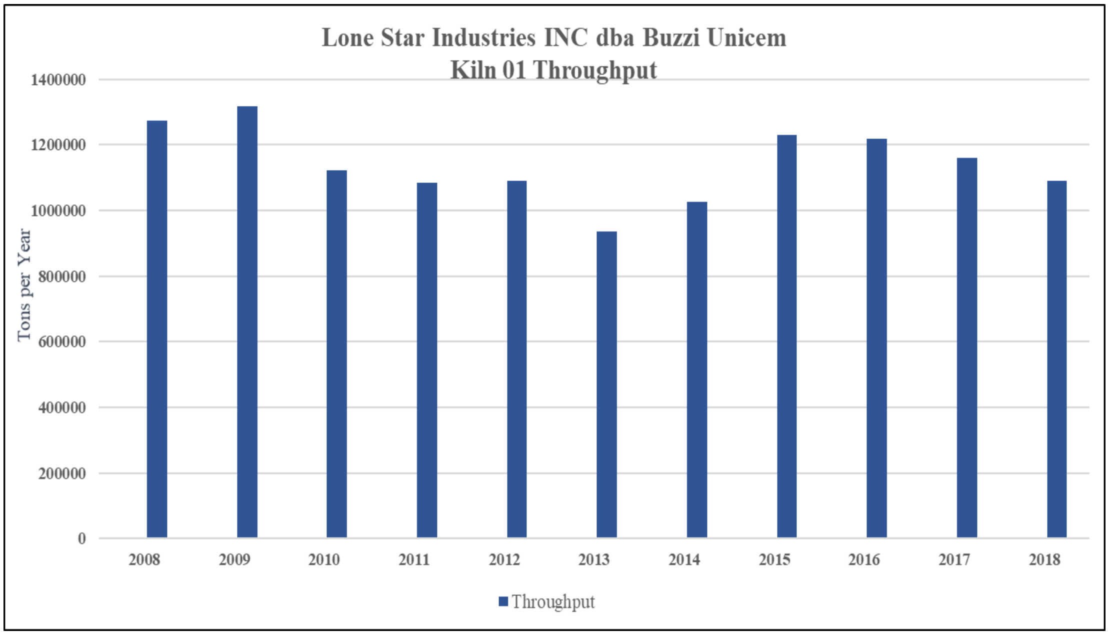
The SO_2 bar graph shows that SO_2 emissions from the Greencastle kiln are low throughout the entire 11-year period. This is likely due to the low sulfur in the raw materials as well as the inherent scrubbing effect of the crusher/dryer. NO_x emissions tend to correspond to changes in production since cement kiln NO_x emissions are predominantly thermal NO_x formation from the combustion of fuel.

The Greencastle kiln units are subject to the Standards of Performance for Portland Cement Plants, 40 CFR 60, Subpart F for facilities that commenced construction or modification after August 17, 1971, but on or before June 16, 2008. However, the NO_x and SO_2 emission limitations in Subpart F apply to kiln units constructed or modified after 2008. Therefore, the anomalies shown in the NO_x and SO_2 emissions trends cannot be attributed to the NESHAPs or NSPS for Portland cement plants.

Graph 4-3 Lone Star Industries Kiln NO_x and SO_2 Emissions



Graph 4-4 Lone Star Industries Kiln Kilns Throughput



5.0 SELECTED SOURCES FOUR-FACTOR ANALYSES

5.1 Mitchell Plant Four Factor Analysis for Chosen NO_x and SO_2 BART

On June 27, 2019, the Lehigh Cement Company was issued a Title V Significant Source Modification permit to construct a new pyroprocessing system consisting of one five stage preheater, calciner, rotary kiln. Fuels to be used in the pyroprocessing consist of coal, coke, natural gas, fuel oil, and non-hazardous alternative fuels (e.g., chipped and whole tires, engineered fuels, and dried biosolids). The preheater design includes multiple cyclone preheater vessels in which hot exhaust gases from the rotary kiln pass upward through the downward-moving raw materials in the preheater vessels. The first fuel introduction points are within the calciner/loop duct/kiln riser duct area, which is designed to create a combustion atmosphere that reduces NO_x emissions from the kiln. SNCR will also be utilized to further control NO_x emissions from the pyroprocessing system. SNCR will inject aqueous ammonia in various areas of the kiln riser duct, calciner and loop duct to control NO_x emissions.

Calcined material from the preheater and calciner will enter the kiln where the kiln exhaust gases exit the kiln. As the calcined material migrates through the kiln, its temperature will rise and result in additional chemical reactions until clinker is formed near the discharge end of the kiln. The kiln burner or second fuel source will be located at the clinker discharge end of the kiln. The kiln burner will be the heat source for increasing the temperature of the calcined material and its transformation into clinker.

The preheater exhaust gases will exit the top stage of the preheater and will be cooled and used to supply drying heat in the raw mill or be vented to the main dust collector. In addition to the inherent scrubbing achieved when raw feed interacts with kiln exhaust gases in the inline raw mill, the future system will be equipped with a DSI system in order to control SO_2 emissions. A dry sorbent will be introduced prior to the main dust collector. The sorbent will be metered from the storage bin and delivered to the injection point by a pneumatic system.

SNCR reduces NO_x emissions to elemental nitrogen, N_2, by injecting a nitrogen containing compound, such as ammonia or urea, into the exhaust gas. SNCR reactions occur at a high temperature, which exists in a cement kiln. The optimum range is between 800 and 1000 °C, which can be achieved by most kilns due to the high temperatures necessary to cause calcination. The temperature of the exhaust gas of a preheater/precalciner kiln system is appropriate for SNCR use. The reaction also requires proper retention time and gas mixing within this temperature range for the reduction to take place. SNCR is a proven technology in the US, with a large fraction of the plants using SNCR.

Based on the fact that the Lehigh Cement Company has begun construction and the new kiln will replace the three existing kilns, IDEM does not believe that a four-factor analysis for the Mitchell plant adds value to the cement kiln four-factor analysis and, therefore, is not necessary. The chosen NO_x and SO_2 reasonable level of controls for the cement kiln source category are planned for the new cement kiln units at Mitchell. The new kiln units will be subject to the new NSPS for Portland cement plants. Therefore, the NO_x and SO_2 and emission limitations listed in Table 4-4 below are applicable to the kiln units.

Table 4-4 New Source Performance Standards NO_x and SO_2 Emission Limits

Pollutant	Emission Limit	Averaging Period
NO_x	1.5 lbs/ton clinker	averaged over 30 days
SO_2	0.4 lbs/ton clinker	averaged over 30 days

5.2 Greencastle Plant Four-Factor Analysis for Chosen NO_x and SO_2 BART

5.2.1 Cost of Compliance for Chosen NO_x and SO_2 BART

IDEM relied on a cost estimate provided by Lehigh Cement to develop the cost effectiveness analysis in Appendix D. The estimate was based on three cost estimates Lehigh shared when it was considering NO_x and SO_2 retrofit options for its three existing cement kilns. A 2018 estimate to retrofit the existing kilns (the estimated costs are for one kiln) at the Mitchell plant with SNCR systems for NO_x control, a 2016 estimate to retrofit the existing kilns (the estimated costs are for one kiln) with DSI systems for SO_2 control, and a 2019 estimate to install the new kiln with SNCR and DSI were used to estimate the costs to retrofit the kiln at Lone Star Industries with SNCR and DSI systems.

The estimated capital costs to retrofit the Greencastle kiln with SNCR and DSI systems were carved out of the estimate to install the new kiln with SNCR and DSI systems at the Mitchell plant. The direct and indirect capital costs to retrofit an existing kiln with SNCR and DSI systems are conservative estimates that are not specific to the Greencastle plant kiln, however the estimated capital costs offer a base to build upon. A 2018 proposed estimate to construct a SCR system for SO_2 control in Appendix E was included in Mitchell's Title V PSD Significant Source

Modification permit (SSM permit #093-40198-00002) to construct the new kiln submitted on June 27, 2019. The capital recovery factor found in the SCR cost estimate was used to calculate the total annualized capital costs for the SNCR and DSI systems in the cost estimate for the cost effectiveness analysis.

The list of line items in the SCR estimate were used to develop the line-item list of direct and indirect operations and maintenance costs to retrofit the Greencastle cement kiln with SNCR and DSI. The 2016 DSI cost estimate, the 2018 SNCR cost estimate, and the 2018 SCR cost estimate were all used to estimate the operations and maintenance cost items in the Greencastle estimate for the cost effectiveness analysis.

The estimated total annualized capital costs to install each retrofit system plus the estimated total annual operations and maintenance costs to operate each retrofit system for the Greencastle cement kiln were used to calculate the total annual costs, which were, in turn, were used to calculate the cost effectiveness for both systems. IDEM went with conservative control efficiencies for the SNCR (40%) and DSI (45%), as compared to the control efficiency ranges for each device in Table 3-1 on page 5 and Table 3-3 on page 13. The cost effectiveness per ton of pollutant removed analysis resulted in a cost of $873 per ton for a SNCR retrofit and $8,142 per ton for a DSI retrofit as shown in Appendix D. These results are in line with the cost effectiveness results in Table 3-2 on page 10 and Table 3-4 on page 17.

In spite of the fact that there were no vendor estimates obtained specifically for the Greencastle kiln, IDEM believes that the cost estimates that Lehigh provided are a better source of information than an estimate that Greencastle could obtain for hypothetical SNCR and DSI retrofit installations. These estimates may be flawed, due to the fact that vendors may not put as much work into developing cost estimates for installations that are not likely to take place as they would for installations that are likely to take place.

5.2.2 Time Necessary for Chosen NO_x and SO_2 BART Compliance

The time necessary to install the SNCR and DSI systems is 2 to 3 years for each system depending on a number of variables, such as, time for engineering, construction, and facility preparedness.

5.2.3 Energy and Non-Air Impacts of Chosen NO_x and SO_2 BART

More energy will be consumed by SNCR when the optimum temperature ranges after combustion are not met. DSI consumes more energy when the injection process increases particulate matter in the exhaust gas which causes pressure drops across the PM control devices causing the baghouse filter cake to become saturated with moisture and plug both the filters and the dust removal system. Lone Star does not currently have a bag filter for PM control on the kiln. However, this may become a factor if a bag filter is necessary as a result of installing DSI. For some technologies, a flue gas reheater may be essential to the system thus increasing energy use, also. In addition, the excess particulate collected by PM control devices will need to be disposed of, which increases the facility’s solid waste management burdens. Non-air environmental impacts will include solid, liquid, and/or hazardous waste generation and deposition of atmospheric pollutants on land or water.

5.2.4 Remaining Useful Life for Chosen NO_x and SO_2 BART

The SNCR and DSI systems evaluated in the cost effectiveness analysis was based on a 15-year life for each control system. Since the Greencastle cement kiln was modified in 2000, the cement kiln units are considered 20 years old, however due to the kilns actual age, it is assumed for the purpose of this evaluation that the remaining useful life of the cement kiln is 15 years.

5.3 Visibility Analysis for Four-Factor Analysis Selected Sources

The visibility analyses for the chosen NO_x and SO_2 BART is not included in this cement kiln four-factor analysis. IDEM is still waiting for modeling results, however the visibility analyses will be conducted when the modeling information is available. Since this analysis could not be completed for the cement kiln four-factor analysis, it will be used in the next step of the RH SIP development process, "Decisions on What Control Measures are Necessary to Make Reasonable Progress," outlined in the EPA RH SIP guidance document.

REFERENCES

Colorado Air Pollution Control Division (APCD). *Reciprocating Internal Combustion Engine (RICE) Source Category: NOx Emission 4-Factor Analysis for Reasonable Progress (RP).* November 20, 2014.

Institute of Clean Air Companies. *Typical Installation Timelines for NOx Emissions Control Technologies on Industrial Sources.* December 4, 2006.

Northeast Texas Air Care (NETAC). *A Pilot Project to Assess the Effectiveness of an Emission Control System for Gas Compressor Engines in Northeast Texas.* November 4, 2005.

U.S. Environmental Protection Agency. *Compilation of Air Pollutant Emission Factors. "Chapter 3.2: Natural Gas-Fired Reciprocating Engines.* August 2000.

Western Regional Air Partnership (WRAP) and Western Governors' Association (WGA). *Supplementary Information for Four Factor Analyses by WRAP States*. May 4, 2009.

Appendix A

Cement Kiln Flow Diagram

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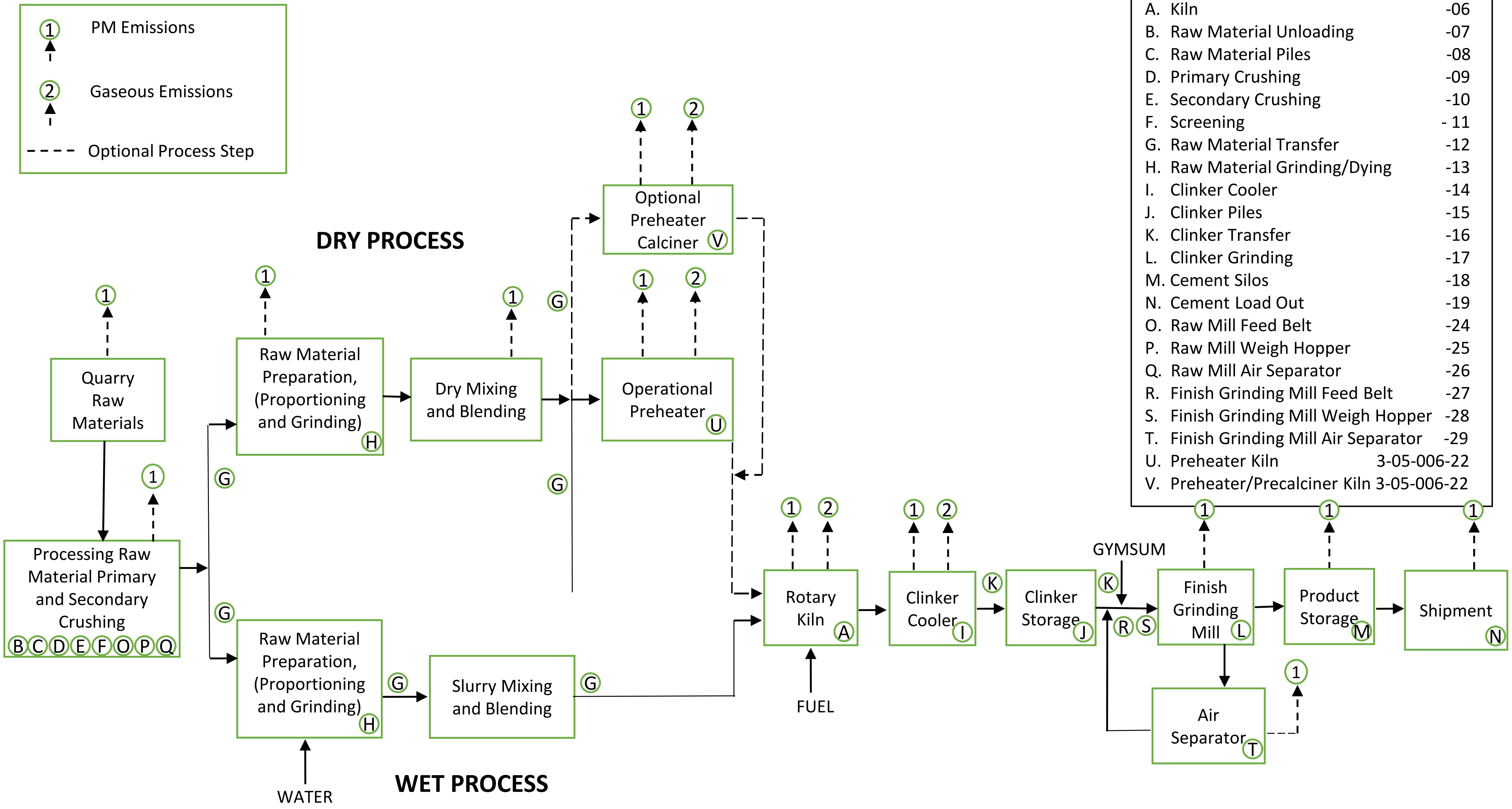

EMISSION SOURCE	SCC
Dry Process-General	3-05-006-
Wet Process-General	3-05-007-
A. Kiln	-06
B. Raw Material Unloading	-07
C. Raw Material Piles	-08
D. Primary Crushing	-09
E. Secondary Crushing	-10
F. Screening	- 11
G. Raw Material Transfer	-12
H. Raw Material Grinding/Dying	-13
I. Clinker Cooler	-14
J. Clinker Piles	-15
K. Clinker Transfer	-16
L. Clinker Grinding	-17
M. Cement Silos	-18
N. Cement Load Out	-19
O. Raw Mill Feed Belt	-24
P. Raw Mill Weigh Hopper	-25
Q. Raw Mill Air Separator	-26
R. Finish Grinding Mill Feed Belt	-27
S. Finish Grinding Mill Weigh Hopper	-28
T. Finish Grinding Mill Air Separator	-29
U. Preheater Kiln	3-05-006-22
V. Preheater/Precalciner Kiln	3-05-006-22

Appendix A - Portland Cement Process Flow Diagram

(Taken from AP-42)

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Appendix B

LADCO 2015 Reference Information

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LADCO's Four-Factor Analysis for Regional Haze in the Northern Midwest Class I Areas
Reference Summary for Cement Kiln Sector
Table 5-1 NO_x Control Options and Table 5-2 SO_2 Control Options for Cement and Lime Manufacturing Kilns

Reference Item	Document	Year Published	Control Measure	Emission Source	Control Measure	Control Driver	Assumed Control Efficiency	
							NO_x	SO_2
Reference 1	LADCO White Paper	2005		Portland Cement Sector		NOx SIP Call	50% NOx reduction	90% SO_2 Reduction
Reference 2	BART Determination	2009 - Revised 2011	Flex Fuels Project and SNCR	Transalta Centralia Generation LLC Power Plant	Flex Fuels Project and SNCR	BART	SNCR - 20%-40%, SCR - up to 95% reduction	SNCR - 20%-40%, SCR - up to 95% Reduction
Reference 3	Supplementary Information for Four Factor Analyses by WRAP States	2009 - Revised 2010						
Reference 4	Control Technology Analysis	2008		Carolinas Cement Company LLC				
Reference 5	National Emission Standards for Hazardous Air Pollutants From the Portland Cement Manufacturing Industry and Standards of Performance for Portland Cement Plants; Final Rule	12/1/2013		Jacksonville Lime LLC	Inherent scrubbing of burning zone exhaust gases by hot lime and of kiln exhaust gases by incoming limestone to reduce SO2 and SAM;	BACT		
Reference 6	Virginia DEQ - Engineering Evaluation of Prevention of Significant Deterioration Permit Application Submitted by Carmeuse Lime & Stone for its Winchester Facility (Registration No. 80504)	4/1/2014		Carmeuse Lime & Stone for its Winchester Facility (Registration No. 80504)	BACT for SO_2 for this project is the inherent scrubbing of SO_2 that will occur within the kilns, which is expected to remove approximately 95% of the SO2	BACT	Carmeuse identified seven control mechanisms or technologies to reduce SO_2 emissions from the proposed kilns: 1. Inherent Dry Scrubbing (95% - base case) 2. Wet Scrubbing (98%) 3. Semi-Wet Scrubbing (Spray Dry Absorber) (90%) 4. Dry Sorbent Injection (DSI) (90%) 5. Lower Sulfur Fuels (varies) 6. Increased Oxygen 7. Catalytic Ceramic Filter Media (CCFM)	

LADCO's Four-Factor Analysis for Regional Haze in the Northern Midwest Class I Areas

Nitrogen Oxide and Sulfur Dioxide Control Technology Information for Cement Kiln Sector

Source Type	Control Technology	Pollutant Controlled	Baseline Emissions	Estimated Control Efficiency (%)	Potential Emissions Reduction (tons/year)	References
Long Wet Kiln	Low NO_x Burners	NOx	8,628	20-30	1,725-2,588	1, 6
	Mid-kiln Firing	NOx	8,628	20-50	1,725-4,313	1, 6
	SCR with Ammonia	NOx	8,628	80-90	6,902-7,764	5, 6
	Urea	NOx	8,628	30-70	2,588-6,039	6
	Biosolid Injection	NOx	8,628	50	4,313	7
	CemStar^{TM} Process	NOx	8,628	20-60	1,725-5,176	1, 3, 7
	LoTOx^{TM}	NOx	8,628	80-90	6,902-7,765	1, 5
	Absorbent Addition	SO_2	1917	60-80	1,150-1,533	
	Wet FDG	SO_2	1917	90-99	1,725-1,897	1
Long Dry Kiln	Low NOx Burners	NOx	19541	40	7,816	1, 6
	Mid-kiln Firing	NOx	19541	11-55	2,149-10,747	1, 6
	SCR with Ammonia	NOx	19541	80-90	1,563-1,758	6
	Biosolid Injection	NOx	19541	50	9,770	7
	LoTOx^{TM}	NOx	19541	80-90	15,633-17,587	1, 5
	CemStarTM Process	NOx	19541	20-60	3,908-1,172	1, 3, 7
	Wet FGD	SO_2	2567	90-99	2,310-2,541	1
	Dry FGD	SO_2	2567	90-95	2,310-2,438	1
	Sorbent Injection	SO_2	2567	60-80	1,540-2,053	
Preheater Kiln	Low NOx Burners	NOx	3204	40	1,281	1, 6
	Mid-kiln Firing	NOx	3204	11-55	352-1,762	1, 6
	SCR with Ammonia	NOx	3204	85	2,723	5, 6
	SNCR with Urea	NOx	3204	35	1,121	5, 6
	SNCR with Ammonia	NOx	3204	35	1,121	5, 6
	LoTOx^{TM}	NOx	3204	80-90	2,563-2,884	1, 5
	CemStarTM Process	NOx	19541	Unknown	Unknown	1, 3, 7
	Biosolid Injection	NOx	3204	23-50	736-1,602	7, 9
	Wet FGD	SO_2	436	90-99	392-431	1
	Dry FGD	SO_2	436	90-95	392-414	1
	Sorbent Injection	SO_2	436	60-80	261-348	8
Precalciner Kiln	Low NOx Burners	NOx	3204	30-40	961-1,281	6
	Mid-kiln Firing	NOx	3204	11-55	352-1,762	1, 6
	SCR with Ammonia	NOx	3204	85	2,723	5, 6
	SNCR with Urea	NOx	3204	35	1,121	5, 6
	SNCR with Ammonia	NOx	3204	35	1,121	5, 6
	LoTOx^{TM}	NOx	3204	80-90	2,563-2,884	1, 5
	CemStarTM Process	NOx	19541	Unknown	Unknown	1, 3, 7
	Biosolid Injection	NOx	3204	50	1602	7
	Wet FGD	SO_2	436	90-99	392-431	1
	Dry FGD	SO_2	436	90-95	392-414	1
	Sorbent Injection	SO_2	436	60-80	261-348	8

Table 7-3 Estimated Cost of Control for Cement Kilns

Source Type	Control Technology	Pollutant Controlled (ton clinker)	Estimated Control Efficiency (%)	Estimated Capital Cost ($1000/Unit)	Estimated Annual Capital Cost ($/yr/unit)	Units	Cost Effectiveness ($/ton)	References
Long Wet Kiln	Low NOx Burners (indirect fired)	NOx	20-47	401-564	100,000-144,000	ton clinker	270-620	1, 6, 7
	Low NO_x Burners (direct fired)	NOx	20-47	1,910	376,000-343,500	ton clinker	855-1,005	1, 6, 7
	Mid-kiln Firing	NOx	20-50	613-3205	183,500-(192,300)	ton clinker	(460)-730	1, 6, 7, 8
	SCR with Ammonia	NOx	80-90	15,100	5780-4,105,000	ton clinker	3,370	5, 6, 7
	LoTOx™	NOx	80-90	Not Available			3,155-3,891[c]	5
	CemStar™ Process	NOx	20-60	1,176	220,000	ton clinker	550	7
	Dry ESP	PM_{10}, $PM_{2.5}$, OC, EC	95-98	Not Available			40-250	9
	Fabric Filter	PM_{10}, $PM_{2.5}$, OC, EC	80-99	Not Available			117-148	9
	Wet FGD	SO_2	90-99	Not Available			2,211-6,917	1, 8
Long Dry Kiln	Low NOx Burners (indirect fired)	NOx	30-40	334-509	83,000-135,500	ton clinker	300 (3)-620	1, 6, 7
	Low NO_x Burners (direct fired)	NOx	40	1,455	298,000-272,500	ton clinker	166-1,299	1, 6, 7
	Mid-kiln Firing	NOx	11-55	455-3,180	89,830-144,000	ton clinker	(460)-730	1, 6, 7, 8
	LoTOx™	NOx	80-90	Not Available				5
	CemStar™ Process	NOx	20-60	Not Available				7
	SCR with Ammonia	NOx	80-90	11,485	3,000,000	ton clinker	586-3,400	6, 7, 8
	Dry ESP	PM_{10}, $PM_{2.5}$, OC, EC	95-98	Not Available			40-250	9
	Fabric Filter	PM_{10}, $PM_{2.5}$, OC, EC	80-99	Not Available			117-148	9
	Wet FGD	SO_2	90-99	5,610-84,000	10,000-30,571	ton clinker	2,000-4,000	1, 8
	Dry FGD	SO_2	90-95	3,300-95,800	9,142-32,286	ton clinker	1,900-7,000	1
Preheater Kiln	Low NOx Burners (indirect fired)	NOx	30-40	379-608	94,500-150,000	ton clinker	300-620	1, 6, 7
	Low NO_x Burners (direct fired)	NOx	40	1,765-1,800	351,500-330,000	ton clinker	175-1,201	1, 6, 7
	CemStar™ Process	NOx	20-60	Not Available				
	SCR with Ammonia	NOx	85	14,400	3,850,000	ton clinker	500-3,805	5, 6, 7, 8
	SNCR with Urea	NOx	35	799	546,500	ton clinker	(310)-2,500	5, 6, 8
	SNCR with Ammonia	NOx	35	1595	635,500	ton clinker	(310)-2,500	5, 6, 8
	LoTOx™	NOx	80-90	Not Available				5
	Biosolids Injection	NOx	50	1,200	(322,000)	ton clinker	(310)	7
	Dry ESP	PM_{10}, $PM_{2.5}$, OC, EC	95-98	0.013	Not Available	cfm	40-250	9
	Fabric Filter	PM_{10}, $PM_{2.5}$, OC, EC	99	0.029	Not Available	cfm	117-148	9
	Wet FGD	SO_2	90-99	3,710-54,000	2,714-15,857	ton clinker	2,000-64,600	1, 8
	Dry FGD	SO_2	90-95	2,100-61,400	2,857-17,571	ton clinker	72,800	1
	Sorbent Injection	SO_2	60-80	Not Available			2,031-7,379	8
	Low NOx Burners (indirect fired)	NOx	30	406-863	101,000-188,500	ton clinker	245-620	6, 7
	Low NO_x Burners (direct fired)	NOx	30	1,945-2,235	382,500-393,500	ton clinker	920-985	6, 7
	CemStar™ Process	NOx	20-60	Not Availablea				
	LoTOx™	NOx	80-90	Not Available[a]			2,412-2,734	5
	SCR with Ammonia	NOx	85	21,950	6,240,000	ton clinker	4,635	5, 6, 7
	SNCR with Urea	NOx	35	1,105	709,000	ton clinker	(310)-2,500	5, 6, 8

Recalciner Kiln	SNCR with Ammonia	NOx	35	1,880	779,500	ton clinker	(310)-2,500	5, 6, 8
	Biosolids Injection	NOx	23-50	5,581	1,498	ton clinker	(310)	7, 8
	Dry ESP	PM_{10}, $PM_{2.5}$, OC, EC	99	0.013	Not Available	cfm	40-250	9
	Fabric Filter	PM_{10}, $PM_{2.5}$, OC, EC	99	0.029	Not Available	cfm	117-148	9
	Sorbent Injection	SO_2	60-80	Not Available[a]			2,031-7,379	8
	Wet FGD	SO_2	90-99	3,710-54,000	2,714-15,857	ton clinker	2,211-6,917	8

LADCO's Four-Factor Analysis for Regional Haze in the Northern

TABLE 9. RANKING OF TECHNICALLY FEASIBLE CONTROL OPTIONS PREHEATER/PRECALCINER KILN SYSTEMS - NOx

Control Technology	Control Efficiency	Notes
SCR (clean side)	60%	1.65 lb/ton clicker
SNCR	30%	1.95 lb/ton clinker
Indirect firing, low-NOx main burner, SCR	NA	Base Case = 2.8 lb/ton clinker

TABLE 10. SUMMARY IMPACT ANALYSIS FOR NO_X

Method	% Removal	NOx Removed tons/yr	Capital Cost	Annualized Cost MMS	Cost Effectiveness $/ton NO_x	Impacts		
						Environmental	Product	Energy
SNCR	30	931	2.71	2.04	2,191	Yes	No	No
SCR	60	1,840	4.6	29.7	16,139	Yes	No	Yes

LADCO's Four-Factor Analysis for Regional Haze in the Northern Midwest Class I Areas

TABLE 11. SUMMARY OF RECENT NO_X PERMIT DETERMINATION FOR CEMENT KILNS (2000-PRESENT)

Company	Location	Kiln Type	Permit Date	Technology Applied and $/Ton	Removal (%)	In Operation (Yes/No)	Limit (lb/ton clinker)	Rejected Technology and $/Ton
Drake Cement	Drake, AZ	PC (new)	Draft	Lo NOx, MSC, SNCR	NA	No	2.3 first 6 months, 1,95 thereafter[2] (1.2 beyond BACT)	
LaFarge - Kiln #1	Harleyville, SC	PC (mod)	8/18/06	Lo NOx, MSC, SNCR	29% (SNCR)	Yes	2.65[2] (3.5 for 1st year)	
LaFarge - Kiln #2	Harleyville, SC	PC (new)	8/18/06	Lo NOx, MSC, SNCR	29% (SNCR)	No	1.95[2] (3.0 for 1st year)	
Suwannee American Cement - Kiln 2	Branford, FL	PC (new)	2/15/06	Lo NOx, MSC, SNCR	20% (SNCR)	No	1.95[2] 2.4 for 1st 6 months	SCR - $12,600
Sumter Cement	Sumter Co., FL	PC (new)	2/6/06	Lo NOx, MSC, SNCR		No	1.95[2] (3.0 for 1st year)	SCR - $10,200
American Cement	Sumter Co., FL	PC (new)	2/06	Lo NOx, MSC, SNCR		No	1.95[2] (3.0 for 1st year)	
Florida Rock Industries - Kiln 2	Newberry, FL	PC (new)	7/22/02	Lo NOx, MSC, SNCR		No	1.95[2] 2.4 for 1st 6 months	SCR
Rinker/Florida Crushed Stone - Kiln 2	Brookville, FL	PC (new)	7/6/05	Lo NOx, MSC, SNCR	28% (SNCR)	No	1.95[2] 2.4 for 1st 6 months	SCR - #16,712
Holcim	Lee Island, MO	PC (new)	6/08/04	Lo NOx, MSC[1]	30	No	3.00 (year 1 &2) 2.80 (after year 2)	SCR
GCC Rio Grande	Pueblo, CO	PC (mod)	3/5/04	Lo NOx, MSC	NA	Yes	2.32	
Lehigh Portland Cement	Mason City, IA	PC (mod)	12/11/03	Lo NOx, SNCR	NA	Yes	2.85	
GCC Dacotah	Rapid City, SD	PC (mod)	04/10/03	Lo NOx, MSC	NA	Yes	5.52 (not BACT)	FGR, MKF, Lo NO_x, TDF, SCR, SNCR
Holcim	Theodore, AL	PC (mod)	2/04/03	Limit not based on BACT	NA	Yes	3.33 (not BACT)	
Holcim (Devil's Slide)	Morgan, UT	PC (mod)	11/20/02	Lo NOx, MSC	NA	Yes	4.55 (not BACT)	FGR, Lo NO_x, staged combustion, SNCR, SCR
Suwannee American Cement - Kiln 1	Branford, FL	PC (mod)	4/01	MSC, SNCR	NA	Yes	2.9 - 24 h 2.4[2]	
Monarch Cement	Humboldt, KS	PC (mod)	1/27/00	Good combustion practices	NA	Yes	4.21	FGR, Lo NO_x, staged combustion, SNCR, SCR
Holcim	Holly Hill, SC	PC (mod)	12/22/99	Lo NOx, MSC	NA	Yes	4.33	
Lafarge	Davenport, IA	PC (mod)	11/9/99			Yes	4.00	
North Texas Cement	Whitwright, TX	PC (new)	3/4/99	Lo NOx, MSC	NA	No	3.87	SNCR

Notes:

1. SNCR is required as Innovative Control Technology after 2 years - 1.8 lb/ton summer season limit
2. Rolling 30 day average.

LADCO's Four-Factor Analysis for Regional Haze in the Northern

TABLE 6. RANKING OF TECHNICALLY FEASIBLE CONTROL OPTIONS PREHEATER/PRECALCINER KILN SYSTEMS - NOx

Control Technology	Control Efficiency[1]
Wet Scrubbing System (Post-baghouse)	75%
DAA (Preheater Gases)	20%
DAA (Preheater Gases, mill off only)	50%
Inherent Dry Scrubbing (Base Case)	NA

[1]The optimum control efficiency listed is at the control point only; this is in addition to the control provided by inherent dry scrubbing.

TABLE 7. SUMMARY IMPACT ANALYSIS FOR NO_X

Method	System Removal %	SO_2 Removed tons/yr	Capital Costs, 1000$	Annualized Cost	Cost Effectiveness $/ton SO_2	Impacts		
						Environmental	Product	Energy
Wet Scrubbing[1]	75	813	26.9	11,341	13,949	Yes	No	Yes
Dry Absorbent[2]	18	197	2.02	2,008	10,171	No	No	No
Wet Absorbent[3]	8.4	91	3.14	756	8,327	No	No	No

[1]System removal is lower than in Table 6 because coal mill gases are not controlled by wet scrubber.

[2] System removal is lower than in Table 6 because coal mill gases are not controlled by DAA.

[3]System removal is lower than in Table 6 because coal mill gases are not controlled by WAA and control system operates during mill-off periods only.

LADCO's Four-Factor Analysis for Regional Haze in the Northern Midwest Class I Areas

TABLE 8. SUMMARY OF RECENT SO_2 PERMIT DETERMINATION FOR CEMENT KILNS (2000-PRESENT)

Company	Location	Kiln Type	Permit Date	Technology Applied and $/Ton	Removal (%)	In Operation (Yes/No)	Limit (lb/ton clinker)	Rejected Technology and $/Ton
LaFarge - Kiln #1	Harleyville, SC	PC (mod)	8/18/06	Process (inherent dry scrubbing)	94	Yes	0.90-30 day 1.6-24 h	WS-$27,300 DAA-8,480 WAA-42,600
LaFarge - Kiln #2	Harleyville, SC	PC (new)	8/18/06	Process (inherent dry scrubbing)	94	No	0.90-30 day 1.6-24 h	WS-$25,900 DAA-7,340 WAA 33,400
Suwannee American Cement - Kiln 2	Branford, FL	PC (new)	2/15/06	Process & hydrated lime injection for mill off	4	No	0.27-24 h	WS-$86,900 DAA-7,271
Sumter Cement	Sumter Co., FL	PC (new)	2/6/06	Low sulfur materials		No	0.20-24 h	
American Cement	Sumter Co., FL	PC (new)	2/06	Low sulfur materials		No	0.20-24 h	WS
Florida Rock Industries - Kiln 2	Newberry, FL	PC (new)	7/22/02	Process (inherent dry scrubbing)	NA	No	0.28-24 h	WS-$20,453
Rinker/Florida Crushed Stone - Kiln 2	Brookville, FL	PC (new)	7/6/05	Process (inherent dry scrubbing)	NA	No	0.23-24 h	
Holcim	Lee Island, MO	PC (new)	6/08/04	Lime spray drying - mill off	93	No	1.26	WS-$13,225
GCC Rio Grande	Pueblo, CO	PC (new)	3/5/04	Process; low sulfur coal	NA	No	1.99	
Lehigh Portland Cement	Mason City, IA	PC (mod)	12/11/03	Wet Scrubbing	90	Yes	1.01	
GCC Dakota	Rapid City, SD	PC (mod)	04/10/03	Process (inherent dry scrubbing)	NA	Yes	2.16	Fuel or raw mix S limits
Holcim	Theodore, AL	PC (mod)	2/04/03	Limit not based on BACT	NA	Yes	0.13	
CEMEX	Demopolis, AL	PC (mod)	9/13/02	Low sulfur coal	NA	Yes	1.14	WS-$10,327
Suwannee American Cement - Kiln 1	Branford, FL	PC (mod)	6/01/00	Process (inherent dry scrubbing)	NA	Yes	0.27-24 h	WS-$29,700 DAA-$7,400
Monarch Cement	Humboldt, KS	PC (mod)	1/27/00	Process (inherent dry scrubbing)	NA	Yes	1.10	WS-$10,345 Lo S fuel, WAA, DAA
Lafarge	Davenport, IA	PC (mod)	11/09/99	Process (inherent dry scrubbing)	NA	Yes	7.62	
North Texas Cement	Whitewright, TX	PC (new)	3/4/99	Wet Scrubbing	85	No	2.75	

Notes:

2. May never be built

PC = Recalcine NA = Not applicable WS = Wet Scrubber S = Sulfur

DAA - Dry absorbent addition (preheater gases, mill-off only) WAA - Wet absorbent addition (Preheater gases only)

Appendix C

Region 8 Cement Kiln BART Analyses

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Company	State	BART Unit	Kiln Type	Fuel	NOx Controls	SNCR Reduction %	NOx Limit (lb/ton clinker)	SNCR Cost		BART	Notes
								$/ton	$/dv		
Armstrong/Cabot	PA		long, wet process kiln								
Ash Grove Cement	MT		long, wet process kiln	coal	LNB+SNCR	41%	7.5	$ 2,058	$ 1,793,984	LNB + SNCR	
CEMEX	CO		preheater/precalciner		SNCR	48%		$ 1,934	$ 4,306,937	SNCR	
Cemex/Wampum	PA	Kiln #3	long, dry kiln		SNCR	35%		$ 1,014	$ 4,678,401	Seasonal NOx controls	
Essroc Cement	IN		long, wet process kiln	coal, coke, WDF	WDF		7.0				Enforced by 2011 Consent Decree
Essroc Cement	PA	Kiln #5	long, wet		SNCR	35%		$ 1,014	$ 7,494,026	Seasonal NOx controls	
GCC Dacotah	SD										
Holcim Cement	CO		preheater/precalciner		SNCR	45%		$ 2,293	$ 8,750,000	SNCR	
Keystone Cement	PA	Kiln #2	long, wet kiln		SNCR	35%		$ 1,014	$ 23,431,248	Seasonal NOx controls	Enforced by 2013 Consent Decree
Lafarge Corporation/Whitehall	PA	Kiln #2	dry preheater		SNCR	25%		$ 1,804	$ 27,177,065	Seasonal NOx controls	
Lafarge Corporation/Whitehall	PA	Kiln #3	dry preheater		SNCR	25%		$ 2,144	$ 24,336,753	Seasonal NOx controls	
LaFarge North America (cement)	MI	Kiln #19	long, dry process kilns		SNCR	35%		$ 731		SNCR	
LaFarge North America (cement)	MI	Kiln #20	long, dry process kilns		SNCR	35%		$ 731		SNCR	
LaFarge North America (cement)	MI	Kiln #21	long, dry process kilns		SNCR	35%		$ 731		SNCR	
LaFarge North America (cement)	MI	Kiln #22	long, dry process kilns		SNCR	40%		$ 498		SNCR	
LaFarge North America (cement)	MI	Kiln #23	long, dry process kilns		SNCR	40%		$ 498		SNCR	
LaFarge North America (cement)	OH	Kiln #1	long, wet process kiln	coal, coke, WDF	WDF		6.01				Enforced by 2010 Consent Decree
LaFarge North America (cement)	OH	Kiln #2	long, wet kiln	coal, coke, WDF	WDF		5.46				Enforced by 2010 Consent Decree
LaFarge North America (cement)	WA		wet process kiln		SNCR	40%		$ 4,190	$ 1,758,980	SNCR or mid-kiln firing of whole tires	
Lehigh Cement Company/Evansville	PA	Kiln #1	long dry preheater	natural gas, No. 2 fuel oil, tires, coal	process optimization	20%	3.49	$1,263	$ 14,515,575	process optimization including mid-kiln fuel [i.e., tire derived fuel (TDF)] injection, and secondary mixing air injection	BART for SO2 from Kiln Nos. 1 and 2 is identified as compliance with a 67.7 lb SO2/hr rolling 30-day limit
Lehigh Cement Company/Evansville	PA	Kiln #2	long dry preheater			20%	3.49	$1,263	$ 14,515,575		
Lehigh Cement/Waco	TX		long, wet process kiln	pet. Coke	LNB+WDF						
Lehigh Cement/York	PA		long, wet process kiln								
Lehigh Cement/York	PA		white cement		SNCR	35%		$ 1,505	$ 10,606,000	Seasonal NOx controls	
Oldcastle Cement	MT		long, wet kiln		SNCR	50%		$ 488	$ 919,376	SNCR	
Oldcastle Cement	MT		long, wet kiln		SNCR	40%		$ 3,257	$ 6,138,784	SNCR	
St. Mary's Cement	MI		preheater/precalciner		SNCR	50%		$ 983	$ 3,093,993	EPA SNCR	

Summary of SNCR Performance Data for Long Cement Kilns (EPA Region 8, 12/15/2016)								
Consent Decree	**Plant**	**Kiln #**	**Kiln Type**	**Baseline NO_x Rate (lb/ton)**	**Controlled NO_x Rate (lb/ton)**	**Final 30-day Rolling Ave Emission Limit (lb/ton)**	**Ammonia Molar Ratio During Demo**	**Percent Reduction**
Lafarge Consent Decree Demonstration[a]								
Lafarge	Alpena	19	Long Dry	6.62	3.65	4.72	1.0	45%
Lafarge	Paulding	2	Long Wet	7.36	4.70	5.46	0.75	36%
Lafarge	Paulding	1	Long Wet	7.12	5.02	6.01	1.0	29%
Lafarge	Alpena	21	Long Dry	5.08	3.52	4.48	1.0	31%
Lafarge	Alpena	22	Long Dry	8.53	4.75	5.47	1.0	44%
Lafarge	Alpena	23	Long Dry	8.96	4.73	5.69	1.0	47%
Ash Grove Consent Decree Demonstration[b]								
Ash Grove	Montana City	1	Long Wet	11.60	7.01	7.5[d]	0.7 -1.2	40%
Ash Grove Midlothian (from TCEQ Emission Data)[c]								
Ash Grove	Midlothian	1	Long Wet	4.9	1.8	3.6[f]	NA	63%
Ash Grove	Midlothian	2	Long Wet	4.4	2.7	3.6[f]	NA	39%
Ash Grove	Midlothian	3	Long Wet	4.5	2.7	3.6[f]	NA	40%
					Average Percent Reduction for All Long Kilns			41%

Notes:

(a) For the LaFarge kilns, the baseline NO_x rate is the mean for all days during the baseline period, while the controlled NO_x rate is the mean of all 30-day rolling averages during the demonstration period. This data was supplied by the EPA Office of Enforcement and Compliance Assurance (OECA).

(b) For the Ash Grove Montana City kiln, both the baseline and controlled NO_x rate are the mean for all days during those periods. This data was supplied by OECA.

(c) For the Ash Grove Midlothian kilns, the baseline NO_x rate is the mean for June through August 2006, while the controlled NO_x rate is the mean for June through August 2008. Refer to emissions data provided by TCEQ contained in docket ID EPA-R08-OAR-2011-0851-0226 (Montana Regional Haze FIP).

(d) The emission limit for Ash Grove Montana City is tentative.

(e) Molar ratio for NH_3:NO_x, where NOx is expressed on a NO_2 basis. Data supplied by OECA.

(f) The emission limits for the Ash Grove Midlothian kilns are taken from a settlement agreement between the company and the cities of Dallas and Arlington, Texas. These limits became effective in March of 2011.

Operating company		**Ash Grove Cement**	
Facility		**Montana City**	
State		**MT/EPA R-8**	
Contact			
Distance to nearest Class I Area (km)			
Baseline Visibility Impact (dv at Max Class I)		4.446	Gates of Mountains
# of Class I Areas evaluated	**12**		**of 12 within 300 km**
Baseline Visibility Impact (dv at Summed Class I)		8.217	
Long wet kiln			
Current Emissions (lb/ton clinker)		12.8	EPA pending FRN
Current Emissions (tpy)		1,891	EPA 4/20/2012 FRN
LNB Cost-effectiveness	**rejected by EPA**		
Control effectiveness		15%	EPA 4/20/2012 FRN
New Emision Rate (tpy)		1,607	EPA 4/20/2012 FRN
Reductions (tpy)		284	EPA 4/20/2012 FRN
Capital Cost	$	266,309	EPA 4/20/2012 FRN
O&M Cost	$	92,988	EPA 4/20/2012 FRN
Capital Recovery Factor		0.0944	EPA 4/20/2012 FRN
Total Annual Cost	$	158,630	EPA 4/20/2012 FRN
Cost-Effectiveness ($/ton)	$	559	EPA 4/20/2012 FRN
Visibility analyses			
Visibility Impact before BART (dv at Max Class I)		4.446	EPA 4/20/2012 FRN
Visibility Impact after BART (dv at Max Class I)		4.087	calculated from EPA report
Visibility Improvement (dv at Max Class I)		0.359	EPA 4/20/2012 FRN
Cost-Effectiveness ($/98th % dv at Max Class I)	$	1,211	calculated
Pollutant Control Effectiveness (dv/ton)		0.00126	calculated
Visibility Impact before BART (dv at Summed Class I)		8.217	calculated
Visibility Impact after BART (dv at Summed Class I)		7.398	calculated
Visibility Improvement (dv at Summed Class I)		0.819	calculated
Cost-Effectiveness ($/98th % dv at Summed Class I)	$	531	calculated
Pollutant Control Effectiveness (dv/ton)		0.00288	calculated
SNCR Cost-effectiveness	**rejected by EPA**		
Control effectiveness		50%	EPA 4/20/2012 FRN
New Emision Rate (tpy)		945	EPA 4/20/2012 FRN
Reductions (tpy)		946	EPA 4/20/2012 FRN
Capital Cost	$	925,324	EPA 4/20/2012 FRN
O&M Cost	$	1,896,199	EPA 4/20/2012 FRN
Capital Recovery Factor		0.0944	EPA 4/20/2012 FRN
Total Annual Cost	$	2,080,262	EPA 4/20/2012 FRN
Cost-Effectiveness ($/ton)	$	2,199	EPA 4/20/2012 FRN
Visibility analyses			
Visibility Impact before BART (dv at Max Class I)		4.446	EPA 4/20/2012 FRN
Visibility Impact after BART (dv at Max Class I)		3.590	calculated from EPA report
Visibility Improvement (dv at Max Class I)		0.856	EPA 4/20/2012 FRN
Cost-Effectiveness ($/98th % dv at Max Class I)	$	6,658	calculated
Pollutant Control Effectiveness (dv/ton)		0.00090	calculated
Visibility Impact before BART (dv at Summed Class I)		8.217	calculated
Visibility Impact after BART (dv at Summed Class I)		6.300	calculated
Visibility Improvement (dv at Summed Class I)		1.917	calculated
Cost-Effectiveness ($/98th % dv at Summed Class I)	$	2,973	calculated
Pollutant Control Effectiveness (dv/ton)		0.00203	calculated
LNB+SNCR Cost-effectiveness	**approved by EPA**		
Control effectiveness		58%	EPA 4/20/2012 FRN
New Emision Rate (tpy)		803	EPA 4/20/2012 FRN
Reductions (tpy)		1,088	EPA 4/20/2012 FRN
Capital Cost	$	1,191,633	EPA 4/20/2012 FRN
O&M Cost	$	1,989,187	EPA 4/20/2012 FRN
Capital Recovery Factor		0.0944	EPA 4/20/2012 FRN
Total Annual Cost	$	2,238,892	EPA 4/20/2012 FRN
Cost-Effectiveness ($/ton)	$	2,058	EPA 4/20/2012 FRN
Visibility analyses			
Visibility Impact before BART (dv at Max Class I)		4.45	EPA R-8 report for Gates of the Mountains WA
Visibility Impact after BART (dv at Max Class I)		3.20	calculated from EPA report
Visibility Improvement (dv at Max Class I)		1.248	calculated from EPA report
Cost-Effectiveness ($/98th % dv at Max Class I)	$	4,915	calculated
Pollutant Control Effectiveness (dv/ton)		0.00115	calculated
Visibility Impact before BART (dv at Summed Class I)		8.217	calculated
Visibility Impact after BART (dv at Summed Class I)		5.446	calculated
Visibility Improvement (dv at Summed Class I)		2.771	calculated
Cost-Effectiveness ($/98th % dv at Summed Class I)	$	2,214	calculated
Pollutant Control Effectiveness (dv/ton)		0.00255	calculated
BART limit (lb/ton clinker)		**8.0**	**30-day rolling average**
Control effectiveness		38%	
Reductions (tpy)		709	
Proposed revised BART limit (lb/ton clinker)		**7.5**	**30-day rolling average**
Control effectiveness		41%	
Reductions (tpy)		783	

All costs are based upon Holcim's June 2007 BART submittal.

EPA 4/20/2012 FRN
When the control effectiveness on all three kilns (Ash Grove-Midlothian, TX) are averaged together, a 47.5% reduction was achieved. This is within the range of control effectiveness values that have been demonstrated at other kilns.
The concentration of baseline NOX emissions is one parameter affecting the effectiveness of SNCR. The percentage of control effectiveness is greater when initial NOX concentrations are greater.
The reaction kinetics decrease as the concentration of reactants decreases.
This is due to thermodynamic considerations that limit the reduction process at low NOX concentrations.
The baseline NOX emissions of the Ash Grove Montana City kiln are significantly higher than those at Midlothian, indicating that SNCR on the Montana City kiln would be expected to achieve even greater control effectiveness when compared to SNCR on the Midlothian kilns.

Subsequently, as required by the consent decree, Ash Grove proposed, and EPA approved, a 30-day rolling average emission limit of 7.5 lb NO_x/ton clinker which is lower than the BART emission limit of 8.0 lb NO_x/ton clinker.

The 7.5 lb NOx/ton clinker emission limit was approved by the EPA on December 29, 2016.[1]

[1] EPA letter to Ash Grove Cement Co., December 29, 2016.

Operating company	CalPortland Cement		
Facility	Rillito Plant		
State	AZ		
Contact	**Thomas Webb**	**(415) 947–4139**	**webb.thomas@epa.gov.**
Distance to nearest Class I Area (km)	8	SAGU	EPA 2/18/2014
Baseline Visibility Impact (dv at Max Class I)	1.26		EPA 2/18/2014
# of Class I Areas evaluated	12	of 12	EPA 2/18/2014
Baseline Visibility Impact (dv at Summed Class I)	3.9		EPA 2/18/2014
Emissions Unit	Kiln #4		EPA 2/18/2014
Type	precalciner kiln		EPA 2/18/2014
Throughput (tpd)			
Throughput (tpy)	1,053,932		TSD
Fuel			
Emission Factor (lb/ton clinker)	3.59		TSD
Current Emissions (tpy)	2,082		EPA 2/18/2014
SNCR Cost-effectiveness	chosen by EPA		
Control effectiveness	35%		EPA 9/03/2014
Emission Factor (lb/ton clinker)	2.67		EPA 9/03/2014
New Emisison Rate (tpy)	1,353		calculated
Reductions (tpy)	729		EPA 2/18/2014
Capital Cost	$1,336,373		TSD
O&M Cost	$478,439		TSD
Total Annual Cost	$ 1,100,000		EPA 2/18/2014
Cost-Effectiveness ($/ton)	$ 1,850		EPA 9/03/2014
Visibility analyses			
Visibility Impact after BART (dv at Max Class I)	1.08		calculated
Visibility Improvement (dv at Max Class I)	0.18		EPA 9/03/2014
Cost-Effectiveness ($/98th % dv at Max Class I)	$ 6,111,111		EPA 2/18/2014
Pollutant Control Effectiveness (dv/ton)	0.00025		calculated
Visibility Impact after BART (dv at Summed Class I)	3.3		calculated
Visibility Improvement (dv at Summed Class I)	0.59		EPA 9/03/2014
Cost-Effectiveness ($/98th % dv at Summed Class I)	$ 1,864,407		EPA 2/18/2014
Pollutant Control Effectiveness (dv/ton)	0.00081		calculated
BART limit (lb/ton)		The owner/operator of kiln 4 of the Rillito Plant, as identified in paragraph (k)(1) of this section, shall not emit or cause to be emitted from kiln 4 NOX in excess of 3.46 pounds of NOX per ton of clinker produced, based on a rolling 30-kiln operating day basis. In addition, if the owner/operator installs an ammonia injection system to comply with the limits specified in this paragraph (k)(3), the owner/operator shall also comply with the control technology demonstration requirements set forth in paragraph (k)(6) of this section.	

Operating company	**CEMEX**		
Facility	**Lyons**		
State	**CO**		
Contact			
Distance to nearest Class I Area (km)			**Rocky Mountain National Park**
# of Class I Areas evaluated/within 300 km		**2 of 2**	
Proposed BART Control Option for preheater/precalciner kiln		**SNCR**	**single-stage flash calciner preceding dry kiln**
Current Emissions (lb/ton clinker)		7.39	CDPHE report
Current Emissions (tpy)		1,747.1	CDPHE report
Capital Cost			not available
O&M Cost			not available
Total Annual Cost	$	1,636,636	CDPHE report
Reduction (annual average)		48.4%	CDPHE report
Reductions (tpy)		846.1	CDPHE report
New Emisison Rate (lb/hr on a 30-day rolling average)		**255.3**	CDPHE report
New Emisison Rate (tpy)		901.0	CDPHE report
Cost-Effectiveness ($/ton)	$	1,934	CDPHE report
Visibility analyses			
Visibility Impact before BART (dv at Max Class I)		0.76	CDPHE report
Visibility Impact after BART (dv at Max Class I)		0.38	CDPHE report
Visibility Improvement (dv at Max Class I)		0.38	CDPHE report
Cost-Effectiveness ($/98th % dv at Max Class I)	$	4,306,937	calculated
Pollutant Control Effectiveness (dv/ton)		0.00045	calculated
Visibility Impact before BART (dv at Summed Class I)		0.95	calculated
Visibility Impact after BART (dv at Summed Class I)		0.48	calculated
Visibility Improvement (dv at Summed Class I)		0.48	calculated
Cost-Effectiveness ($/98th % dv at Summed Class I)	$	3,445,549	calculated
Pollutant Control Effectiveness (dv/ton)		0.00056	calculated

Accordingly, as part of its five factor consideration the state has elected to generally employ criteria for NOx post-combustion control options to aid in the assessment and determinations for BART – a $/ton of NOx removed cap, and two minimum applicable Δdv improvement figures relating to CALPUFF modeling for certain emissions control types, as follows.
- For the highest-performing NOx post-combustion control options (i.e., SCR systems for electric generating units) that do not exceed $5,000/ton of pollutant reduced by the state's calculation, and which provide a modeled visibility benefit on 0.50 Δdv or greater at the primary Class I Area affected, that level of control is generally viewed as reasonable.
- For lesser-performing NOx post-combustion control options (e.g., SNCR technologies for electric generating units) that do not exceed $5,000/ton of pollutant reduced by the state's calculation, and which provide a modeled visibility benefit of 0.20 Δdv or greater at the primary Class I Area affected, that level of control is generally viewed as reasonable.

The Lyons plant was originally constructed by Martin Marietta in the late 1960's and utilized a long dry kiln to produce Portland cement. During the 1980's the plant was operated by the Southdown Corporation and was later acquired by CEMEX in 2000. In 1980 a flash vessel was added to the kiln system, which destroys organic material (kerogen) present in the limestone and allows some of the calcination process to occur prior to entering the kiln. Along with this change the kiln was cut in half. The flash vessel was installed to allow kerogen to be combusted such that it is not vaporized and then emitted to the atmosphere where it can condense forming fine particulate matter that can result in a blue haze.
Cemex has a single stage preheater/precalciner type system.
Particulate emissions are controlled by fabric filter baghouses and wet dust suppression techniques.

NOx: Installation of selective non-catalytic reduction (SNCR) on the kiln system to reduce existing actual NOx levels by 40% on a 30-day rolling hourly average basis. This is approximately 60% below the existing permit limit. Compliance will be demonstrated by use of a continuous emission monitor as defined in the operating permit.
The Division is also aware that Cemex may be able to do better than 40% and will require that 50% reduction be met on an annual ton per year (rolling 12-month) basis. The Division will propose that the 12-month rolling total emissions be reduced 50% from the 2005-2006 annual average total of 1801.5 tons of NOx to 901.0 tons of NOx per year (12-month rolling total). This means that there will be a 40% reduction required on 30-day rolling hourly average and a 50% reduction on a 12-month rolling total basis from actual levels. These reductions are also 66% lower than the current allowable NOx limit contained in the operating permit. The Division also notes that the flash vessel at Cemex is unique and may affect how well SNCR will perform at the plant. Because of this uncertainty the Division will not specify the ammonia injection or slip rate but will allow Cemex to meet the NOx limits through SNCR technology and process controls. Improving process controls may allow Cemex to limit formation of NOx in the kiln and thus meet the NOx limits while reducing ammonia use.

SO2: No additional control because the cement manufacturing process inherently controls SO2 through interaction of sulfur compounds with the limestone in the kiln and the dust cake inside the fabric filter baghouses. New allowable emission rates will be established based on the process control of SO2.
Compliance will be demonstrated by use of a
continuous emission monitor as defined in the operating permit.

Particulate Matter: Cemex will continue to utilize particulate controls including fabric filter baghouses and dust suppression techniques, currently required to meet the MACT standard for Portland cement plants. Compliance will be demonstrated by continuous opacity monitors, periodic stack testing, and work practice requirements.

Operating company	**GCC**		
Facility	**Dacotah**		
State	**SD**		
Contact			
Distance to nearest Class I Area (km)			
Baseline Visibility Impact (dv at Max Class I)			
Distance to nearest NPS Class I Area (km)			
Baseline Visibility Impact nearest NPS Class I Area (dv)			
# of Class I Areas evaluated			**of 12 within 300 km**
Baseline Visibility Impact (dv at Summed Class I)			calculated
Long wet kiln			
Current Emissions (lb/ton clinker)			EPA pending FRN
Current Emissions (tpy)			EPA 4/20/2012 FRN
LNB Cost-effectiveness	**rejected by EPA**		
Control effectiveness	#DIV/0!		EPA 4/20/2012 FRN
New Emisison Rate (tpy)		-	EPA 4/20/2012 FRN
Reductions (tpy)			EPA 4/20/2012 FRN
Capital Cost			EPA 4/20/2012 FRN
O&M Cost			EPA 4/20/2012 FRN
Capital Recovery Factor			EPA 4/20/2012 FRN
Total Annual Cost			EPA 4/20/2012 FRN
Cost-Effectiveness ($/ton)	#DIV/0!		EPA 4/20/2012 FRN
Visibility analyses			
Visibility Impact before BART (dv at Max Class I)		0.000	EPA 4/20/2012 FRN
Visibility Impact after BART (dv at Max Class I)		0.000	calculated from EPA report
Visibility Improvement (dv at Max Class I)			EPA 4/20/2012 FRN
Cost-Effectiveness ($/98th % dv at Max Class I)	#DIV/0!		calculated
Pollutant Control Effectiveness (dv/ton)	#DIV/0!		calculated
Visibility Impact before BART (dv at YELL)		0.411	calculated
Visibility Impact after BART (dv at YELL)		0.411	calculated
Visibility Improvement (dv at YELL)			calculated
Cost-Effectiveness ($/98th % dv at YELL)	#DIV/0!		calculated
Pollutant Control Effectiveness (dv/ton)	#DIV/0!		calculated
Visibility Impact before BART (dv at Summed Class I)		0.000	calculated
Visibility Impact after BART (dv at Summed Class I)		0.000	calculated
Visibility Improvement (dv at Summed Class I)			calculated
Cost-Effectiveness ($/98th % dv at Summed Class I)	#DIV/0!		calculated
Pollutant Control Effectiveness (dv/ton)	#DIV/0!		calculated
MKF Cost-effectiveness	**rejected by EPA**		
Control effectiveness	#DIV/0!		EPA 4/20/2012 FRN
New Emisison Rate (tpy)		-	EPA 4/20/2012 FRN
Reductions (tpy)			EPA 4/20/2012 FRN
Capital Cost			EPA 4/20/2012 FRN
O&M Cost			EPA 4/20/2012 FRN
Capital Recovery Factor			EPA 4/20/2012 FRN
Total Annual Cost			EPA 4/20/2012 FRN
Cost-Effectiveness ($/ton)	#DIV/0!		EPA 4/20/2012 FRN
Visibility analyses			
Visibility Impact before BART (dv at Max Class I)			
Visibility Impact after BART (dv at Max Class I)			
Visibility Improvement (dv at Max Class I)			
Cost-Effectiveness ($/98th % dv at Max Class I)			
Pollutant Control Effectiveness (dv/ton)			
Visibility Impact before BART (dv at Summed Class I)			
Visibility Impact after BART (dv at Summed Class I)			
Visibility Improvement (dv at Summed Class I)			
Cost-Effectiveness ($/98th % dv at Summed Class I)			
Pollutant Control Effectiveness (dv/ton)			
SNCR Cost-effectiveness	**approved by EPA**		
Control effectiveness	#DIV/0!		EPA 4/20/2012 FRN
New Emisison Rate (tpy)		-	EPA 4/20/2012 FRN
Reductions (tpy)			EPA 4/20/2012 FRN
Capital Cost			EPA 4/20/2012 FRN
O&M Cost			EPA 4/20/2012 FRN
Capital Recovery Factor			EPA 4/20/2012 FRN

Total Annual Cost				EPA 4/20/2012 FRN
Cost-Effectiveness ($/ton)		#DIV/0!		EPA 4/20/2012 FRN
Visibility analyses				
Visibility Impact before BART (dv at Max Class I)			0.000	EPA 4/20/2012 FRN
Visibility Impact after BART (dv at Max Class I)			0.000	calculated from EPA report
Visibility Improvement (dv at Max Class I)				EPA 4/20/2012 FRN
Cost-Effectiveness ($/98th % dv at Max Class I)		#DIV/0!		calculated
Pollutant Control Effectiveness (dv/ton)		#DIV/0!		calculated
Visibility Impact before BART (dv at YELL)				EPA 4/20/2012 FRN
Visibility Impact after BART (dv at YELL)			0.000	calculated from EPA report
Visibility Improvement (dv at YELL)				calculated
Cost-Effectiveness ($/98th % dv at YELL)		#DIV/0!		calculated
Pollutant Control Effectiveness (dv/ton)		#DIV/0!		calculated
Visibility Impact before BART (dv at Summed Class I)			0.000	calculated
Visibility Impact after BART (dv at Summed Class I)			-0.415	calculated
Visibility Improvement (dv at Summed Class I)			0.415	calculated
Cost-Effectiveness ($/98th % dv at Summed Class I)	$		-	calculated
Pollutant Control Effectiveness (dv/ton)		#DIV/0!		calculated
LNB+SNCR Cost-effectiveness		**rejected by EPA**		
Control effectiveness		#DIV/0!		EPA 4/20/2012 FRN
New Emisison Rate (tpy)			(645)	EPA 4/20/2012 FRN
Reductions (tpy)			645	EPA 4/20/2012 FRN
Capital Cost	$		-	EPA 4/20/2012 FRN
O&M Cost	$		-	EPA 4/20/2012 FRN
Capital Recovery Factor			0.0944	EPA 4/20/2012 FRN
Total Annual Cost	$		-	EPA 4/20/2012 FRN
Cost-Effectiveness ($/ton)	$		-	EPA 4/20/2012 FRN
Visibility analyses				
Visibility Impact before BART (dv at Max Class I)			0.000	EPA R-8 report for Gates of the Mountains WA
Visibility Impact after BART (dv at Max Class I)			-0.424	calculated from EPA report
Visibility Improvement (dv at Max Class I)			0.424	calculated from EPA report
Cost-Effectiveness ($/98th % dv at Max Class I)	$		-	calculated
Pollutant Control Effectiveness (dv/ton)			0.00066	calculated
Visibility Impact before BART (dv at YELL)			0.411	EPA 4/20/2012 FRN
Visibility Impact after BART (dv at YELL)			0.240	calculated from EPA report
Visibility Improvement (dv at YELL)			0.171	calculated
Cost-Effectiveness ($/98th % dv at YELL)	$		-	calculated
Pollutant Control Effectiveness (dv/ton)			0.00027	calculated
Visibility Impact before BART (dv at Summed Class I)			0.000	calculated
Visibility Impact after BART (dv at Summed Class I)			-0.595	calculated
Visibility Improvement (dv at Summed Class I)			0.595	calculated
Cost-Effectiveness ($/98th % dv at Summed Class I)	$		-	calculated
Pollutant Control Effectiveness (dv/ton)			0.00092	calculated
BART limit (lb/ton clinker)			**6.5**	**30-day rolling average**
Control effectiveness		#DIV/0!		
Reductions (tpy)		#DIV/0!		
Proposed revised BART limit (lb/ton clinker)			**7.5**	**30-day rolling average**
Control effectiveness		#DIV/0!		
Reductions (tpy)		#DIV/0!		

Operating company	**Holcim Cement**	
Facility	**Florence**	
State	**CO**	
Contact		
Distance to nearest Class I Area (km)	66	**Great Sand Dunes**
# of Class I Areas evaluated/within 300 km		
Proposed RP Control Option for Preheater/Precalciner kiln	**SNCR**	
Current Emissions (tpy)	2,628	CDPHE report
Current Emissions (tpy)	3,186	permit limit--CDPHE report
Capital Cost	$ 1,000,000	CDPHE report
O&M Cost		
Total Annual Cost	$ 2,520,000	CDPHE report
Reduction	45%	CDPHE report
Reductions (tpy)	1,099	CDPHE report
New Emisison Rate (tpy)	2,087	CDPHE report
Cost-Effectiveness ($/ton)	$ 2,293	CDPHE report
Visibility analyses		
Visibility Impact before BART (dv at Max Class I)	0.814	CDPHE report
Visibility Impact after BART (dv at Max Class I)	0.526	CDPHE report
Visibility Improvement (dv at Max Class I)	0.288	CDPHE report
Cost-Effectiveness ($/98th % dv at Max Class I)	$ 8,750,000	calculated
Pollutant Control Effectiveness (dv/ton)	0.00026	calculated
Visibility Impact before BART (dv at Summed Class I)		
Visibility Impact after BART (dv at Summed Class I)		
Visibility Improvement (dv at Summed Class I)		
Cost-Effectiveness ($/98th % dv at Summed Class I)		
Pollutant Control Effectiveness (dv/ton)		

Operating company **LaFarge North America (cement)**
Facility **Alpena**
State **MI**
Contact

Distance to nearest Class I Area (km) **250** **Seney NWR**
# of Class I Areas evaluated/within 300 km **1 of 1**

	NOx Controls					SO2 Controls			
	Kiln #19	**Kiln #20**	**Kiln #21**	**Kiln #22**	**Kiln #23**	**Kiln #22**	**Kiln #23**		
Proposed BART Control Option for long, dry process kilns	**SNCR**	**SNCR**	**SNCR**	**SNCR**	**SNCR**	**wet FGD**	**wet FGD**	**Totals**	
Current Emissions (tpy)	3,459	3,459	3,459	5,742	5,742	12,093	12,093	$ 46,046	calculated
Reductions (tpy)	1,210	1,210	1,210	2,297	2,297	10,884	10,884	$ 29,992	calculated
Reductions	35%	35%	35%	40%	40%	90%	90%		company report
Capital Cost	$ 2,526,285	$ 2,526,285	$ 2,526,285	2,250,080	2,250,080	$ 63,136,000	$ 63,136,000	$ 138,351,015	company report
O&M Cost	$ 323,804	$ 323,804	$ 323,804	516,011	516,011	$ 1,503,034	$ 1,503,034	$ 5,009,502	company report
Total Annual Cost	$ 884,867	$ 884,867	$ 884,867	1,143,871	1,143,871	$ 11,830,426	$ 11,830,426	$ 28,603,195	sum of company reports
Cost-Effectiveness ($/ton)	$ 731	$ 731	$ 731	$ 498	$ 498	$ 1,087	$ 1,087		company report

New Emisison Rate (lb/day)
New Emisison Rate (tpy)

Visibility analyses

Visibility Impact before BART (dv at Max Class I)	1.301	company report
Visibility Impact after BART (dv at Max Class I)	0.746	company report
Visibility Improvement (dv at Max Class I)	0.555	calculated
Cost-Effectiveness ($/98th % dv at Max Class I)	$ 51,537,288	calculated
Pollutant Control Effectiveness (dv/ton)		
Visibility Impact before BART (dv at Summed Class I)		
Visibility Impact after BART (dv at Summed Class I)		
Visibility Improvement (dv at Summed Class I)		
Cost-Effectiveness ($/98th % dv at Summed Class I)		
Pollutant Control Effectiveness (dv/ton)		

Operating company	Lafarge North America					
Facility	Whitehall Facility					
State	PA					
Contact						
Class I Areas evaluated/within 300 km	Brigantine WR					
Distance to nearest Class I Areas (km)	156.2				company report	Jan-17
	Kiln #1	**Kiln #3**	**Kiln #1**	**Kiln #3**		
Visibility Impact before BART (3-yr Avg. 98th percentile dv at Class I)	0.058	0.033			company report	Jan-17
Cumulative Visibility Impact before BART (3-yr Avg. 98th percentile dv at Clas	0.091				company report	Jan-17
Throughput (each ton clinker/hr)						
Proposed BART Control Option for dry preheater kilns						
Pollutant	**NOx**		**SO2**			
Current Emissions (tpy)		907.72			calculated	
Q/d		5.81			calculated	
`						
Proposed BART Control Option for dry preheater kilns						
Control Technology	**Low NOx Burner (K3 Only)**		**Dry Scrubbing - optimization**			
Reductions		25%	95%		PA DEP report	7-Sep-17
Reductions (tpy)		227	228		PA DEP report	7-Sep-17
New Emisison Rate (tpy)		681			calculated	
Capital Cost						
O&M Cost						
Total Annual Cost		$828,975	$515,675		calculated	
Cost-Effectiveness ($/ton)		$3,653	$2,259		PA DEP report	7-Sep-17
Visibility analyses						
Visibility Improvement (98 percentile dv at Class I)		0.003	0.030		company report	Jan-17
Visibility Impact after BART (dv at Class I)		0.030	0.061		calculated	
Cost-Effectiveness ($/98th % dv at goth Class I)		$ 310,865,734	$17,000,288		calculated	
Pollutant Control Effectiveness (dv/ton)		0.00001	0.00013		calculated	
Visibility Improvement (dv at Summed Class I)						
Cost-Effectiveness ($/98th % dv at Summed Class I)						
Pollutant Control Effectiveness (dv/ton)						
Control Technology	**SNCR Optimization**		**Wet Scrubbing**			
Reductions	70%		80%		PA DEP report	7-Sep-17
Reductions (tpy)	400		228		PA DEP report	7-Sep-17
New Emisison Rate (tpy)						
Capital Cost						
O&M Cost						
Total Annual Cost	$748,288		$659,284		calculated	
Cost-Effectiveness ($/ton)	$1,871		$2,888		PA DEP report	7-Sep-17
Visibility analyses						
Visibility Improvement (98 percentile dv at Class I)	0.022		0.027		company report	Jan-17
Visibility Impact after BART (dv at Class I)	0.069		0.064		calculated	
Cost-Effectiveness ($/98th % dv at goth Class I)	$34,536,357		$24,417,928		calculated	
Pollutant Control Effectiveness (dv/ton)	0.00005		0.00012		calculated	
Visibility Improvement (dv at Summed Class I)						
Cost-Effectiveness ($/98th % dv at Summed Class I)						
Pollutant Control Effectiveness (dv/ton)						
BART limit (lb/hr)	**297.7**	**202.3**	**362.0**	**195.0**	PA DEP report	7-Sep-17
BART limit (30-day rolling average lb/ton clinker)	**2.58**	**2.92**	**4.06**	**3.19**	PA DEP report	7-Sep-17
Control effectiveness	0%	0%	0%	0%		
Reductions (tpy)	0	0	0	0	-	

Operating company	**LaFarge North America (cement)**		
Facility	**Seattle**		
State	**WA**		
Contact	**Al Newman**	**360-407-6810**	**anew461@ecy.wa.gov**
Distance to nearest Class I Area (km)	**53**	**Alpine Lakes WA**	
# of Class I Areas evaluated/within 300 km	**1 of 9**		
	NOx	**SO2**	
Proposed BART Control Option for wet process kiln	**SNCR or mid-kiln firing of whole tires**	**dry sorbent injection**	**WA Ecology report**
Current Emissions (tpy)	2,172.5	570	WA Ecology report
Reductions (tpy)	869	142.5	WA Ecology report
Reductions	40%	25%	WA Ecology report
Capital Cost	$ 1,499,410	$ 6,090,000	WA Ecology report
O&M Cost	$ 1,082,997		WA Ecology report
Total Annual Cost	$ 1,224,541	$ 574,896	WA Ecology report
Cost-Effectiveness ($/ton)	$ 1,409	$ 4,034	WA Ecology report
New Emisison Rate (lb/day)	**22,960**	**8,620**	WA Ecology report
New Emisison Rate (tpy)	4,190	1,573	calculated from WA Ecology report
Visibility analyses			**combined NOx + SO2 controls**
Visibility Impact before BART (dv at Max Class I)		2.96	WA Ecology report at Olympic NP
Visibility Impact after BART (dv at Max Class I)		1.937	WA Ecology report at Olympic NP
Visibility Improvement (dv at Max Class I)		1.02	calculated from WA Ecology report
Cost-Effectiveness ($/98th % dv at Max Class I)		$ 1,758,980	calculated from WA Ecology report
Pollutant Control Effectiveness (dv/ton)		0.00101	calculated from WA Ecology report
Visibility Impact before BART (dv at Summed Class I)		12.96	calculated from WA Ecology report
Visibility Impact after BART (dv at Summed Class I)		8.254	calculated from WA Ecology report
Visibility Improvement (dv at Summed Class I)		4.706	calculated from WA Ecology report
Cost-Effectiveness ($/98th % dv at Summed Class I)		$ 382,371	calculated from WA Ecology report
Pollutant Control Effectiveness (dv/ton)		0.00465	calculated from WA Ecology report

Operating company	Lehigh Cement Company
Facility	Evansville Facility
State	PA
Contact	

Distance to nearest Class I Area (km)	161.6	Brigantine Wildlife Refuge				
Visibility Impact before BART (dv at Max Class I)	0.617				PA DEP report	18-Jun-08
# of Class I Areas evaluated/within 300 km	1 of 2					
Proposed BART Control Option for dry preheater kilns	**Kiln #1**		**Kiln #2**		PA DEP report	18-Jun-08
Pollutant	**NOx**	**SO2**	**NOx**	**SO2**		
Current Emissions (tpy)	1,275.20	181.3	1,333.80	215.9	PA DEP report	18-Jun-08
Visibility Impact before BART (dv at Max Class I)	0.280	0.014	0.306	0.015	PA DEP report	18-Jun-08
Control Technology	**Indirect Firing**	**Dry Injection**	**Indirect Firing**	**Dry Injection**		
Reductions	15%	40.2%	15%	40.2%	PA DEP report	18-Jun-08
Reductions (tpy)	191	73	200	87	calculated	
New Emisison Rate (tpy)	1,084	108	1,134	129	calculated	
Capital Cost						
O&M Cost						
Total Annual Cost	$ 6,625,939	$ 513,273	$ 8,157,254	$ 611,228	calculated	
Cost-Effectiveness ($/ton)	$ 34,640	$7,045	$ 40,772	$7,045	PA DEP report	18-Jun-08
Visibility analyses						
Visibility Improvement (98 percentile dv at Max Class I)	0.005	0.0097	0.005	0.0108	PA DEP report	18-Jun-08
Visibility Impact after BART (dv at Max Class I)	0.275	0.004	0.301	0.004	calculated	
Cost-Effectiveness ($/98th % dv at Max Class I)	$ 1,332,162,809	$36,419,817	$ 1,352,435,404	$35,623,205	PA DEP report	18-Jun-08
Pollutant Control Effectiveness (dv/ton)	0.00003	0.00013	0.00002	0.00012	calculated	
Visibility Impact before BART (dv at Summed Class I)					calculated	
Visibility Impact after BART (dv at Summed Class I)					calculated	
Visibility Improvement (dv at Summed Class I)					calculated	
Cost-Effectiveness ($/98th % dv at Summed Class I)					calculated	
Pollutant Control Effectiveness (dv/ton)					calculated	
Control Technology	**Low NOx Burner**	**Semi-Dry**	**Low NOx Burner**	**Semi-Dry**		
Reductions	20%	90%	20%	90%	PA DEP report	18-Jun-08
Reductions (tpy)	255	163	267	194	calculated	
New Emisison Rate (tpy)	1,020	18	1,067	22	calculated	
Capital Cost						
O&M Cost						
Total Annual Cost	$ 297,377	$ 302,844	$ 410,810	$ 570,688	calculated	
Cost-Effectiveness ($/ton)	$ 1,166	$ 1,856	$ 1,540	$ 2,937	PA DEP report	18-Jun-08
Visibility analyses						
Visibility Improvement (98 percentile dv at Max Class I)	0.007	0.004	0.007	0.005	PA DEP report	18-Jun-08
Visibility Impact after BART (dv at Max Class I)	0.273	0.010	0.299	0.010	calculated	
Cost-Effectiveness ($/98th % dv at Max Class I)	$ 50,880,783	$ 171,079,211	$ 51,275,899	$ 150,988,971	PA DEP report	18-Jun-08
Pollutant Control Effectiveness (dv/ton)	0.00003	0.00002	0.00003	0.00003	calculated	
Visibility Impact before BART (dv at Summed Class I)					calculated	
Visibility Impact after BART (dv at Summed Class I)					calculated	
Visibility Improvement (dv at Summed Class I)					calculated	
Cost-Effectiveness ($/98th % dv at Summed Class I)					calculated	
Pollutant Control Effectiveness (dv/ton)					calculated	
Control Technology	**SNCR**	**Wet Scrubber**	**SNCR**	**Wet Scrubber**		
Reductions	60%	95%	60%	95%	PA DEP report	18-Jun-08
Reductions (tpy)	765	172	800	205	calculated	
New Emisison Rate (tpy)	510	9	534	11	calculated	
Capital Cost						
O&M Cost						
Total Annual Cost	$ 479,730	$ 2,341,018	$ 501,776	$ 4,451,394	calculated	
Cost-Effectiveness ($/ton)	$ 627	$ 13,592	$ 627	$ 21,703	PA DEP report	18-Jun-08
Visibility analyses						
Visibility Improvement (98 percentile dv at Max Class I)	0.020	0.005	0.040	0.005	PA DEP report	18-Jun-08
Visibility Impact after BART (dv at Max Class I)	0.260	0.009	0.266	0.010	calculated	
Cost-Effectiveness ($/98th % dv at Max Class I)	$ 14,267,800	$ 1,253,151,622	$ 14,267,800	$ 1,115,868,499	PA DEP report	18-Jun-08
Pollutant Control Effectiveness (dv/ton)	0.00003	0.00003	0.00005	0.00002	calculated	
Visibility Impact before BART (dv at Summed Class I)					calculated	
Visibility Impact after BART (dv at Summed Class I)					calculated	
Visibility Improvement (dv at Summed Class I)					calculated	
Cost-Effectiveness ($/98th % dv at Summed Class I)					calculated	
Pollutant Control Effectiveness (dv/ton)					calculated	
BART limit (lb/ton clinker)						
Control effectiveness	0%					
Reductions (tpy)	-					

Operating company Lehigh Cement Company
Facility Evansville Facility
State PA
Contact

Pollutant	**NOx**		**SO2**				
Class I Areas evaluated/within 300 km	Brigantine WR	Shenandoah NP	Brigantine WR	Shenandoah NP			
Distance to nearest Class I Areas (km)	161.6	263.8	161.6	263.8	company report	Aug-18	
Visibility Impact before BART (98th percentiledv at Class I)	0.179	0.096	0.179	0.096	PA DEP report	31-Aug-18	
Cumulative Visibility Impact before BART (98th percentiledv at both Class I)	0.275		0.275		PA DEP report	31-Aug-18	
Proposed BART Control Option for dry preheater kilns	**Kilns #1 & #2**		**Kilns #1 & #2**		PA DEP report	31-Aug-18	
Throughput (each ton clinker/hr)	90		90		PA DEP report	31-Aug-18	
Current Emissions (tpy)	2,299.43		311.23		PAL	PA DEP report	31-Aug-18
Q/d	14.23	8.72	1.93	1.18			
`							
Control Technology	**Indirect Firing**		**Dry Sorbent Injection**				
Reductions	15%		95%		PA DEP report	31-Aug-18	
Reductions (tpy)	345		296		PA DEP report	31-Aug-18	
New Emisison Rate (tpy)	1955		16		calculated		
Capital Cost							
O&M Cost							
Total Annual Cost	$4,690,083		$1,701,868		PA DEP report	31-Aug-18	
Cost-Effectiveness ($/ton)	$13,598		$5,756		PA DEP report	31-Aug-18	
Visibility analyses							
Visibility Improvement (98 percentile dv at Class I)	0.023	0.007	0.054	0.019	PA DEP report	31-Aug-18	
Visibility Impact after BART (dv at Class I)	0.156	0.089	0.125	0.077	PA DEP report	31-Aug-18	
Cost-Effectiveness ($/98th % dv at goth Class I)	$ 203,916,652	$ 670,011,857	$ 31,516,072	$ 89,571,994	calculated		
Pollutant Control Effectiveness (dv/ton)	0.00007	0.00002	0.00018	0.00006	calculated		
Visibility Improvement (dv at Summed Class I)	0.030		0.073		calculated		
Cost-Effectiveness ($/98th % dv at Summed Class I)	$156,336,100		$23,313,259		calculated		
Pollutant Control Effectiveness (dv/ton)	0.00009		0.00025		calculated		
Control Technology	**SNCR**		**Wet Scrubbing**				
Reductions	20%		95%		PA DEP report	31-Aug-18	
Reductions (tpy)	460		296		PA DEP report	31-Aug-18	
New Emisison Rate (tpy)	1840		16		calculated		
Capital Cost							
O&M Cost							
Total Annual Cost	$580,623		$7,357,711		PA DEP report	31-Aug-18	Lehigh assumed 10 yr life for SNCR and 5% interest rate.
Cost-Effectiveness ($/ton)	$1,263		$24,885		PA DEP report	31-Aug-18	
Visibility analyses							
Visibility Improvement (98 percentile dv at Class I)	0.030	0.010	0.054	0.019	PA DEP report	31-Aug-18	
Visibility Impact after BART (dv at Class I)	0.149	0.086	0.125	0.077	PA DEP report	31-Aug-18	
Cost-Effectiveness ($/98th % dv at goth Class I)	$ 19,354,100	$ 58,062,300	$ 136,253,900	$ 387,247,928	calculated		
Pollutant Control Effectiveness (dv/ton)	0.00007	0.00002	0.00018	0.00006	calculated		
Visibility Improvement (dv at Summed Class I)	0.040		0.073		calculated		
Cost-Effectiveness ($/98th % dv at Summed Class I)	$14,515,575		$ 100,790,556		calculated		
Pollutant Control Effectiveness (dv/ton)	0.00009		0.00025		calculated		
Control Technology	**SCR**		**Semi-Dry**				
Reductions	42%		90%		PA DEP report	31-Aug-18	
Reductions (tpy)	966		280		PA DEP report	31-Aug-18	
New Emisison Rate (tpy)	1334		31		calculated		
Capital Cost							
O&M Cost							
Total Annual Cost	$10,529,688		$1,315,382		calculated		Lehigh assumed 20 yr life for SNCR and 5% interest rate.
Cost-Effectiveness ($/ton)	$10,903		$4,696		PA DEP report	31-Aug-18	
Visibility analyses							
Visibility Improvement (98 percentile dv at Class I)	0.080	0.033	0.020	0.019	PA DEP report	31-Aug-18	
Visibility Impact after BART (dv at Class I)	0.099	0.063	0.159	0.077	PA DEP report	31-Aug-18	
Cost-Effectiveness ($/98th % dv at goth Class I)	$ 131,621,098	$ 319,081,449	$ 65,769,124	$ 69,230,656	calculated		
Pollutant Control Effectiveness (dv/ton)	0.00008	0.00003	0.00007	0.00007	calculated		
Visibility Improvement (dv at Summed Class I)	0.113		0.039		calculated		
Cost-Effectiveness ($/98th % dv at Summed Class I)	$93,183,078		$33,727,756		calculated		
Pollutant Control Effectiveness (dv/ton)	0.00012		0.00014		calculated		
BART limit (lb/hr)	**313.8**		**67.7**		**30-day rolling average**	PA DEP report	31-Aug-18
BART limit (lb/ton clinker)	3.49		0.8		calculated		
Control effectiveness	0%		0%				
Reductions (tpy)		- -		-			

Operating company	**Oldcastle Cement**		
Facility	**Trident**		
State	**MT/EPA R-8**		
Contact			
Distance to nearest Class I Area (km)	**97**		Gates of Mountains
Baseline Visibility Impact (dv at Max Class I)		0.980	Gates of Mountains
Distance to nearest NPS Class I Area (km)	120		Yellowstone NP
Baseline Visibility Impact nearest NPS Class I Area (dv)		0.411	Yellowstone NP
# of Class I Areas evaluated	**2**		**of 12 within 300 km**
Baseline Visibility Impact (dv at Summed Class I)		1.391	calculated
Long wet kiln			
Current Emissions (lb/ton clinker)		12.6	EPA pending FRN
Current Emissions (tpy)		1,112	EPA 4/20/2012 FRN
LNB Cost-effectiveness	**rejected by EPA**		
Control effectiveness		15%	EPA 4/20/2012 FRN
New Emisison Rate (tpy)		945	EPA 4/20/2012 FRN
Reductions (tpy)		167	EPA 4/20/2012 FRN
Capital Cost	$	4,385,307	EPA 4/20/2012 FRN
O&M Cost	$	300,658	EPA 4/20/2012 FRN
Capital Recovery Factor		0.0944	EPA 4/20/2012 FRN
Total Annual Cost	$	714,629	EPA 4/20/2012 FRN
Cost-Effectiveness ($/ton)	$	4,279	EPA 4/20/2012 FRN
Visibility analyses			
Visibility Impact before BART (dv at Max Class I)		0.980	EPA 4/20/2012 FRN
Visibility Impact after BART (dv at Max Class I)		0.855	calculated from EPA report
Visibility Improvement (dv at Max Class I)		0.125	EPA 4/20/2012 FRN
Cost-Effectiveness ($/98th % dv at Max Class I)	$	15,663	calculated
Pollutant Control Effectiveness (dv/ton)		0.00075	calculated
Visibility Impact before BART (dv at YELL)		0.411	calculated
Visibility Impact after BART (dv at YELL)		0.360	calculated
Visibility Improvement (dv at YELL)		0.051	calculated
Cost-Effectiveness ($/98th % dv at YELL)	$	38,390	calculated
Pollutant Control Effectiveness (dv/ton)		0.00031	calculated
Visibility Impact before BART (dv at Summed Class I)		1.391	calculated
Visibility Impact after BART (dv at Summed Class I)		1.215	calculated
Visibility Improvement (dv at Summed Class I)		0.176	calculated
Cost-Effectiveness ($/98th % dv at Summed Class I)	$	11,124	calculated
Pollutant Control Effectiveness (dv/ton)		0.00105	calculated
MKF Cost-effectiveness	**rejected by EPA**		
Control effectiveness		30%	EPA 4/20/2012 FRN
New Emisison Rate (tpy)		778	EPA 4/20/2012 FRN
Reductions (tpy)		334	EPA 4/20/2012 FRN
Capital Cost			EPA 4/20/2012 FRN
O&M Cost			EPA 4/20/2012 FRN
Capital Recovery Factor		0.0944	EPA 4/20/2012 FRN
Total Annual Cost	$	473,738	EPA 4/20/2012 FRN
Cost-Effectiveness ($/ton)	$	1,418	EPA 4/20/2012 FRN
Visibility analyses			
Visibility Impact before BART (dv at Max Class I)			
Visibility Impact after BART (dv at Max Class I)			
Visibility Improvement (dv at Max Class I)			
Cost-Effectiveness ($/98th % dv at Max Class I)			
Pollutant Control Effectiveness (dv/ton)			
Visibility Impact before BART (dv at Summed Class I)			
Visibility Impact after BART (dv at Summed Class I)			
Visibility Improvement (dv at Summed Class I)			
Cost-Effectiveness ($/98th % dv at Summed Class I)			
Pollutant Control Effectiveness (dv/ton)			
SNCR Cost-effectiveness	**approved by EPA**		
Control effectiveness		50%	EPA 4/20/2012 FRN
New Emisison Rate (tpy)		556	EPA 4/20/2012 FRN
Reductions (tpy)		556	EPA 4/20/2012 FRN
Capital Cost	$	1,312,800	EPA 4/20/2012 FRN
O&M Cost	$	147,288	EPA 4/20/2012 FRN
Capital Recovery Factor		0.0944	EPA 4/20/2012 FRN

Total Annual Cost	$	271,216	EPA 4/20/2012 FRN
Cost-Effectiveness ($/ton)	$	488	EPA 4/20/2012 FRN
Visibility analyses			
Visibility Impact before BART (dv at Max Class I)		0.980	EPA 4/20/2012 FRN
Visibility Impact after BART (dv at Max Class I)		0.685	calculated from EPA report
Visibility Improvement (dv at Max Class I)		0.295	EPA 4/20/2012 FRN
Cost-Effectiveness ($/98th % dv at Max Class I)	$	2,519	calculated
Pollutant Control Effectiveness (dv/ton)		0.00053	calculated
Visibility Impact before BART (dv at YELL)		0.411	EPA 4/20/2012 FRN
Visibility Impact after BART (dv at YELL)		0.291	calculated from EPA report
Visibility Improvement (dv at YELL)		0.120	calculated
Cost-Effectiveness ($/98th % dv at YELL)	$	6,192	calculated
Pollutant Control Effectiveness (dv/ton)		0.00022	calculated
Visibility Impact before BART (dv at Summed Class I)		1.391	calculated
Visibility Impact after BART (dv at Summed Class I)		0.976	calculated
Visibility Improvement (dv at Summed Class I)		0.415	calculated
Cost-Effectiveness ($/98th % dv at Summed Class I)	$	1,791	calculated
Pollutant Control Effectiveness (dv/ton)		0.00075	calculated
LNB+SNCR Cost-effectiveness		**rejected by EPA**	
Control effectiveness		58%	EPA 4/20/2012 FRN
New Emisison Rate (tpy)		467	EPA 4/20/2012 FRN
Reductions (tpy)		645	EPA 4/20/2012 FRN
Capital Cost	$	5,698,107	EPA 4/20/2012 FRN
O&M Cost	$	447,946	EPA 4/20/2012 FRN
Capital Recovery Factor		0.0944	EPA 4/20/2012 FRN
Total Annual Cost	$	985,845	EPA 4/20/2012 FRN
Cost-Effectiveness ($/ton)	$	1,528	EPA 4/20/2012 FRN
Visibility analyses			
Visibility Impact before BART (dv at Max Class I)		0.980	EPA R-8 report for Gates of the Mountains WA
Visibility Impact after BART (dv at Max Class I)		0.556	calculated from EPA report
Visibility Improvement (dv at Max Class I)		0.424	calculated from EPA report
Cost-Effectiveness ($/98th % dv at Max Class I)	$	6,370	calculated
Pollutant Control Effectiveness (dv/ton)		0.00066	calculated
Visibility Impact before BART (dv at YELL)		0.411	EPA 4/20/2012 FRN
Visibility Impact after BART (dv at YELL)		0.240	calculated from EPA report
Visibility Improvement (dv at YELL)		0.171	calculated
Cost-Effectiveness ($/98th % dv at YELL)	$	15,795	calculated
Pollutant Control Effectiveness (dv/ton)		0.00027	calculated
Visibility Impact before BART (dv at Summed Class I)		1.391	calculated
Visibility Impact after BART (dv at Summed Class I)		0.796	calculated
Visibility Improvement (dv at Summed Class I)		0.595	calculated
Cost-Effectiveness ($/98th % dv at Summed Class I)	$	4,539	calculated
Pollutant Control Effectiveness (dv/ton)		0.00092	calculated
BART limit (lb/ton clinker)		**6.5**	**30-day rolling average**
Control effectiveness		48%	
Reductions (tpy)		538	
Proposed revised BART limit (lb/ton clinker)		**7.5**	**30-day rolling average**
Control effectiveness		40%	
Reductions (tpy)		450	

Operating company		**Oldcastle Cement**	
Facility		**Trident**	
State		**MT/EPA R-8**	
Contact			

Distance to nearest Class I Area (km)			
Baseline Visibility Impact (dv at Max Class I)		1.438	Gates of Mountains
Baseline Visibility Impact (dv)		0.603	Yellowstone NP
# of Class I Areas evaluated	**2**		**of 12 within 300 km**
Baseline Visibility Impact (dv at Summed Class I)		2.041	calculated

Long wet kiln		
Current Emissions (lb/ton clinker)	12.6	EPA pending FRN
Current Emissions (tpy)	1,632	EPA 4/20/2012 FRN

LNB Cost-effectiveness	**rejected by EPA**	
Control effectiveness		EPA 4/20/2012 FRN
New Emisison Rate (tpy)		EPA 4/20/2012 FRN
Reductions (tpy)		EPA 4/20/2012 FRN
Capital Cost		EPA 4/20/2012 FRN
O&M Cost		EPA 4/20/2012 FRN
Capital Recovery Factor		EPA 4/20/2012 FRN
Total Annual Cost		EPA 4/20/2012 FRN
Cost-Effectiveness ($/ton)		EPA 4/20/2012 FRN
Visibility analyses		
Visibility Impact before BART (dv at Max Class I)		EPA 4/20/2012 FRN
Visibility Impact after BART (dv at Max Class I)		calculated from EPA report
Visibility Improvement (dv at Max Class I)		EPA 4/20/2012 FRN
Cost-Effectiveness ($/98th % dv at Max Class I)		calculated
Pollutant Control Effectiveness (dv/ton)		calculated
Visibility Impact before BART (dv at YELL)		calculated
Visibility Impact after BART (dv at YELL)		calculated
Visibility Improvement (dv at YELL)		calculated
Cost-Effectiveness ($/98th % dv at YELL)		calculated
Pollutant Control Effectiveness (dv/ton)		calculated
Visibility Impact before BART (dv at Summed Class I)		calculated
Visibility Impact after BART (dv at Summed Class I)		calculated
Visibility Improvement (dv at Summed Class I)		calculated
Cost-Effectiveness ($/98th % dv at Summed Class I)		calculated
Pollutant Control Effectiveness (dv/ton)		calculated

MKF Cost-effectiveness	**rejected by EPA**	
Control effectiveness		EPA 4/20/2012 FRN
New Emisison Rate (tpy)		EPA 4/20/2012 FRN
Reductions (tpy)		EPA 4/20/2012 FRN
Capital Cost		EPA 4/20/2012 FRN
O&M Cost		EPA 4/20/2012 FRN
Capital Recovery Factor		EPA 4/20/2012 FRN
Total Annual Cost		EPA 4/20/2012 FRN
Cost-Effectiveness ($/ton)		EPA 4/20/2012 FRN
Visibility analyses		
Visibility Impact before BART (dv at Max Class I)		
Visibility Impact after BART (dv at Max Class I)		
Visibility Improvement (dv at Max Class I)		
Cost-Effectiveness ($/98th % dv at Max Class I)		
Pollutant Control Effectiveness (dv/ton)		
Visibility Impact before BART (dv at Summed Class I)		
Visibility Impact after BART (dv at Summed Class I)		
Visibility Improvement (dv at Summed Class I)		
Cost-Effectiveness ($/98th % dv at Summed Class I)		
Pollutant Control Effectiveness (dv/ton)		

SNCR Cost-effectiveness		**proposed by EPA**	
Control effectiveness		40%	EPA 4/20/2012 FRN
New Emisison Rate (tpy)		1,103	EPA 4/20/2012 FRN
Reductions (tpy)		529	Oldcastle
Capital Cost	$	2,500,000	Oldcastle
O&M Cost	$	147,288	EPA 4/20/2012 FRN
Capital Recovery Factor		0.0944	EPA 4/20/2012 FRN
Total Annual Cost	$	1,723,000	Oldcastle
Cost-Effectiveness ($/ton)	$	3,257	Oldcastle
Visibility analyses			
Visibility Impact before BART (dv at Max Class I)		1.438	EPA 4/20/2012 FRN
Visibility Impact after BART (dv at Max Class I)		1.16	calculated from EPA report
Visibility Improvement (dv at Max Class I)		0.28	EPA 4/20/2012 FRN
Cost-Effectiveness ($/98th % dv at Max Class I)	$	16,819	calculated
Pollutant Control Effectiveness (dv/ton)		0.00053	calculated
Visibility Impact before BART (dv at YELL)		0.60	EPA 4/20/2012 FRN
Visibility Impact after BART (dv at YELL)		0.49	calculated from EPA report
Visibility Improvement (dv at YELL)		0.11	calculated
Cost-Effectiveness ($/98th % dv at YELL)	$	41,346	calculated
Pollutant Control Effectiveness (dv/ton)		0.00022	calculated
Visibility Impact before BART (dv at Summed Class I)		2.041	calculated
Visibility Impact after BART (dv at Summed Class I)		1.646	calculated
Visibility Improvement (dv at Summed Class I)		0.395	calculated
Cost-Effectiveness ($/98th % dv at Summed Class I)	$	11,955	calculated
Pollutant Control Effectiveness (dv/ton)		0.00075	calculated

Oldcastle

Because ammonia reagent comprises a large proportion of the annualized SNCR costs, a description of reagent selection is warranted. The original cost estimate assumed that an aqueous solution of urea would supply the required ammonia for SNCR in the kiln. As design progressed, a 19 percent aqueous solution of ammonia was determined to be the more cost-effective and efficient reagent for SNCR at Trident. This decision was based on a number of considerations. Most notably, the “salt-out” temperature of urea of about 40° F would require that all urea solution tankage and piping be insulated and heat-traced. If the insulation were to tear and/or the heat-tracing fail during the cold of winter, the resulting plugged urea lines could lead to increased NOx emissions, and reopening the lines would be costly in terms of both maintenance expenses and production disruptions. Using aqueous ammonia will avoid these potential issues because it will not salt out.

A urea reagent system also requires additional handling equipment, depending on the form of urea purchased. Solid or concentrated aqueous urea must be diluted to the proper concentration onsite. Large volumes of water required to dissolve and dilute these forms of urea must be treated to remove hardness; otherwise, precipitates are likely to occur in the system. The aqueous ammonia proposed for use at Trident can be injected directly, thereby eliminating the need for a mixing station and water treatment. According to Oldcastle's SNCR design engineers, ammonia injection performs better than urea injection to reduce NOx emissions from cement kilns. The chemical efficiency of ammonia is much higher than urea for reducing NOx to elemental nitrogen inside of the cement kiln. Empirical data indicate that approximately two times more urea than aqueous ammonia, on an ammonia-equivalent basis, is required to achieve an equivalent level of NOx reduction in a cement kiln.

19% High Purity Aqua Ammonia, Bulk US$0.1634/lb

LNB+SNCR Cost-effectiveness		**current BART**	
Control effectiveness		48%	EPA 4/20/2012 FRN
New Emisison Rate (tpy)		842	EPA 4/20/2012 FRN
Reductions (tpy)		790	EPA 4/20/2012 FRN
Capital Cost	$	2,500,000	EPA 4/20/2012 FRN
O&M Cost	$	147,288	EPA 4/20/2012 FRN
Capital Recovery Factor		0.0944	EPA 4/20/2012 FRN
Total Annual Cost	$	1,723,000	EPA 4/20/2012 FRN
Cost-Effectiveness ($/ton)	$	2,181	EPA 4/20/2012 FRN
Visibility analyses			
Visibility Impact before BART (dv at Max Class I)		1.438	EPA R-8 report for Gates of the Mountains WA
Visibility Impact after BART (dv at Max Class I)		0.92	calculated from EPA report
Visibility Improvement (dv at Max Class I)		0.52	calculated from EPA report
Cost-Effectiveness ($/98th % dv at Max Class I)	$	9,090	calculated
Pollutant Control Effectiveness (dv/ton)		0.00066	calculated
Visibility Impact before BART (dv at YELL)		0.603	EPA 4/20/2012 FRN
Visibility Impact after BART (dv at YELL)		0.39	calculated from EPA report
Visibility Improvement (dv at YELL)		0.21	calculated
Cost-Effectiveness ($/98th % dv at YELL)	$	22,539	calculated

Pollutant Control Effectiveness (dv/ton)		0.00027	calculated
Visibility Impact before BART (dv at Summed Class I)		2.041	calculated
Visibility Impact after BART (dv at Summed Class I)		1.312	calculated
Visibility Improvement (dv at Summed Class I)		0.729	calculated
Cost-Effectiveness ($/98th % dv at Summed Class I)	$	6,478	calculated
Pollutant Control Effectiveness (dv/ton)		0.00092	calculated
BART limit (lb/ton clinker)		**6.5**	**30-day rolling average**
Control effectiveness		48%	
Reductions (tpy)		790	
Proposed revised BART limit (lb/ton clinker)		**7.6**	**30-day rolling average**
Control effectiveness		40%	
Reductions (tpy)		648	

Operating company	Phoenix Cement		
Facility	Clarkdale Plant		
State	AZ		
Contact	**Thomas Webb**	**(415) 947–4139**	**webb.thomas@epa.gov.**

Distance to nearest Class I Area (km)	10	SYCA	EPA 2/18/2014
Baseline Visibility Impact (dv at Max Class I)	5.15		EPA 2/18/2014
# of Class I Areas evaluated	12	of 12	EPA 2/18/2014
Baseline Visibility Impact (dv at Summed Class I)	7.5		EPA 2/18/2014
Emissions Unit	Kiln #4		EPA 2/18/2014
Type	precalciner kiln		EPA 2/18/2014
Throughput (tpd)			
Throughput (tpy)			
Fuel			
Emission Factor (lb/ton clinker)			
Current Emissions (tpy)	1,620		EPA 2/18/2014
SNCR Cost-effectiveness	chosen by EPA		
Control effectiveness	50%		EPA 2/18/2014
New Emisison Rate (tpy)	810		calculated
Reductions (tpy)	810		EPA 2/18/2014
Capital Cost			
O&M Cost			
Total Annual Cost	$ 940,000		EPA 2/18/2014
Cost-Effectiveness ($/ton)	$ 1,160		EPA 2/18/2014
Visibility analyses			
Visibility Impact after BART (dv at Max Class I)	3.3		calculated
Visibility Improvement (dv at Max Class I)	1.85		EPA 2/18/2014
Cost-Effectiveness ($/98th % dv at Max Class I)	$ 508,108		EPA 2/18/2014
Pollutant Control Effectiveness (dv/ton)	0.00228		calculated
Visibility Impact after BART (dv at Summed Class I)	4.5		calculated
Visibility Improvement (dv at Summed Class I)	3.0		EPA 2/18/2014
Cost-Effectiveness ($/98th % dv at Summed Class I)	$ 313,333		EPA 2/18/2014
Pollutant Control Effectiveness (dv/ton)	0.00370		calculated
BART limit (lb/ton)		The owner/operator of kiln 4 of the Clarkdale Plant, as identified in paragraph (k)(1) of this section, shall not emit or cause to be emitted from kiln 4 NOX in excess of 2.12 pounds of NOX per ton of clinker produced, based on a rolling 30-kiln operating day basis. In addition, if the owner/operator installs an ammonia injection system to comply with the limits specified in this paragraph (k)(3), the owner/operator shall also comply with the control technology demonstration requirements set forth in paragraph (k)(6) of this section. Alternative emissions limitation. In lieu of the emission limitation listed in paragraph (k)(3)(i) of this section, the owner/operator of kiln 4 of the Clarkdale Plant may choose to comply with the following limitation by providing notification per paragraph (k)(13)(iv) of this section. The owner/ operator of kiln 4 of the Clarkdale Plant, as identified in paragraph (k)(1) of this section, shall not emit or cause to be emitted from kiln 4 NOX in excess of 810 tons per year, based on a rolling 12 month basis.	

Operating company **St. Mary's Cement**
Facility **Charlevoix**
State **MI**
Contact

Distance to nearest Class I Area (km)		**Seney NWR**						
# of Class I Areas evaluated/within 300 km	**1 of 1**							
Proposed BART Control Option for preheater/precalciner kiln	**existing LNB**	**rejected SNCR**			**EPA SNCR**			
Current Emissions (tpy)	5,243		5,243	company report		2,518	EPA 5/24/12	
Reductions (tpy)			10%	company report		50%	EPA FR Notice	
Reductions			524	company report		1,259	EPA FR Notice	
Capital Cost		$	3,470,224	company report	$	4,979,017	EPA 5/24/12	
O&M Cost		$	2,486,096	company report	$	541,063	EPA 5/24/12	
Total Annual Cost		$	3,967,626	company report	$	1,237,597	calculated	
Cost-Effectiveness ($/ton)		$	7,568	company report	$	983	EPA FR Notice	
New Emisison Rate (lb/day)								
New Emisison Rate (tpy)								
Visibility analyses								
Visibility Impact before BART (dv at Max Class I)	5.26			company report				
Visibility Impact after BART (dv at Max Class I)								
Visibility Improvement (dv at Max Class I)						0.4	EPA FR Notice	
Cost-Effectiveness ($/98th % dv at Max Class I)					$	3,093,993	calculated	
Pollutant Control Effectiveness (dv/ton)								
Visibility Impact before BART (dv at Summed Class I)								
Visibility Impact after BART (dv at Summed Class I)								
Visibility Improvement (dv at Summed Class I)								
Cost-Effectiveness ($/98th % dv at Summed Class I)								
Pollutant Control Effectiveness (dv/ton)								

ANALYSIS TABLE - Cement Kilns, SO2 (based on BART proposal cost calculations)

							ACTUAL		ACTUAL, from Owner Modeling		ACTUAL, from MANE-VU Modeling				
Facility	Unit	2002 Emissions TPY SO2	Flue Gas Flow Rate ACFM	Existing Controls	Remaining Useful Life	Candidate Controls	Emission Reduction	Cost/ton	Process Visibility Impairment in Class 1 Area	Projected Emission Control Improvement to Visibility Impairment in Class 1 Area	Process Visibility Impairment in Class 1 Area	Projected Emission Control Improvement to Visibility Impairment in Class 1 Area	Listed Capital Investment (TCI)	Listed Total Annual Cost	Owner based Visibility Improvment Annual $/DV
Keystone	2	2,027.3	275,000	Fabric Filter	15 Years	Dry Injection	50%	$8,894	0.318	0.0930	0.378	0.1106	$459,469	$9,015,834	$81,543,995
						Semi-Dry	90%	$5,404		0.1674		0.1990	$9,859,750	$9,859,750	$49,542,678
						Wet Scrubber	90%	$2,224		0.1674		0.1990	$9,419,115	$4,057,729	$20,389,032
Carmeuse	5	60.8	160,472	Fabric Filter	15 Years	Dry Injection	*40.2%*	*$7,045*	-	-	0.059	*0.0039*		*$172,186*	*$44,443,313*
						Semi-Dry	*82.0%*	*$18,405*		-		*0.0079*		*$918,301*	*$116,115,993*
						Wet Scrubber	*88.2%*	*$28,374*		-		*0.0085*		*$1,522,322*	*$179,008,878*
Essroc Bessemer	5	516.6	255,000	ESP	15 Years	Dry Injection	*40.2%*	*$7,045*	0.114	*0.0106*	0.296	*0.0274*		*$1,462,531*	*$53,289,989*
						Semi-Dry	*82.0%*	*$18,405*		*0.0216*		*0.0560*		*$7,799,968*	*$139,229,494*
						Wet Scrubber	80%	$32,370		0.0210		0.0546	$11,685,136	$13,377,682	$244,863,120
CEMEX	3	799.8	117,000	ESP	15 Years	Dry Injection	*40.2%*	*$7,045*	-	-	0.159	*0.0439*		*$2,264,290*	*$51,611,948*
						Semi-Dry	*82.0%*	*$18,405*		-		*0.0896*		*$12,075,908*	*$134,845,317*
						Wet Scrubber	*88.2%*	*$28,374*		-		*0.0963*		*$20,018,961*	*$207,882,724*
						Selective Mining	70%					0.0764			
Lafarge	2	813.2	130,465	Fabric Filter	15 Years	Dry Injection	25%	$3,636	0.2	0.0270	0.140	0.0189	$1,529,000	$739,109	$39,131,591
						Semi-Dry	50%	$31,722		0.0540		0.0378	$2,378,378	$12,898,224	$341,443,569
						Wet Scrubber	81%	$4,854		0.0874		0.0612	$15,572,935	$3,197,211	$52,245,069
Lafarge	3	496.6	75,000	Fabric Filter	15 Years	Dry Injection	25%	$5,076	0.14	0.0191	0.091	0.0124	$1,529,000	$630,140	$50,655,946
						Semi-Dry	50%	$37,538		0.0383		0.0249	$2,378,378	$9,320,716	$374,638,720
						Wet Scrubber	81%	$10,500		0.0620		0.0403	$12,177,087	$4,223,783	$104,797,270
Lehigh White Cement Kiln,York		56.9	131,249	ESP	15 Years	Dry Injection	*40.2%*	*$7,045*	0.2	*0.0097*	0.173	*0.0084*		*$161,088*	*$19,134,542*
						Semi-Dry	90%	$67,093		0.0218		0.0189	$9,362,345	$3,435,819	$182,236,281
						Wet Scrubber	90%	$102,117		0.0218		0.0189	$22,000,000	$5,229,419	$277,369,055
Lehigh, Evansville	1	181.3	210,000	Fabric Filter	15 Years	Dry Injection	*40.2%*	*$7,045*	0.2	*0.0097*	0.292	*0.0141*		*$513,273*	*$36,419,817*
						Semi-Dry	90%	$4,533		0.0216		0.0316	$2,378,378	$739,666	$23,435,508
						Wet Scrubber	95%	$33,205		0.0228		0.0333	$25,000,000	$5,719,040	$171,664,606
Lehigh, Evansville	2	215.9	210,000	Fabric Filter	15 Years	Dry Injection	*40.2%*	*$7,045*	0.2	*0.0108*	0.317	*0.0172*		*$611,228*	*$35,623,205*
						Semi-Dry	90%	$3,768		0.0242		0.0384	$2,378,378	$732,094	$19,052,236
						Wet Scrubber	95%	$27,845		0.0256		0.0406	$25,000,000	$5,711,047	$140,803,596

Values shown in italics were not submitted in company BART proposals and are derived from company BART proposals submitted by other companies.

1. All SO2 control processes should be evaluated for each BART affected kiln.
   This will be done for DI, SDA/FF and WS. Selective mining costs will not be evaluated.

   DI - Reagent costs are much greater than amortization of capital costs. Reagent use is proportional to SO2 throughput.

   Cost per ton of SO2 removed and % removal for kilns not evaluated by the company will be based on SO2 inlet weighted average of data submitted by other companies.

   DI averages 40.2% $7,045

   SDA/FF - Amortization of capital equipment are generally greater than reagent costs. Calculations proportional to flue gas throughput will be used.

   Cost per ton of SO2 removed and % removal for kilns not evaluated by the company will be based on flue gas throughput weighted average of data submitted by other companies.

   SDA/FF averages 82.0% $18,405

   WS - Amortization of capital equipment costs are much greater than reagent costs. Capital costs are roughly proportional to flue gas throughput.

   Cost per ton of SO2 removed and % removal for kilns not evaluated by the company will be based on flue gas throughput weighted average of data submitted by other companies.

   WS averages 88.2% $28,374

ANALYSIS TABLE - Cement Kilns, NOx

							ACTUAL		ACTUAL, from Owner Modeling		ACTUAL, from MANE-VU Modeling				
Facility	Unit	2002 Emissions TPY NOx	Flue Gas Flow Rate ACFM	Existing Controls	Remaining Useful Life	Candidate Controls	Emission Reduction	Cost/ton	Process Visibility Impairment in Class 1 Area	Projected Emission Control Improvement to Visibility Impairment in Class 1 Area	Process Visibility Impairment in Class 1 Area	Projected Emission Control Improvement to Visibility Impairment in Class 1 Area	Listed Capital Investment (TCI)	Estimated Total Annual Cost	Owner based Visibility Improvment Annual $/DV
Keystone	2	1,315.6	275,000	Fabric Filter	15 Years	Indirect Firing	20%	$2,796	0.318	0.0241	0.378	0.0287	$3,500,000	$735,614	$25,631,276
						Low NOx Burner	20%	$874		0.0241		0.0287	$117,997	$230,016	$8,014,534
						Staged Air Combustion	20%	$1,066		0.0241		0.0287	$1,179,732	$280,571	$9,776,041
						SNCR	*35%*	*$1,446*		*0.0423*		*0.0502*		*$665,711*	*$13,254,633*
Carmeuse	5	293.2	160,472	Fabric Filter	15 Years	*Indirect Firing*	*18.4%*	*$35,974*	-	-	0.059	*0.0085*		*$1,938,852*	*$226,951,386*
						Low NOx Burner	*20%*	*$1,297*		-		*0.0093*		*$76,029*	*$8,180,729*
						SNCR	*35%*	*$1,446*				*0.0163*		*$148,343*	*$9,120,976*
Essroc Bessemer	5	1,604.5	255,000	ESP	15 Years	*Indirect Firing*	*18.4%*	*$35,974*	0.114	-	0.296	*0.0390*		*$10,611,569*	*$272,127,257*
						Low NOx Burner	*20%*	*$1,297*		-		*0.0424*		*$416,116*	*$9,809,147*
						SNCR	*35%*	*$1,446*				*0.0742*		*$811,898*	*$10,936,554*
CEMEX	3	351.0	117,000	ESP	15 Years	*Indirect Firing*	*18.4%*	*$35,974*	-	-	0.159	*0.0088*		*$2,321,384*	*$263,558,281*
						Low NOx Burner	*20%*	*$1,297*		-		*0.0096*		*$91,029*	*$9,500,268*
						SNCR	*35%*	*$1,446*				*0.0168*		*$177,611*	*$10,592,175*
Lafarge	2	692.1	130,465	Fabric Filter	15 Years	*Indirect Firing*	*18.4%*	*$35,974*	0.2	*0.0169*	0.140	*0.0118*		*$4,577,293*	*$387,205,522*
						Low NOx Burner	*20%*	*$1,297*		*0.0184*		*0.0129*		*$179,491*	*$13,957,278*
						SNCR	25%	$1,804		0.0230		0.0161	$906,708	$312,052	$19,412,189
Lafarge	3	410.7	75,000	Fabric Filter	15 Years	*Indirect Firing*	*18.4%*	*$35,974*	0.14	*0.0116*	0.091	*0.0076*		*$2,716,218*	*$359,025,463*
						Low NOx Burner	20%	$2,750		0.0127		0.0082	$118,919	$225,889	$27,446,090
						SNCR	25%	$2,144		0.0158		0.0103	$639,552	$220,108	$21,394,947
Lehigh White Cement Kiln,York		391.3	131,249	ESP	15 Years	Indirect Firing	15%	$105,490	0.2	0.0250	0.128	0.0160	$25,000,000	$6,191,734	$387,263,583
						Low NOx Burner	*20%*	*$1,297*		*0.0333*		*0.0213*		*$101,481*	*$4,760,360*
						Cadence Fan	30%	$1,129		0.0500		0.0320	$295,293	$132,476	$4,142,873
						SNCR	*35%*	*$1,446*		*0.0583*		*0.0373*		*$198,003*	*$5,307,489*
Lehigh, Evansville	1	1,275.2	210,000	Fabric Filter	15 Years	Indirect Firing	15%	$35,298	0.2	0.0253	0.292	0.0370	$28,000,000	$6,751,884	$182,488,056
						Low NOx Burner	20%	$1,348		0.0338		0.0493	$118,919	$343,843	$6,969,970
						SNCR	60%	$1,269		0.1014		0.1480	$1,500,000	$971,310	$6,563,075
Lehigh, Evansville	2	1,333.8	210,000	Fabric Filter	15 Years	Indirect Firing	15%	$33,748	0.2	0.0250	0.317	0.0396	$28,000,000	$6,751,884	$170,654,310
						Low NOx Burner	20%	$1,279		0.0333		0.0528	$89,189	$341,319	$6,470,145
						SNCR	60%	$1,214		0.0998		0.1583	$1,500,000	$971,310	$6,137,481

Values shown in italics were not submitted in company BART proposals and are derived from company BART proposals submitted by other companies.

1. All NOx control processes should be evaluated for each BART affected kiln.
   This is done for Indirect Firing and Low NOx Burner for all kilns. SNCR is evaluated for the preheater kilns, (Lafarge & Lehigh/Evansville) only. Other control technologies contained in company BART proposals for individual kilns are also included for that unit.

   Indirect Firing - Amortization of capital equipment is most of total costs. Calculations proportional to flue gas throughput will be used.

   Cost per ton of NOx removed and % removal for kilns not evaluated by the company will be based on flue gas throughput weighted average of data submitted by other companies.

   Indirect Firing averages 18.4% $35,974

   Low NOx Burner - Amortization of capital equipment are generally greater than reagent costs. Calculations proportional to flue gas throughput will be used.

   Cost per ton of NOx removed and % removal for kilns not evaluated by the company will be based on flue gas throughput weighted average of data submitted by other companies.

   Low NOx Burner averages 20.0% $1,297

   SNCR - Amortization of capital equipment are generally greater than reagent costs. Calculations proportional to flue gas throughput will be used.

   Cost per ton of NOx removed kilns not evaluated by the company will be based on flue gas throughput weighted average of data submitted by other companies.

   SNCR averages 49.6% $1,446

   For wet & Dry long kilns NOx removal of 35% will be used rather than a average of preheater kilns.

Table 3 - Available Retrofit Control Technologies for BART Evaluation

Keystone - Unit 2

Pollutant	Uncontrolled Emission Rate TPY (2002EI)	Control Technology	Emission Control %	Visibility Improvement dv	Control Cost	
					$ per Ton Controlled	Annual $ per dv Improvement
SO2	2,027	Dry Injection	50%	0.111	8,894	81,543,995
SO2	2,027	Semi-Dry	90%	0.199	5,404	49,542,678
SO2	2,027	Wet Scrubber	90%	0.199	2,224	20,389,032
NOx	1,316	Indirect Firing	20%	0.029	2,796	25,631,276
NOx	1,316	Low NOx Burner	20%	0.029	874	8,014,534
NOx	1,316	Staged Air Combustion	20%	0.029	1,066	9,776,041
NOx	1,316	SNCR	35%	0.050	1,446	13,254,633

Table 3 - Available Retrofit Control Technologies for BART Evaluation

Carmeuse - Unit 5

Pollutant	Uncontrolled emission rate TPY (2002EI)	Control Technology	% Control	Visibility Improvement dv	Control Cost	
					$ per Ton Removed	Annual $ per dv Improvement
SO2	61	Dry Injection	40%	0.004	7,045	44,443,313
SO2	61	Semi-Dry	82%	0.008	18,405	116,115,993
SO2	61	Wet Scrubber	88%	0.009	28,374	179,008,878
NOx	293	Indirect Firing	18%	0.009	35,974	226,951,386
NOx	293	Low NOx Burner	20%	0.009	1,297	8,180,729
NOx	293	SNCR	35%	0.016	1,446	9,120,976

Table 3 - Available Retrofit Control Technologies for BART Evaluation

Essroc/Bessemer - Unit 5

Pollutant	Uncontrolled emission rate TPY (2002EI)	Control Technology	% Control	Visibility Improvement dv	Control Cost	
					$ per Ton Removed	Annual $ per dv Improvement
SO2	517	Dry Injection	40%	0.027	7,045	53,289,989
SO2	517	Semi-Dry	82%	0.056	18,405	139,229,494
SO2	517	Wet Scrubber	80%	0.055	32,370	244,863,120
NOx	1,605	Indirect Firing	18%	0.039	35,974	272,127,257
NOx	1,605	Low NOx Burner	20%	0.042	1,297	9,809,147
NOx	1,605	SNCR	35%	0.074	1,446	10,936,554

Table 3 - Available Retrofit Control Technologies for BART Evaluation

CEMEX/Wampum - Unit 3

Pollutant	Uncontrolled emission rate TPY (2002EI)	Control Technology	% Control	Visibility Improvement dv	Control Cost	
					$ per Ton Removed	Annual $ per dv Improvement
SO2	800	Dry Injection	40%	0.044	7,045	51,611,948
SO2	800	Semi-Dry	82%	0.090	18,405	134,845,317

SO2	800	Wet Scrubber	88%	0.096	28,374	207,882,724
SO2	800	Selective Mining	70%	0.076		
NOx	351	Indirect Firing	18%	0.009	35,974	263,558,281
NOx	351	Low NOx Burner	20%	0.010	1,297	9,500,268
NOx	351	SNCR	35%	0.017	1,446	10,592,175

Table 3 - Available Retrofit Control Technologies for BART Evaluation

Lafarge - Unit K-2

Pollutant	Uncontrolled emission rate TPY (2002EI)	Control Technology	% Control	Visibility Improvement dv	Control Cost	
					$ per Ton Removed	Annual $ per dv Improvement
SO2	813	Dry Injection	25%	0.019	3,636	39,131,591
SO2	813	Semi-Dry	50%	0.038	31,722	341,443,569
SO2	813	Wet Scrubber	81%	0.061	4,854	52,245,069
NOx	692	Indirect Firing	18%	0.012	35,974	387,205,522
NOx	692	Low NOx Burner	20%	0.013	1,297	13,957,278
NOx	692	SNCR	25%	0.016	1,804	19,412,189

Table 4 - Available Retrofit Control Technologies for BART Evaluation

Lafarge - Unit K-3

Pollutant	Uncontrolled emission rate TPY (2002EI)	Control Technology	% Control	Visibility Improvement dv	Control Cost	
					$ per Ton Removed	Annual $ per dv Improvement
SO2	497	Dry Injection	25%	0.012	5,076	50,655,946
SO2	497	Semi-Dry	50%	0.025	37,538	374,638,720
SO2	497	Wet Scrubber	81%	0.040	10,500	104,797,270
NOx	411	Indirect Firing	18%	0.008	35,974	359,025,463
NOx	411	Low NOx Burner	20%	0.008	2,750	27,446,090
NOx	411	SNCR	25%	0.010	2,144	21,394,947

Table 3 - Available Retrofit Control Technologies for BART Evaluation

Lehigh/York - White Cement Kiln

Pollutant	Uncontrolled emission rate TPY (2003EI)	Control Technology	% Control	Visibility Improvement dv	Control Cost	
					$ per Ton Removed	Annual $ per dv Improvement
SO2	57	Dry Injection	40%	0.008	7,045	19,134,542
SO2	57	Semi-Dry	90%	0.019	67,093	182,236,281
SO2	57	Wet Scrubber	90%	0.019	102,117	277,369,055
NOx	391	Indirect Firing	15%	0.016	105,490	387,263,583
NOx	391	Low NOx Burner	20%	0.021	1,297	4,760,360
NOx	391	Cadence Fan	30%	0.032	1,129	4,142,873
NOx	391	SNCR	35%	0.037	1,446	5,307,489

Table 3 - Available Retrofit Control Technologies for BART Evaluation

Lehigh/Evansville - Unit 1

Pollutant	Uncontrolled emission rate TPY (2002EI)	Control Technology	% Control	Visibility Improvement dv	Control Cost	
					$ per Ton Removed	Annual $ per dv Improvement
SO2	181	Dry Injection	40%	0.014	7,045	36,419,817
SO2	181	Semi-Dry	90%	0.032	4,533	23,435,508
SO2	181	Wet Scrubber	95%	0.033	33,205	171,664,606
NOx	1,275	Indirect Firing	15%	0.037	35,298	182,488,056
NOx	1,275	Low NOx Burner	20%	0.049	1,348	6,969,970
NOx	1,275	SNCR	60%	0.148	1,269	6,563,075

Table 4 - Available Retrofit Control Technologies for BART Evaluation

Lehigh/Evansville - Unit 2

Pollutant	Uncontrolled emission rate TPY (2002EI)	Control Technology	% Control	Visibility Improvement dv	Control Cost	
					$ per Ton Removed	Annual $ per dv Improvement
SO2	216	Dry Injection	40%	0.017	7,045	35,623,205
SO2	216	Semi-Dry	90%	0.038	3,768	19,052,236
SO2	216	Wet Scrubber	95%	0.041	27,845	140,803,596
NOx	1,334	Indirect Firing	15%	0.040	33,748	170,654,310
NOx	1,334	Low NOx Burner	20%	0.053	1,279	6,470,145
NOx	1,334	SNCR	60%	0.158	1,214	6,137,481

Appendix D

Greencastle BART Controls Analyses

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Cement Kiln BART Controls Cost Effectiveness Analysis

Operating company	**Lone Star Industry, Inc dba Buzzi Unicem**
Facility	**Greencastle Plant**
State	**IN**

Proposed BART Control Option for Greencastle Long, Dry Process Kiln	**NO_x Controls SNCR**	**SO_2 Controls DSI**
Current Emissions (ton/yr)	1,713	104
Control Effectiveness	40%	45%
New Emission Rate (tons/yr)	1,028	57
Emission Reductions (tons/yr)	685	47
Capital Cost	$ 1,724,229	$ 908,461
O&M Cost	$ 408,822	$ 282,403
Total Annual Cost	$ 598,142	$ 382,152
Cost-Effectiveness ($/ton)	$ 873	$ 8,142

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Appendix E

SCR Cost Estimate

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KILN SOURCE-SPECIFIC COST ESTIMATE Selective Catalytic Reduction (Cold-Side Application) CAPITAL COST		
Direct Capital Cost (DCC)		
Base SCR System	$35,000,000	GEA Proposal No. 30012556-00
Catalyst	-	Included in base SCR
Heat Exchanger	-	Included in base SCR
ID Fan	-	Included in base SCR
Civil Engineering Costs	-	Included in base SCR
Ammonia Storage System	$2,000,000	ACT
Additional Out of Scope Items (5% of VC)	$1,750,000	ACT
Instrumentation and Controls (5% of VC)	$1,750,000	
Total Purchased Equipment Cost (PEC)	$40,500,000	
Direct Installation	-	Included in base SCR
Direct Installation of Heat Exchangers	-	Included in base SCR
Sales Tax (7% of PEC)	$2,835,000	Indiana Sales Tax
Seismic Zone Installation Connection	-	
Total DCC	$43,335,000	
Indirect Capital Cost (DCC)		
Engineering, Supervision (10% of DCC)	$4,333,500	NSR Workshop
Electrical Expense (20% of DCC)	$8,667,000	Engineering Estimate
Construction & Field Expense (10 % of DCC)	$4,333,500	NSR Workshop
Construction Fees (10% of DCC)	$4,333,500	NSR Workshop
Start-up (2% of DCC)	$866,700	NSR Workshop
Testing (3% of DCC)	$1,300,050	NSR Workshop
Contingencies 2% of PEC)	$8,100,000	ACT
Total ICC	$31,934,250	
Total Capital Cost	$75,269,250	DCC=ICC
Capital Recovery Factor (7%, 15 years)	10.98%	ACT
Total Annualized Capital Costs	$8,264,564	NSR Workshop
OPERATING COST		
Direct Operating Cost (DOC)		
Operating Labor	$90,000	1 Man-Years @ $90.000/year
Supervision (@ 20% of operating labor)	$18,000	Plant Data
Maintenance Labor	$90,000	1 Man-Years @ $90.000/year
Maintenance Materials (5% of DCC)	$2,166,750	Plant Data
Reagent	$978,096	19% NH3 Solution
Energy Penalty	$161,555	
Electricity	$1,838,988	3170 kW/hr + 180 kW/hr for 20 hours of start-up
Gas Reheat with Heat Recovery	$3,620,720	1070 scfm
Total DOC	$8,964,109	
Indirect Operating Cost (IOC)		
Payroll Overhead (30% operations, labor, and sup.	$32,400	NSR Workshop
Plant Overhead (26% total labor & materials)	$614,835	NSR Workshop
Property Tax (1% TCC)	$752,693	NSR Workshop
Insurance (1% TCC)	$752,693	NSR Workshop
Administration (2% TCC)	$1,505,385	NSR Workshop
Total IOC	$3,658,006	
Total Annual Operating Cost	$12,622,115	
TOTAL COST		
Total Annual Cost (Capital & Operating)	$20,886,273	
Base NO_x Emissions (tons/yr)	$3,879	Baseline of 2.9 lb/ton
Total NO_x Created (tons/yr) form Reheat	$14	
NO_x Removal Rate (%)		
NO_x Emission with SCR (tons/yr)	$1,872	Guarantee Emission Rate = 1.4 lb/ton
Total NO_x Removed (tons/yr)	$2,006	(nothing including NOx caused by reheat)
Total Cost/Ton NO_x Removed	**$10,412**	

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