REGIONAL HAZE 2ND IMPLEMENTATION PERIOD FOUR-FACTOR ANALYSIS

GCC Rio Grande, Inc.> Tijeras, NM

Tijeras Plant Four-Factor Analysis

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1. EXECUTIVE SUMMARY

GCC Rio Grande, Inc. (GCC) owns and operates a Portland cement manufacturing facility located at 11783 State Highway 337 South, Tijeras, New Mexico (GCC Tijeras, or the facility). This report provides a four-factor control technology analysis of the two dry kilns at GCC Tijeras. Both kilns are older, rotary, dry kilns with two-stage preheaters that are permitted to produce approximately 33 tons/hr of clinker. The facility operates under the jurisdiction of air quality program of the City of Albuquerque Environmental Health Department (EHD) and the Albuquerque/Bernalillo County Air Quality Control Board (AQCB)'s Air Quality Division (AQD).

This report is provided in response to the EHD request for GCC to perform a four-factor control analysis. Per EHD, only sulfur dioxide (SO_2) and oxides of nitrogen (NO_X) need to be considered as visibility impairing pollutants for this analysis for emission units with a potential to emit 10 or more pounds per hour of either pollutant. EHD also specified that analysis of individual emission points that emit a total of 5 tons per year or less of either pollutant (such as the facility's quarry mining operation[1]) are not required to be undergo this analysis, and thus are not included in this report.

The United States Environmental Protection Agency's (U.S. EPA's) guidelines in 40 CFR Part 51.308 are used to evaluate reduction measures for the two cement kilns at the GCC Tijeras plant. In establishing a reasonable progress goal for any mandatory Class I Federal area within the State, the State must consider the following four factors and include a demonstration showing how these factors were taken into consideration in selecting the goal. 40 CFR 51. 308(d)(1)(i)(A):

1. The costs of compliance
2. The time necessary for compliance
3. The energy and non-air quality environmental impacts of compliance
4. The remaining useful life of any potentially affected sources

The purpose of this report is to provide information to EHD, the Albuquerque-Bernalillo County Air Quality Control Board (AQCB), New Mexico Environment Department (NMED) and the Western Regional Air Partnership (WRAP) regarding potential SO_2 and NO_X emission reduction measures for the GCC Tijeras Portland cement kilns. Based on the Regional Haze Rule, associated U.S. EPA guidance, and EHD's request, GCC understands that EHD will only move forward with requiring emission reductions from the GCC Tijeras kilns if EHD / AQCB / NMED determine that the emission reductions are needed to show reasonable progress and provide the most cost-effective controls among all options available. In other words, control reductions should be imposed by the Regional Haze Rule only if these potential measures result in a reduction in the existing visibility impairment in a Class I area needed to meet reasonable progress goals. While it is not expected that EHD will conduct site-specific visibility impairment analysis for GCC's Tijeras plant, GCC understands that emissions modeling conducted by WRAP will be used by EHD to inform any decisions made regarding imposed emission reduction measures for the site. GCC is submitting this report to provide preliminary results of the four-factor analysis and further discuss the feasibility or infeasibility of these potential options.

In the case of SO_2 emissions, the SO_2 produced at this facility is minimal when compared to the emissions of the state as a whole. The baseline emission rate is less than 3.5% of the total SO_2 emissions reported for New Mexico

[1] GCC's permit sets allowable emission limits for quarry blasting at 1.9 tpy NO_X and 0.22 tpy SO_2.

in 2017. At this small baseline rate, reductions in SO_2 from this facility will produce only limited improvement to visibility in the region, and perhaps no measurable visibility improvement at all.

Both of the GCC Tijeras kilns are older kilns and use older technology for cement manufacturing. GCC Tijeras' kilns were constructed as long dry kilns in 1959; the kiln lengths were reduced as a part of two-stage preheater installation in 1980. The nature of these older kilns results in significant technical challenges and barriers faced when designing, installing, and operating modern control technology, due in large part to inconsistency in operating conditions. In addition to the inconsistencies in the operating conditions for GCC's Tijeras facility relative to other Portland cement plants in the industry, GCC Tijeras is a landlocked facility, with no access to rail or river. Therefore, all materials and equipment transported to and from the facility must be delivered via truck. This complication, in combination with the challenges of the older kilns, results in a cost of producing cement that is significantly higher than the costs at other GCC facilities. Additionally, the cost of limestone at the Tijeras plant is approximately 2.5 times the cost at the other GCC plants. These higher costs of production and equipment shipping mean that a control technology that may be considered cost effective for a different cement plant would not be cost effective for this facility.

The SO_2 and NO_X emission reduction measures considered are summarized in the table below:

Table 1-1. Summary of Findings

Pollutant	Emission Reduction Measure	Technically Feasible?	Cost Effective?	Appropriate for Emissions Reduction?	Notes
SO_2	Alternative Low-Sulfur Fuels	Yes	No	No	Costs per ton removed are well over $50,000 for every available fuel option.
	Dry Sorbent Injection	Yes	Possibly	No	Emissions reductions would be minimal, and additional negative impacts on energy and the environment make the technology inappropriate for SO_2 reduction.
	Wet Scrubbing	Yes	No	No	Not cost effective and has negative environmental impacts outweighing any benefit.
	Semi-Wet/Dry Scrubbing	Yes	No	No	Cost ineffective.
NO_X	Alternative Fuel (TDF)	Possibly [1]	No	No	TDF is not readily available at this facility. Cost ineffective for lower rates of fuel substitution.
	Low-NO_X Burners	Yes	No	No	LNB would require significant changes to the entire kiln system, resulting in high capital costs.
	Selective Catalytic Reduction (SCR)	Yes	No	No	Cost ineffective and has accompanying technical challenges as an unproven control on cement kilns.
	Selective Non-Catalytic Reduction (SNCR)	Yes	Possibly	No	Technically challenging for this facility, costly, and results in negative environmental and safety impacts.
	Catalytic Filters	No	N/A	No	Not commercially proven for control on cement kilns.

[1] While technologically possible, TDF is not readily available in sufficient quantities at the GCC Tijeras facility and is thus not technically feasible for the purposes of regional haze.

Through this four-factor analysis, GCC Tijeras concludes that the existing control measures are the most suitable for SO_2 and NO_X emissions from the kilns at the plant. The emissions reduction methods analyzed in this report are found to be either technically infeasible, cost ineffective, or insignificant for emissions reductions relative to the total emissions in the area.

2. INTRODUCTION AND BACKGROUND

In the 1977 amendments to the Clean Air Act (CAA), Congress set a national goal to restore national parks and wilderness areas to natural conditions by preventing any future, and remedying any existing, man-made visibility impairment. On July 1, 1999, the U.S. EPA published the final Regional Haze Rule (RHR). The objective of the RHR is to restore visibility to natural conditions in 156 specific areas across with United States, known as Class I areas. The Clean Air Act defines Class I areas as certain national parks (over 6000 acres), wilderness areas (over 5000 acres), national memorial parks (over 5000 acres), and international parks that were in existence on August 7, 1977.

The RHR requires States to set goals that provide for reasonable progress towards achieving natural visibility conditions for each Class I area in their state. In establishing a reasonable progress goal for a Class I area, the state must:

(A) Consider the costs of compliance, the time necessary for compliance, the energy and non-air quality environmental impacts of compliance, and the remaining useful life of any potentially affected sources, and include a demonstration showing how these factors were taken into consideration in selecting the goal. 40 CFR 51. 308(d)(1)(i)(A).

(B) Analyze and determine the rate of progress needed to attain natural visibility conditions by the year 2064. To calculate this rate of progress, the State must compare baseline visibility conditions to natural visibility conditions in the mandatory Federal Class I area and determine the uniform rate of visibility improvement (measured in deciviews) that would need to be maintained during each implementation period in order to attain natural visibility conditions by 2064. In establishing the reasonable progress goal, the State must consider the uniform rate of improvement in visibility and the emission reduction. 40 CFR 51. 308(d)(1)(i)(B).

The EHD sent a letter to GCC requesting that they conduct "the four factor analysis of all potential new control measures for nitrogen oxides ("NO_X") and sulfur dioxide ("SO_2") on individual equipment that has the potential to emit (PTE) greater than ten (10) pounds per hour of NO_X or SO_2."[2] Furthermore, the letter specifies that individual emission points with total annual emissions less than 5 tons per year of either pollutant are not required to undergo this analysis. The GCC Tijeras permit has a limit of 1.9 tons per year of NO_X and 0.22 tons per year of SO_2 for the facility's quarry blasting. Therefore, quarry blasting is excluded from this analysis. The two emission units that have a potential to emit greater than 10 pounds per hour and 5 tons per year are the two cement kilns.

GCC Tijeras understands that the information provided in a four-factor review of reduction options will be used by EHD in their evaluation of reasonable progress goals for New Mexico. Based on the RHR, associated U.S. EPA guidance, and EHD's request, GCC understands that EHD will only move forward with requiring emission reductions from the GCC Tijeras kilns if EHD / AQCB / NMED determine that the emission reductions are needed to show reasonable progress and provide the most cost-effective controls among all options available. In other words, control reductions should be imposed by the RHR only if they result in a reduction in the existing visibility impairment in a Class I area needed to meet reasonable progress goals. While it is not expected that EHD will conduct site-specific visibility impairment analysis for GCC's Tijeras plant, GCC understands that emissions modeling conducted by WRAP will be used by EHD to inform any decisions made regarding imposed

[2] Refer to letter from the City of Albuquerque Environmental Health Department to GCC Tijeras sent on August 13, 2019.

emission reduction measures for the site. The purpose of this report is to provide information to EHD, AQCB, NMED and WRAP regarding SO_2 and NO_X emission reduction measures that could or could not be achieved for the GCC Tijeras kilns, if the emission reduction measures are determined by EHD to be necessary to meet the reasonable progress goals.

The information presented in this report considers the following four factors for the emission reductions:

1. Costs of compliance
2. Time necessary for compliance
3. Energy and non-air quality environmental impacts of compliance
4. Remaining useful life of the kilns

Factors 1 and 3 of the four factors that are listed above are considered by conducting a step-wise review of emission reduction options in a top-down fashion similar to the top-down approach that is included in the U.S. EPA RHR guidelines[3] for conducting a review of Best Available Retrofit Technology (BART) for a unit[4]. These steps are as follows:

Step 1. Identify all available retrofit control technologies
Step 2. Eliminate technically infeasible control technologies
Step 3. Evaluate the control effectiveness of remaining control technologies
Step 4. Evaluate impacts and document the results

Factor 4 is also addressed in the step-wise review of the emission reduction options, primarily in the context of the costing of emission reduction measures and whether any capitalization of expenses would be impacted by limited equipment life. Once the step-wise review of reduction options is completed, a review of the timing of the emission reductions is provided to satisfy Factor 2 of the four factors.

A review of the four factors for SO_2 and NOx can be found in Sections 5 and 6 of this report, respectively. Section 4 of this report includes information on the GCC Tijeras kilns' existing/baseline emission.

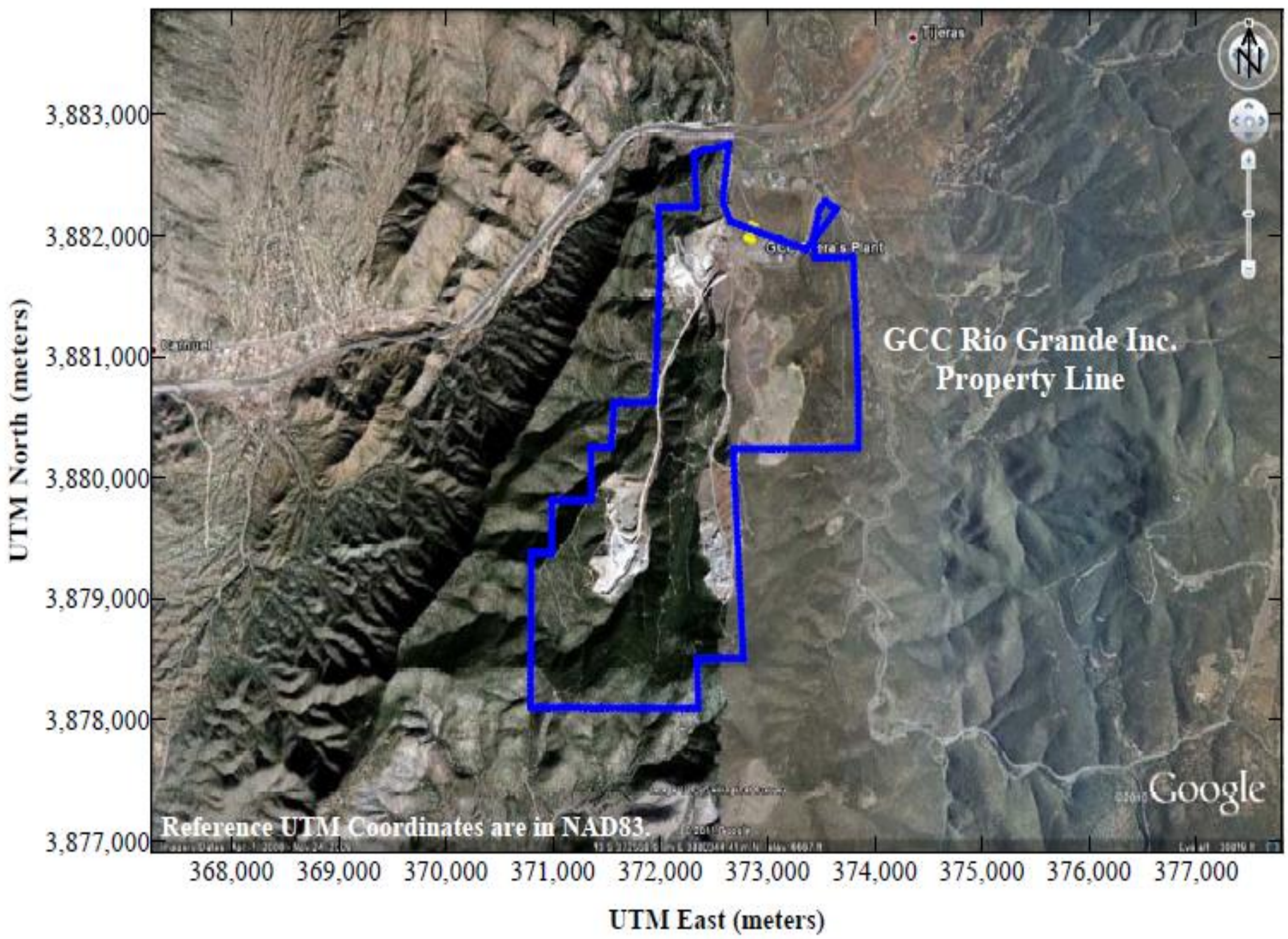
[3] The BART provisions were published as amendments to the EPA's RHR in 40 CFR Part 51, Section 308 on July 5, 2005.

[4] References to BART and BART requirements in this Analysis should not be construed as an indication that BART is applicable to the GCC's Tijeras facility.

The GCC Rio Grande, Inc. Tijeras Creek Plant is located at 11783 State Highway 337, Tijeras, Bernalillo County, New Mexico, approximately 17 miles east of Albuquerque. The nearest Class I area to the plant is the Bandelier National Monument. It is approximately 48 miles north of the GCC Tijeras plant. The Tijeras plant is landlocked, with no access to rail or river, meaning all materials and equipment transferred to and from the facility must travel by truck.

An aerial photograph of the GCC Facility is provided below in Figure 3-1.

Figure 3-1. Aerial Photograph of GCC Tijeras Facility



3.1. PROCESS DESCRIPTION

The Tijeras Plant has several systems used in the manufacturing of Portland cement. These systems include an onsite limestone mining operation, a crushing and screening system, ball-type raw mills used for grinding raw materials into raw meal (kiln feed), a blending system used for homogenization of raw meal, a raw meal metering system, a raw meal metering feed system, pyroprocessing systems used to convert raw materials into clinker (an intermediate product), and ball-type finish mills used to grind clinker into various Portland cement products. In addition, there are many auxiliary systems and equipment associated with the facility including storage silos and buildings, various conveying systems including belt, screw, pneumatic and airslide conveyors as well as bucket elevators. There are also many auxiliary support systems and equipment associated with the facility including storage silos used for processing and storing various raw materials, intermediate and final products. The transferring of materials throughout the facility is carried out by various conveying systems including belt, screw, and airslide conveyors, as well as bucket elevators.

The Tijeras Plant operates two 2-stage preheater kiln systems, including associated clinker coolers. Both kilns currently use coal as the primary fuel while natural gas is utilized as fuel during startup and as a supplemental fuel. The kilns are also permitted to use tire-derived fuel (TDF). Limestone and other raw materials are homogenized and fired in the preheater kilns to produce clinker. The clinker is cooled and conveyed to intermediate storage, then to finish mills where it is mixed with additive materials and milled into finished cement product. Cement manufacturing operations at the Tijeras Plant include on-site quarries, crushing and screening, raw material receiving, transfer, preparation, and storage, additive and finished materials transfer and storage, fuel preparation and storage, kiln system consisting of pyro-processing rotary preheater kilns, coal mills, clinker coolers, finish mills, cement transfer, storage, and shipping.

Both dry kilns were retrofitted with two-stage preheaters in the 1980s for the purposes of fuel efficiency and other improvements. As part the project to retrofit the preheaters, the length of each kiln was reduced by roughly 30 feet.

The kilns also utilize baghouse dust collectors to reduce particulate matter emissions. In 2012, AQD issued a permit authorizing construction of new baghouses combining kiln and clinker cooler exhausts and a common stack venting both kilns and clinker coolers exhausts. These modifications were performed to comply with the revised emission limits of Portland Cement Maximum Achievable Control (MACT) regulations. GCC installed the baghouses and the stack in 1st Quarter 2015.

4. EXISTING EMISSIONS AND VISIBILITY IMPAIRMENT ASSESSMENT

This section summarizes emission rates that are used as baseline rates in the four factor analyses presented in Sections 5 and 6 of this report.

4.1. ANNUAL BASELINE EMISSION RATES

Baseline emission rates in tons per year of NO_x and SO_2 are used in the reduction cost-effectiveness analysis to determine the annual dollars of control cost per ton of pollutant reduced.

Table 4-1 below summarizes the kiln emission factors on a pounds pollutant per ton of clinker (lb/ton) basis using stack tests conducted each year. As shown in the table, NO_X and SO_2 emissions are highly variable, which is typical for cement kilns. NO_X and SO_2 emission levels range from 3.9 to 5.9 lb NO_X/ton and 0.4 to 1.8 lb SO_2/ton.

Use of the average emission factor over the baseline three-year period for SO_2 or NO_X does not appropriately represent the facility's baseline emission levels because the regional haze baseline and projected 2028 emissions should more cautiously represent what present and near future emissions would be under expected operating conditions. GCC believes the levels observed during short-term emission testing programs such as stack tests may represent a snapshot of unusually low or unusually high emission levels. SO_2 emissions in cement kilns are highly variable, as the emissions for a given day and even a given hour are highly dependent on fuel sulfur content, raw material sulfur content, and the operating conditions of the kiln itself. The Portland Cement Association (PCA) describes this variability in the amount of sulfur compounds in their published analysis of SO_2 formation in cement kilns:[5]

> Depending on the temperature, excess oxygen (O_2) level, alkali level, chloride level, presence of carbon monoxide (CO) and/or other reducing species, and a number of other controlling factors, the forms of sulfur in the various zones of the cement kiln system can be highly variable.

Figure 4-1 below illustrates this SO_2 variability by showing the SO_2 level during each run of the three stack tests conducted during the baseline years. As most apparent during the 2017 test, the SO_2 levels changed by nearly double from one hour to the next, and the 3-run average during the 2017 test is over double that of the 2018 test and over four times the level during the 2016 test. Figure 4-2 illustrates a similar variability in the NO_X emissions from the GCC Tijeras kilns. The details of the stack test run results are included in Appendix F of this report. For the purposes of the baseline emissions for regional haze specifically, no one stack test run or 3-run average can adequately represent continuous facility emissions. However, with the limited data points available, the maximum of the three-run average stack test is the most representative of expected current and near future typical operating conditions. Therefore, the maximum 3-run average stack test over the most recent three years is used for developing the facility's baseline emission factor in order to account for the inherent variability of SO_2 and NO_X from the Tijeras kilns.

[5] Miller, F. M., Young, G. L., and von Seebach, M., "Formation and Techniques for Control of Sulfur Dioxide and Other Sulfur Compounds in Portland Cement Kilns." Portland Cement Association, 2001. R&D Serial No. 2460, Page 12. http://www2.cement.org/pdf_files/sn2460.pdf.

Table 4-1. Stack Test Emission Factors (lb/ton clinker)

	2016	2017	2018
SO_2	0.37	**1.75**[a]	0.60
NO_X	4.81	**5.90**[a]	3.87

[a] Emission factors provided in bold represent the selected emission factor for each pollutant for the baseline emissions in this report.

Figure 4-1. SO_2 Stack Test Summary

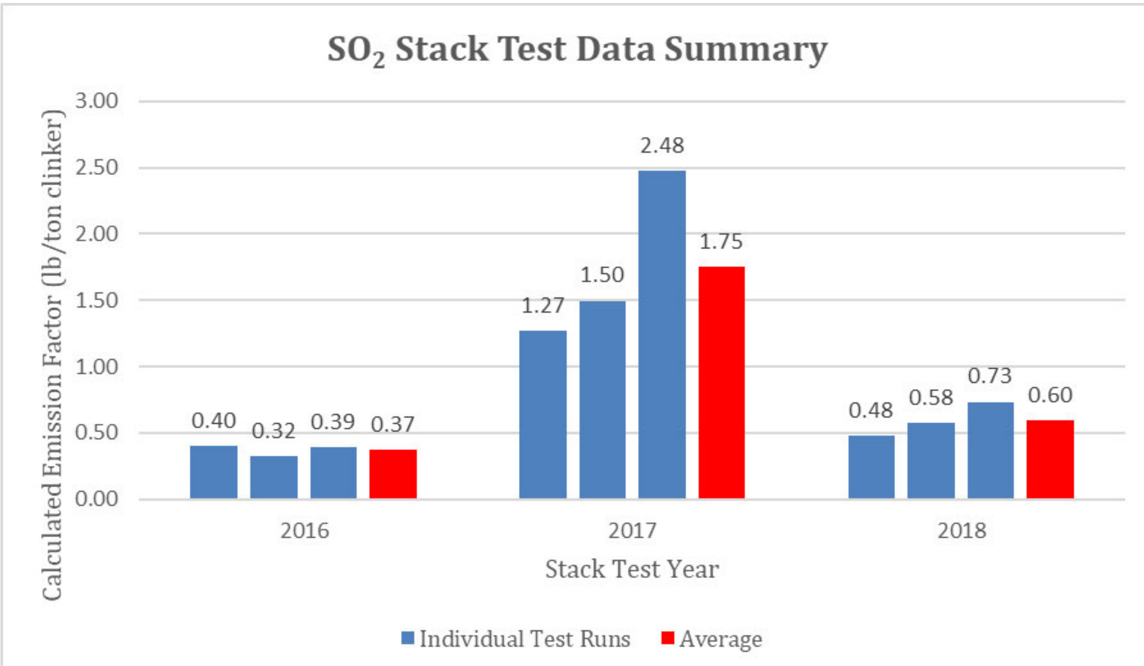


Figure 4-2. NO_X Stack Test Summary

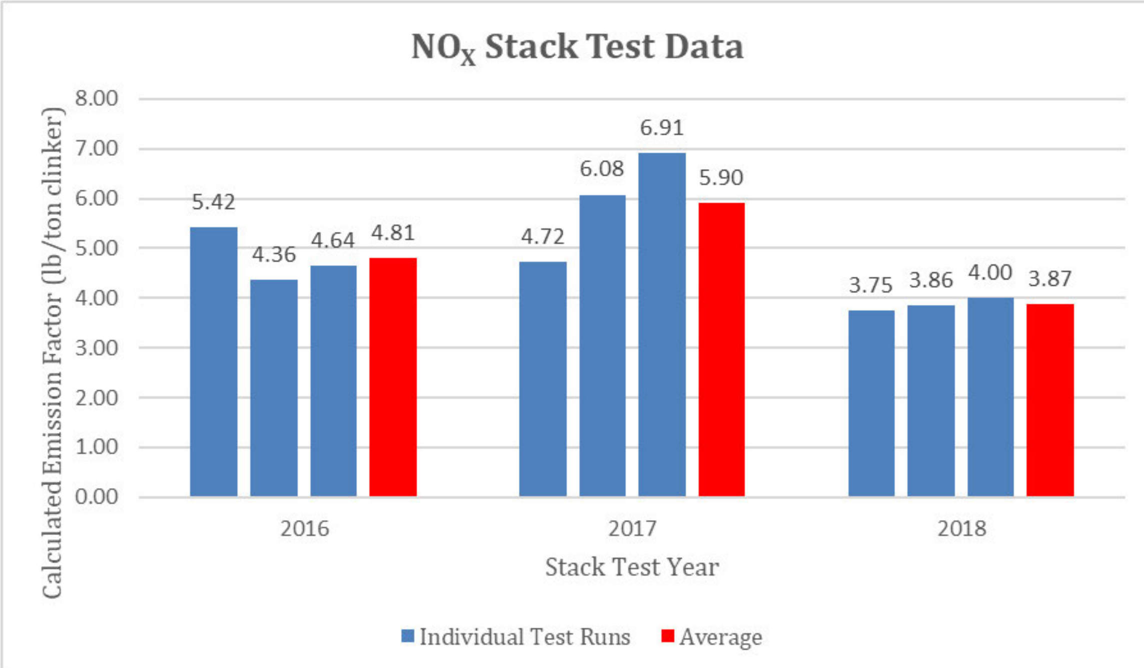


Table 4-2 below summarizes the baseline annual emission rates in tons per year, including the actual annual clinker production rates used to calculate each baseline emission rate.

Table 4-2. Baseline Annual Emissions

	Emission Factor (lb/ton Clinker)	2016	2017	2018	Average
Average Clinker Production (tpy)	--	410,587	404,674	411,057	408,773
SO_2 (tpy)	1.75	359	354	359	357
NO_X (tpy)	5.90	1,212	1,194	1,213	1,206

SO_2 emissions from the GCC Tijeras kilns are minimal relative to emissions in the state as a whole. Per WRAP's 2017 Milestone Report for SO_2 emissions, the total SO_2 emissions in 2017 totaled 10,419 tons for the state of New Mexico.[6] GCC Tijeras' baseline SO_2 emission rate of 357 tpy is less than 3.5% of the state-wide SO_2

[6] "2017 Regional SO_2 Emissions and Milestone Report," Western Regional Air Partnership (WRAP), March 2019. https://www.env.nm.gov/wp-content/uploads/2019/02/DRAFT-2017-Milestone-Report_2192019.pdf

emissions. At this small baseline rate, reductions in SO_2 from this facility will produce only limited improvement to visibility in the region, and perhaps no measurable visibility improvement at all.

The rate of SO_2 emitted from the Tijeras kilns is exceptionally low and no add-on controls are necessary to bring the kilns' SO_2 emissions to levels comparable with new kilns with in-line raw mills. The Portland Cement Association (PCA), in its review of SO_2 emissions and controls for cement kilns, included reference to SO_2 emission rates from various types of cement kilns. Long dry kilns have an average reported SO_2 emissions baseline of 7.83 lb SO_2 per ton clinker, with a range of values of 2 to 13 lb SO_2 per ton of clinker.[7] The baseline emissions for the GCC Tijeras kilns are below the minimum for long dry kilns. Furthermore, the Tijeras kilns baseline level is below the average SO_2 emission rate for preheater kilns, the kiln type with the lowest SO_2 emission level (1.75 lb/ton baseline compared to an average of 1.83 lb/ton for preheater kilns). Recent stack tests at the GCC Tijeras site indicate that the SO_2 emission levels from the kilns are comparable to permitted values for some new or modified kilns, which include newer kilns with in-line raw mills. [8]

The NO_x emission factors published by the U.S. EPA for long dry kilns range from 6.1-10.5 lb/ton.[9] Considering the age and type of these kilns, both kilns emit lower NO_x than comparable kilns. The maximum emission factor observed during the recent stack tests indicates that the NO_x emission levels are still below the comparable long dry kiln.

[7] Miller, F. M., Young, G. L., and von Seebach, M., "Formation and Techniques for Control of Sulfur Dioxide and Other Sulfur Compounds in Portland Cement Kilns." Portland Cement Association, 2001. R&D Serial No. 2460, Page 19. http://www2.cement.org/pdf_files/sn2460.pdf.

[8] RBLC search results are provided in Appendix C of this report.

[9] U.S. EPA, Office of Air Quality Planning and Standards, Alternative Control Techniques Document Update - NOx Emissions from New Cement Kilns, EPA-453/R-07-006, Table 2-1, November 2007.

5. SO_2 FOUR FACTOR EVALUATION

The four-factor analysis is satisfied by conducting a step-wise review of emission reduction options in a top-down fashion. The steps are as follows:

Step 1. Identify all available retrofit control technologies
Step 2. Eliminate technically infeasible control technologies
Step 3. Evaluate the control effectiveness of remaining control technologies
Step 4. Evaluate impacts and document the results

Cost (Factor 1) and energy / non-air quality impacts (Factor 3) are key factors determined in Step 4 of the step-wise review. However, timing for compliance (Factor 2) and remaining useful life (Factor 4) are also discussed in Step 4 to fully address all four factors as part of the discussion of impacts. Factor 4 is primarily addressed in in the context of the costing of emission reduction options and whether any capitalization of expenses would be impacted by a limited equipment life.

The baseline SO_2 emission rates that are used in the SO_2 four-factor analysis are summarized in Table 4-1 and Table 4-2. The basis of the emission rates is provided in Section 4 of this report.

5.1. STEP 1: IDENTIFICATION OF AVAILABLE RETROFIT SO_2 REDUCTION TECHNOLOGIES

SO_2 is generated during fuel combustion in a cement kiln, as the sulfur in the fuel is oxidized by oxygen in the combustion air. Sulfur in the raw material also contributes to a kiln's SO_2 emissions.

Step 1 of the top-down control review is to identify available retrofit reduction options for SO_2. The available SO_2 retrofit control technologies for the GCC Tijeras kilns are summarized in Table 5-1. The retrofit controls include both add-on controls that eliminate SO_2 after it is formed and switching to lower sulfur fuel that reduces the formation of SO_2.

Table 5-1. Available SO_2 Control Technologies and Measures for GCC Tijeras Kilns 1 and 2

SO_2 Control Technologies
Good Combustion Practices (Base Case)
Alternative Low Sulfur Fuels
Dry Sorbent Injection
Wet Scrubbing
Semi-Wet/Dry Scrubbing
Inherent Dry Scrubbing (Base Case)

5.1.1. Good Combustion Practices (Base Case)

Good combustion practices that maximize fuel efficiency reduce SO_2 by minimizing the combustion of sulfur contained in the fuel. Sulfur content in the coal fired in GCC Tijeras kilns is low (1.2% at the highest and typically lower than 1%), so minimal SO_2 reduction can be achieved through reduced fuel combustion. Both dry kilns were retrofitted with two-stage preheaters in the 1980s, in part, for the purpose of fuel efficiency. As part of this project, the length of each kiln was reduced by roughly 30 feet. Per the Portland Cement Association, "operating alterations that may reduce SO_2 emissions include an appropriate arrangement of the burner system to provide the necessary O_2 for efficient combustion and flame orientation. It must be noted that oxidizing conditions in the burning zone that limit SO_2 emissions are favorable for the generation of nitrogen oxides (NO_X) in the rotary kiln."[10] The EPA has nevertheless identified that process modifications that focus on reduced heat consumption, energy efficiency, and stable process parameters have a secondary effect of reducing emissions of SO_X.[11]

SO_2 emissions from cement kilns are highly dependent on the sulfur content in the raw material processed, a factor that cannot be controlled via good combustion practices. The use of good combustion practices is considered technically feasible and already implemented. GCC has a financial incentive to optimize combustion and thermal performance, which minimizes fuel costs and promotes kiln stability; as such, GCC prioritizes operating the Tijeras cement kilns to optimize good combustion and energy efficiency, while maintaining clinker quality and process stability. Both kilns undergo an inspection of the components of the combustion system at least once per year and inspection requirements are maintained and revised as necessary under the facility's O&M plan. Therefore, the resulting controlled level of SO_2 emissions is accounted for in the baseline emissions for this analysis.

5.1.2. Inherent Dry Scrubbing (Base Case)

Inherent dry scrubbing occurs in the cement kiln system as SO_2 in the combustion gases interacts with the reducing agents contained in the raw materials processed in the kiln. Baseline emissions account for this form of SO_2 reduction. All alternative methods of SO_2 reduction in this analysis will assume that the kilns maintain the current level of inherent dry scrubbing.

5.1.3. Alternative Low Sulfur Fuels

Fuels that can be considered for the cement kilns must have sufficient heat content, be dependable and readily available locally in significant quantities to not disrupt continuous production. In addition, they must not adversely affect product quality or have a negative impact on the environment.

Currently the GCC Tijeras kilns utilize coal during normal operations. Alternative lower-sulfur fuels that can be considered as primary fuels include natural gas, diesel, and TDF.

[10] Miller, F. M., Young, G. L., and von Seebach, M., "Formation and Techniques for Control of Sulfur Dioxide and Other Sulfur Compounds in Portland Cement Kilns." Portland Cement Association, 2001. R&D Serial No. 2460, Page 4. http://www2.cement.org/pdf_files/sn2460.pdf.

[11] USEPA, Office of Air Quality Planning and Standards. NO_X Control Technologies for the Cement Industry. EPA-457/R-00-002, Page 54.

5.1.4. Dry Sorbent Injection

Dry sorbent injection involves spraying a powdered sorbent, typically consisting of lime, sodium bicarbonate, or trona[12] into the flue gas stream. The sorbent interacts with acid gases (HCl, for example) or SO_2 and forms larger particles that can be removed using a filter downstream of the injection.

5.1.5. Wet Scrubbing

A wet scrubber is a tailpipe technology that may be installed downstream of the kilns, either prior to or downstream from the baghouse. In a typical wet scrubber, the flue gas flows upward through a reactor vessel that has an alkaline reagent flowing down from the top. The scrubber mixes the flue gas and alkaline reagent using a series of spray nozzles to distribute the reagent across the scrubber vessel. The alkaline reagent, often a calcium compound, reacts with the SO_2 in the flue gas to form calcium sulfite and/or calcium sulfate that is removed with the scrubber sludge and disposed. Most wet scrubber systems used forced oxidation to assure that only calcium sulfate sludge is produced.

5.1.6. Semi-Wet/Dry Scrubbing

This technology is considered a semi-wet or semi-dry control technology. A scrubber tower is installed prior to the baghouse. Atomized hydrated lime slurry is sprayed into the exhaust flue gas. The lime absorbs the SO_2 in the exhaust and is converted to a powdered calcium/sulfur compound. The particulate control device removes the solid reaction products from the gas stream.

5.2. STEP 2: ELIMINATE TECHNICALLY INFEASIBLE SO_2 CONTROL TECHNOLOGIES

Step 2 of the top-down control review is to eliminate technically infeasible SO_2 control technologies that were identified in Step 1.

5.2.1. Alternative Low Sulfur Fuels

Natural gas and diesel, as primary fuels, are both considered technically feasible replacements for coal as the primary fuel source at this facility, and thus they will be evaluated further. It is worth noting, however, that the combustion of natural gas tends to increase thermal NO_X production. Diesel and natural gas as the primary fuel source for the kilns are both costly reduction options. Tijeras kilns are currently permitted to use coal or natural gas as primary fuels. If the economics of utilizing more natural gas become feasible, GCC maintains the flexibility of using more natural gas at the facility.

The facility is currently permitted for the use of TDF for its two cement kilns but does not actively utilize this fuel. In its evaluation of the impact of firing TDF in cement kilns on SO_2 emissions, the Portland Cement Association (PCA) concluded that while there may be a slight beneficial impact, "the variability of sulfur dioxide emissions is too large to conclusively demonstrate the benefits of TDF firing on emissions."[13]

[12] Trona is a sodium carbonate compound, which is processed into soda ash or baking soda. https://www.wyomingmining.org/minerals/trona/

[13] Richards, J., Goshaw, D., Speer, D. and Holder, T. "Air Emissions Data Summary for Portland Cement Pyroprocessing Operations Firing Tire-Derived Fuels." Portland Cement Association, 2008. PCA R&D Serial No. 3050. https://swap.stanford.edu/20120110003514/http://www.epa.gov/epawaste/conserve/materials/tires/pubs/tdf-report08.pdf

Additionally, in a study investigating the potential to remove sulfur from TDF, it was determined that TDF can have a sulfur content as high as 2.5%.[14] This is more than 2 times the maximum sulfur content of the coal received at GCC (1.2%). Due to the substantial uncertainty in the effectiveness of TDF for SO_2 control and the likelihood sulfur in the TDF would be similar to or higher than the sulfur content in the base case coal, the use of TDF is not considered as a SO_2 reduction option for the GCC Tijeras kilns.

5.2.2. Dry Sorbent Injection

Dry sorbent injection will necessitate the production, storage, and transportation of significant quantities of lime. The lime manufacturing process results in the emission of SO_2 and NO_X, as well as other visibility-impairing pollutants, in significant quantities. This result is directly counter to the goals of the regional haze program. While this does not directly impact the technical feasibility of the control technology at the Tijeras facility, it is important to note that the impact of the control technology on regional haze is reduced when considering the associated secondary emissions directly caused by the use of the lime. Dry sorbent injection is technically feasible and will be considered further.

5.2.3. Wet Scrubbing

The GCC Tijeras plant has on-site wells with a water supply currently sufficient for the water required to operate a wet scrubber. There are significant concerns, however, regarding the use of a water-intensive processes in arid climates such as New Mexico's. With careful use of water resources at the forefront of environmental conservation efforts in the area, any control technologies that require the use of water should be considered with caution. This technology is nevertheless considered technically feasible and will be evaluated further. The application of wet scrubber is limited in the U.S. cement industry, as only a few cement plants have installed wet scrubber and the specifics of its installation, use, and success remain unproven.[15]

5.2.4. Semi-Wet/Dry Scrubbing

As with wet scrubbing processes, effort should be placed to limit the unnecessary use of water in arid regions of the country like New Mexico. Semi-wet/dry scrubbing is technically feasible and will be considered further.

[14] Unapumnuk, K., Keener, T.C., Lu, M., Liang, F. "Investigation into the removal of sulfur from tire derived fuel by pyrolysis." Department of Civil and Environmental Engineering, University of Cincinnati. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.495.7118&rep=rep1&type=pdf

[15] The only documented instance of a wet scrubber being installed in the RBLC search results are in reference to particulate matter (PM) or sulfuric acid control at the LafargeHolcim Midlothian, TX cement plant. These results are included in Appendix C because the Midlothian permit states the scrubber was also for SO_2 emissions controls. According to Colorado's previous regional haze progress analysis, LafargeHolcim's Florence, CO facility has installed a wet scrubber for SO_2 control (https://www.colorado.gov/pacific/sites/default/files/AP_PO_Holcim-Portland-Cement-Plant_0.pdf). Per the control technology analysis conducted for the Carolinas Cement Company's Castle Hayne, NC plant, only three other plants have wet scrubbers: TXI's Midlothian, TX plant and Lehigh's Mason City, IA plant, as well as Holcim's Dundee, MI plant (which has since closed in 2009 due to economic challenges). https://ncdenr.s3.amazonaws.com/s3fs-public/Air%20Quality/permits/psd/docs/titan/Carolinas_Cement_Control_Technology_Analysis_Report_040808.pdf

5.3. STEP 3: RANK OF TECHNICALLY FEASIBLE SO_2 REDUCTION OPTIONS BY EFFECTIVENESS

Step 3 of the top-down control review is to rank the technically feasible options by effectiveness. Table 5-2 presents available and feasible SO_2 control technologies for the kilns and their associated reduction efficiencies.

Table 5-2. Ranking of SO_2 Control Technologies by Effectiveness

Pollutant	Control Technology	Potential Reduction Efficiency (%)
SO_2	Wet Scrubbing[a]	95
	Semi-wet/dry Scrubbing[a]	90
	Alternative Low Sulfur Fuel – All Natural Gas[b]	65
	Alternative Low Sulfur Fuel – All Diesel[b]	65
	Dry Sorbent Injection[c]	50
	Inherent Dry Scrubbing[d]	Base Case
	Good Combustion Practices	Base Case

[a] Wet Scrubber and Semi-wet/dry Scrubber reduction efficiencies are determined using the EPA Air Pollution Control Technology Fact Sheet, Flue Gas Desulfurization (FGD) – Wet, Spray Dry, and Dry Scrubbers. (https://www3.epa.gov/ttn/catc/dir1/ffdg.pdf) Wet scrubber efficiency is that of systems that use lime as the sorbent of choice (page 3), and semi-dry efficiency is the upper end of the range provided, for conservatism (page 4).

[b] Alternative fuel scenario reduction efficiencies are calculated using a material balance on the fuel sulfur (coal sulfur content based on data for the Title V renewal application filed in 2016), with fuel sulfur emissions reductions assumed to be independent of feed sulfur emissions and inherent dry scrubbing.

[c] Dry sorbent injection reduction efficiency is determined based on values for hydrated lime injection with a baghouse, provided in the EPA Documentation for EPA's Power Sector Modeling Platform v6, Using the Integrated Planning Model Appendix 5-5: DSI Cost Development Methodology, April 2017. Table 1, Page 8. https://www.epa.gov/sites/production/files/2018-05/documents/attachment_5-5_dsi_cost_development_methodology.pdf

[d] Estimated reduction efficiency from inherent dry scrubbing is approximately 90%. This reduction efficiency is determined using a balance on the sulfur entering and exiting the kiln, and the value falls within the range provided in the Portland Cement Association's "Formation and Techniques for Control of Sulfur Dioxide and Other Sulfur Compounds in Portland Cement Kiln Systems" (PCA R&D Serial No. 2460), Page 39. http://www2.cement.org/pdf_files/sn2460.pdf. A reduction efficiency of approximately 90% is required for the calculated fuel sulfur entering the system to be less than the reported annual sulfur emissions. The reduction efficiency will be applied prior to the additional reduction efficiency of add-on control technologies. Detailed calculations are provided in Appendix A of the report.

The calculation of reduction efficiency for the alternative fuel scenarios takes into account two key assumptions:

- Changing the primary fuel will fully reduce sulfur by the difference in sulfur levels between the fuel types being compared, affecting only the emissions directly resulting from sulfur contained in the fuel. SO_2 emitted from sulfur contained in the raw material that is processed in the kilns is assumed to not be affected.
- The reduction efficiencies assume the same level of inherent scrubbing reduction takes place under all fuel scenarios. These alternative fuel efficiency values are the incremental reduction efficiencies that take place as a result of the fuel switching beyond the inherent control.

Given the complexity in SO_2 generation resulting from fuel sulfur vs. raw material sulfur, assuming the fuel switching fully reduces sulfur by the difference in sulfur levels between the fuel types is particularly conservative. In reality, inherent SO_2 reduction would likely be substantially reduced when the SO_2 concentration in the exhaust stream routed through the pre-heater is reduced. Therefore, assuming constant inherent SO_2 reduction will produce conservatively high SO_2 reduction estimates and conservatively low cost of the reduction option in terms of dollars per ton.

5.4. STEP 4: EVALUATION OF IMPACTS FOR TECHNICALLY FEASIBLE SO_2 CONTROLS

Step 4 of the top-down control review is the impact analysis. The impact analysis considers the:

- Cost of compliance
- Energy impacts
- Non-air quality impacts; and
- The remaining useful life of the source

5.4.1. Cost of Compliance

For purposes of this four-factor analysis, the capital costs, operating costs, and cost effectiveness of wet scrubbing, semi-wet/dry scrubbing, dry sorbent injection, and fuel switching have been estimated. Currently, the GCC Tijeras kilns combust coal during normal operation and pipeline natural gas during kiln startups. The two scenarios that have been considered are (1) switching to all diesel and (2) switching to all natural gas.

5.4.1.1. Control Costs

The capital and operating costs of the wet scrubber and semi-wet/dry scrubber that are used in the cost effectiveness calculations are estimated based on recent vendor quotes for similar sources, along with published calculations methods. The capital cost is annualized over a 20-year period and then added to the annual operating costs to obtain the total annualized cost. The details of the capital and operating cost estimates are provided in Appendix B of this report.

Dry sorbent injection cost estimates are based on data from the Portland Cement Association, as well as quotes for projects at similar facilities. Costs are then annualized over a 20-year period.

The cost of the fuel switching that is used in the cost effectiveness calculations is determined by calculating the current annual cost of using coal and determining the increased cost of switching to all diesel and all natural gas. Details are provided in Appendix B.

Switching fuel may require changes to the burners and the fuel storage, processing and delivery system. Upgrades would include piping for the fuel, tanks for the storage of the necessary diesel or natural gas, and a new burner nozzle for the combustion of the new fuel. These additions represent a substantial capital cost. However, these capital expenses are not included in this cost analysis because the cost of switching the fuels alone is cost ineffective for SO_2 emissions reduction. The control cost for each option is summarized in Table 5-3.

5.4.1.2. Annual Tons Reduced

The annual tons reduced that are used in the cost effectiveness calculations are determined by subtracting the estimated controlled annual emission rates from the baseline annual emission rates. The baseline annual emission rates are summarized in Table 4-2. For a wet scrubber and semi-wet/dry scrubber, the controlled annual emission rate is based on the assumed maximum reduction efficiency noted in Table 5-2. For alternative fuel scenarios, the controlled annual emission rates are estimated by conducting a mass balance on the sulfur in the various fuels relative to the current baseline. The coal sulfur content was provided in the Title V permit application (0.81%).[16] For diesel, it is assumed that typical sulfur concentrations would remain at 15 parts per million (0.0015%).[17] For natural gas, it is assumed that supplies would contain less than 0.2 grains sulfur per 100 standard cubic feet.[18] Details are provided in Appendix B.

An estimate of the amount of SO_2 that may be reduced annually for each of the proposed options is summarized in Table 5-3.

5.4.1.3. Cost Effectiveness

The cost effectiveness is determined by dividing the annual control cost by the annual tons reduced. Table 5-3 summarizes the results of the cost effectiveness calculations.

Costs and cost effectiveness considerations at the GCC Tijeras facility should be treated differently than other facilities in the Portland cement industry for multiple reasons. First, complications associated with the older kilns at GCC Tijeras result in inconsistencies in operating conditions causing higher likelihood of unforeseen control costs and higher kiln operating costs. Second, the limitations on the transportation of products, raw material, fuel, and equipment due to the lack of access to rail or water-based transport cause higher plant operating costs. Lastly, in the case of GCC Tijeras, the raw material cost of limestone is also higher. On a dollar per ton clinker produced basis, limestone costs at Tijeras are approximately 2.5 times more expensive when compared to the other GCC facilities (based on a weighted average of costs at other facilities accounting for the production rates at each facility). Therefore, considering higher limestone costs alone, if a cost effectiveness value of $5,000 per ton is used at another cement plant to demonstrate a technology is not cost effective, an equivalent threshold at GCC Tijeras should be at least 2.5 times lower (or $2,000 per ton). While this does not directly impact the individual control costs themselves for each control technology, an accurate assessment of the financial impact of each control technology on the GCC Tijeras operations and whether the technology is cost effective for GCC Tijeras must take into account this substantial difference in the costs of operating at this facility.

[16] City of Albuquerque Environmental Health Department, Air Quality Division, Title V Permit Application for GCC Rio Grande Inc. (Tijeras Plant), Appendix A, Section 5, Fuels and Fuel Usage

[17] Ultra-low sulfur diesel (ULSD) value used to determine diesel sulfur content. EPA, Diesel Fuel Standards and Rulemakings. https://www.epa.gov/diesel-fuel-standards/diesel-fuel-standards-and-rulemakings

[18] Sulfur content provided in the U.S. EPA's AP-42 Section 1.4.3 "Natural Gas Combustion". https://www3.epa.gov/ttnchie1/ap42/ch01/final/c01s04.pdf

As demonstrated in Table 5-3, most SO_2 reduction options cost over $15,000 per ton of SO_2 reduced (most well over this value), and therefore these options are not cost effective.

Table 5-3. SO_2 Cost of Compliance Based on Emissions Reduction

Control Option	Control Cost ($/yr)	Baseline Emission Level (tons)	SO_2 Reduction (%)	Emission Reduction (tons)	Cost Effectiveness ($/ton removed)
Wet Scrubbing	$5,429,039	357	95.00%	305[b]	$17,786
Semi-wet/dry Scrubbing	$4,613,620	357	90.00%	289[b]	$15,955
Dry Sorbent Injection	$154,755	357	50.00%	161[b]	$963
Alt. Fuel – All Natural Gas	$5,764,159	357	32%	113	$50,807
Alt. Fuel – All Diesel	$34,591,075	357	32%	113	$305,128

[a] Assumes a 90% Uptime for the add-on control device to allow for maintenance, bulk loading and unloading, and unanticipated process interruptions. In the case of controls involving the use of lime, moisture from even changes in weather can result in plugging of system components.

5.4.2. Timing for Compliance

GCC Tijeras believes that reasonable progress compliant controls are already in place. However, if EHD determines that one of the SO_2 reduction options analyzed in this report is necessary to achieve reasonable progress, it is anticipated that this change could be implemented within three years of the determination in the case of dry sorbent injection, based on experience at other GCC facilities for sorbent injection systems used for HCl control. In the case of wet or semi-wet scrubbers, a time span of five years is anticipated due to the increased complexity associated with the design and installation.

5.4.3. Energy Impacts

The cost of energy required to operate the control devices has been included in the cost analyses found in Appendix B. To operate any of the add-on control devices, there would be decreased overall plant efficiency due to the operation of these add-on controls. At a minimum, this would require increased electrical usage by the plant with an associated increase in indirect (secondary) emissions from nearby power stations.

In the case of the scrubbers, the static pressure drop through the wet scrubber can increase the electrical energy demand for the project, resulting in an adverse impact on energy usage at the site. There is also the potential for an increased energy demand for reheating stack gases, depending on the resulting operating conditions after the wet scrubber is installed.[19]

The use of emissions reduction options involving the injection of lime (dry sorbent injection, wet scrubbing, a semi-wet/dry scrubbing) also pose significant implications for energy impacts. The production of lime is an energy-intensive process, one that can have direct impacts on emission levels directly counter to regional haze efforts. This lime production emissions increase would then be coupled with the energy and emissions impacts resulting from the transportation of the lime to the facility. The production and delivery of lime to the GCC Tijeras facility would require significant energy, and it would result in emission increases of pollutants that directly contribute to visibility impairment around the country. Even though the additional cost associated with the secondary energy impacts may be incorporated in the utility and operating costs for each control technology, the environmental impacts are nevertheless substantial and directly counter to the goals of the regional haze program.

5.4.4. Non-Air Quality Environmental Impacts

Most of the alternative SO_2 reduction options that have been considered in this analysis have additional negative environmental impacts associated with them:

- A semi-wet/dry hydrated lime control system, for example, will require water to hydrate lime. There will also be additional material collected in the baghouses that will require disposal.
- A wet scrubber will require a significant quantity of water as well. In the Colorado Air Pollution Control Division (APCD) general analysis in the Regional Haze SIP, the APCD concluded, with regards to SO_2 controls, that wet scrubbing or wet flue gas desulfurization (FGD) has significant negative environmental impacts, particularly in the arid West, where water scarcity is a significant concern.[20] These considerations are particularly relevant when weighing the benefits of a wet vs. a semi-wet or dry control technology, as wet scrubbing requires a significant quantity of water. In addition, environmental concerns associated with sludge disposal and visible plumes resulted in the APCD's determination that wet scrubbers did not qualify as BART for every source in Colorado where a wet scrubber was considered and not already installed.[21] This logic is equally relevant for regional haze in New Mexico. With careful use of water resources at the forefront of environmental conservation efforts in the area, any control technologies that require the use of water should be considered with caution.
- Diesel fuel will require additional storage tanks at the facility. Petroleum storage adds to the risk of a release to the waterways around the plant.

5.4.5. Remaining Useful Life

The remaining useful life of the kilns does not affect the annualized cost of an add-on control technology because the useful life is anticipated to be at least as long as the capital cost recovery period. All control technologies are assumed to have a remaining useful life of 20 years.

[19] The energy impacts are consistent with an evaluation of wet scrubbers conducted for the Carolinas Cement company. https://ncdenr.s3.amazonaws.com/s3fs-public/Air%20Quality/permits/psd/docs/titan/Carolinas_Cement_Control_Technology_Analysis_Report_040808.pdf

[20] Colorado Air Pollution Control Division (APCD), "Colorado Visibility and Regional Haze State Implementation Plan for 12 Mandatory Class I Federal Areas." 7 January, 2011. Page 46. https://environmentalrecords.colorado.gov/HPRMWebDrawer/RecordView/1208384

[21] Ibid, Appendix C, Pages 126, 129.

5.5. SO_2 CONCLUSION

While several SO_2 reduction options are technically feasible, most are extremely cost ineffective. Wet and semi-wet scrubber technologies and both alternative fuel scenarios are well over $40,000 per ton of SO_2 removed. The only option that offers a potentially cost-effective method of SO_2 reduction for this facility is the use of dry sorbent injection. However, the capital investment and negative energy and environmental impacts from the production, transportation, and storage of lime (or other dry sorbent) outweigh the minimal SO_2 reduction that may be achieved. SO_2 emissions from this facility are insignificant relative to the total emissions from the state, with the GCC Tijeras SO_2 baseline totaling less than 3.5% of state-wide 2017 SO_2 emissions; thus, the SO_2 reduction from dry sorbent injection would be less than 2% of state-wide SO_2 emissions. At this low level, any SO_2 emissions reductions made would be unlikely to result in meaningful visibility improvement in the region.

At this time, there are no SO_2 emission reduction measures that are technically feasible, cost effective, and appropriate to implement for the two kilns at the Tijeras Plant.

As described in Section 2, Factors 1 and 3 of the four-factor analysis were considered by conducting a step-wise review of NO_X emission reduction options in a top-down fashion. The steps are as follows:

Step 1. Identify all available retrofit control technologies
Step 2. Eliminate technically infeasible control technologies
Step 3. Evaluate the control effectiveness of remaining control technologies
Step 4. Evaluate impacts and document the results

Cost (Factor 1) and energy / non-air quality impacts (Factor 3) are key impacts determined in Step 4 of the step-wise review. However, timing for compliance (Factor 2) and remaining useful life (Factor 4) are also discussed in Step 4 to fully address all four factors as part of the discussion of impacts. Factor 4 is primarily addressed in in the context of the costing of emission reduction options and whether any capitalization of expenses would be impacted by a limited equipment life.

The baseline NO_X emission rates that were used in the NO_X four-factor analysis are summarized in Table 4-1 and Table 4-2. The basis of the emission rates is provided in Section 4 of this report.

6.1. STEP 1: IDENTIFICATION OF AVAILABLE RETROFIT NO_X CONTROL TECHNOLOGIES

NO_X emissions are produced during fuel combustion when nitrogen contained in the fuel and combustion air is exposed to high temperatures. The origin of the nitrogen (i.e. fuel vs. combustion air) has led to the use of the terms "thermal" NO_X and "fuel" NO_X when describing NO_X emissions from the combustion of fuel. Thermal NO_X emissions are produced when elemental nitrogen in the combustion air is admitted to a high temperature zone and oxidized. Fuel NO_X emissions are created during the rapid oxidation of nitrogen compounds contained in the fuel. Many variables can affect the equilibrium in the kiln system, which in turn affects the creation of NO_X.[22]

Most of the NO_X formed within a rotary cement kiln is classified as thermal NO_X. Virtually all of the thermal NO_X is formed in the region of the flame at the highest temperatures, approximately 3,000 to 3,600 degrees Fahrenheit. A small portion of NO_X is formed from nitrogen in the fuel that is liberated and reacts with the oxygen in the combustion air.

Step 1 of the top-down control review is to identify available retrofit reduction options for NO_X. The available NO_X retrofit control technologies for the GCC Tijeras kilns are summarized in Table 6-1.

[22] Alternative Control Techniques Document Update - NOx Emissions from New Cement Kilns, U.S. Environmental Protection Agency, November 2007 (EPA-453/R-07-006), p. 3.

Table 6-1. Available NO_X Control Technologies for GCC Tijeras Kilns 1 and 2

NO_x Control Technologies	
Combustion Controls	Good Combustion Practices (Base Case) Alternative Fuel (TDF) Low NO_x Burners (LNB)
Post-Combustion Controls	Selective Catalytic Reduction (SCR) Selective Non-Catalytic Reduction (SNCR) Catalytic Filters

NO_X emissions controls, as listed in Table 6-1, can be categorized as combustion or post-combustion controls. Combustion controls reduce the peak flame temperature and excess air in the kiln burner, which minimizes NO_X formation. Post-combustion controls, such as selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR), convert NO_X in the flue gas to molecular nitrogen and water.

6.1.1. Combustion Controls

6.1.1.1. Good Combustion Practices (Base Case)

Both dry kilns were retrofitted with two-stage preheaters in the 1980s, in part, for the purpose of fuel efficiency. As part of the project to retrofit the preheaters, the length of each kiln was reduced by roughly 30 feet. The use of preheaters allows for lower fuel use and thus lower NO_X formation in the kiln itself. GCC employs several practices to optimize thermal performance, including use of flue gas recirculation, ensuring kiln seal integrity, and use of an oxygen sensor to give feedback to operators to remain within the target range for good combustion.

GCC has a financial incentive to optimize combustion and thermal performance, which minimizes fuel costs and promotes kiln stability; as such, GCC prioritizes operating the Tijeras cement kilns to optimize good combustion and energy efficiency, while maintaining clinker quality and process stability. As a result of these good combustion practices, NO_X emissions are minimized.[23] Both kilns undergo an inspection of the components of the combustion system at least once per year, and inspection requirements are maintained and revised as necessary under the facility's O&M plan. For the purposes of this analysis, baseline emissions already account for the level of control resulting from good combustion practices.

6.1.1.2. Alternative Fuels

Alternate fuels combusted in kiln systems can result in lower NO_X emissions when compared to the burning of coal. Secondary firing is the process of burning fuel at a lower temperature than that of the primary burning zone of the kiln, where the combustion temperature is the highest, in order to preheat and calcine the raw materials in the kiln. Secondary firing results primarily in fuel NO_X emissions. Other notable factors that affect the NO_X emissions from secondary firing are the volatility of the solid fuel and the temperature in the secondary firing zone. An increase in the volatile content of a fuel results in lower

[23] USEPA, Office of Air Quality Planning and Standards. NO_X Control Technologies for the Cement Industry. EPA-457/R-00-002, Page 54.

nitrogen monoxide (NO) conversion, while an increase in temperature causes the rate of the reaction to increase rapidly. Both outcomes can cause a reduction in the NO_X formed.

Secondary firing with alternative fuels can be accomplished in kilns with precalciners, kilns with preheaters, or conventional long dry kilns. Preheater kilns will use secondary firing to a lesser extent than precalciner kilns, with up to 20% of the fuel being fired into the riser duct of the preheater using a second burner. Dry kilns may also use secondary firing by injecting the solid fuels at a transitional point in the rotary kiln using a feed injection mechanism. This technique allows the material to burn at a temperature lower than the primary combustion temperature. The rotation of the kiln only allows for fuel injection into the kiln once per revolution at most. This limitation, as well as the lower temperature, require solid, slow-burning fuels such as tire derived fuels (TDF).[24] TDF will be considered for alternative fuels moving forward in this analysis.

6.1.1.3. Low-NO_X Burners

Low-NO_X Burners (LNBs) reduce the amount of NO_X initially formed in the flame. The principle of all LNBs is the same: stepwise or staged combustion and localized exhaust gas recirculation (i.e., at the flame). LNBs are designed to reduce flame turbulence, delay fuel/air mixing, and establish fuel-rich zones for initial combustion. The longer, less intense flames reduce thermal NO_X formation by lowering flame temperatures. Some of the burner designs produce a low-pressure zone at the burner center by injecting fuel at high velocities along the burner edges. Such a low-pressure zone tends to recirculate hot combustion gas, which is retrieved through an internal reverse flow zone around the extension of the burner centerline. The recirculated combustion gas is deficient in oxygen, thus producing the effect of flue gas recirculation. Reducing the oxygen content of the primary air creates a fuel-rich combustion zone that then generates a reducing atmosphere for combustion. Due to fuel-rich conditions and lack of available oxygen, formation of thermal NO_X and fuel NO_X are minimized.[25] In the case of the GCC Tijeras kilns, the installation of a low-NO_X burner would require the conversion from direct to indirect firing, as well as an upgrade to the existing coal mill system, resulting in additional capital expenses.

6.1.2. Post Combustion Controls

6.1.2.1. Selective Catalytic Reduction

Selective catalytic reduction (SCR) is an exhaust gas treatment process in which ammonia (NH_3) is injected into the exhaust gas upstream of a catalyst bed. On the catalyst surface, NH_3 and nitric oxide (NO) or nitrogen dioxide (NO_2) react to form diatomic nitrogen and water. The overall chemical reactions can be expressed as follows:

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$$

$$2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O$$

[24] USEPA, Office of Air Quality Planning and Standards. Alternative Control Technologies Document – NOx Emissions from Cement Manufacturing. EPA-453/R-94-004, Page 5-5 to 5-8.

[25] Ibid. Page 5-5 to 5-8.

When operated within the optimum temperature range of 480˚F to 800˚F, the reaction can result in removal efficiencies between 70 and 90 percent.[26] The GCC Tijeras kilns are older with less stable operating temperatures; therefore, the SCR removal efficiency would likely be in the lower end of the range, near 70%. However, for conservatism, a 90% control efficiency is applied in the cost calculations. The rate of NO_X removal increases with temperature up to a maximum removal rate at a temperature between 700˚F and 750˚F. As the temperature increases above the optimum temperature, the NO_X removal efficiency begins to decrease. The application of SCR for NO_X emissions control is extremely limited in the U.S. cement industry, as only one cement plant has installed SCR for NO_X emissions control (in 2015) and the specifics of its installation, use, and success remain confidential.

6.1.2.2. Selective Non-Catalytic Reduction

In SNCR systems, a reagent is injected into the flue gas within an appropriate temperature window. The NO_X and reagent (ammonia or urea) react to form nitrogen and water. A typical SNCR system consists of reagent storage, multi-level reagent-injection equipment, and associated control instrumentation. The SNCR reagent storage and handling systems are similar to those for SCR systems. However, both ammonia and urea SNCR processes require three to four times as much reagent as SCR systems to achieve similar NO_X reductions.

Like SCR, SNCR uses ammonia or a solution of urea to reduce NOx through a similar chemical reaction.

$$2NO+4NH_3+2O_2 \rightarrow 3N_2+6H_2O$$

SNCR residence time can vary between 0.001 seconds and 10 seconds.[27] However, increasing the residence time available for mass transfer and chemical reactions at the proper temperature generally increases the NO_X removal. There is a slight gain in performance for residence times greater than 0.5 seconds. SNCR requires a higher temperature range than SCR of between 1,600˚F and 1,900˚F due to the lack of a catalyst to lower the activation energies of the reactions;[28] however, the control efficiencies achieved by SNCR vary across that range of temperatures. At higher temperatures, NO_X reduction rates decrease.[29] In addition, a greater residence time is required for lower temperatures.

In cement kilns, SNCR can be applied in certain combustion zones of kilns to facilitate SNCR in a non-tailpipe mode. For modern kilns, near the calciner or the 4th stage of the preheater are often ideal locations for injecting the ammonia in the appropriate temperature window. However, there are several complications that can occur when attempting to identify and successfully implement the controls in these ideal temperature zones, particularly in the case of older kilns like those of GCC Tijeras without a calciner or 4th stage of the preheater, resulting in significant variability among the reduction efficiencies

[26] Air Pollution Control Cost Manual, Section 4, Chapter 2, Selective Catalytic Reduction, NOx Controls, EPA/452/B-02-001, Page 2-9 and 2-10.

[27] Air Pollution Control Cost Manual, Section 4, Chapter 1, Selective Non-Catalytic Reduction, NOx Controls, EPA/452/B-02-001, Page 1-8

[28] Fuel Tech, Inc. Tail Pipe SNCR quote, 2010. Predicts a NOx control efficiency of 40% to 45% within a temperature window of 1,600 °F to 1,900 °F

[29] USEPA, Office of Air Quality Planning and Standards. Alternative Control Technologies Document – NOx Emissions from Cement Manufacturing. EPA-453/R-94-004, Section 5.2.2, Page 5-21.

achieved with SNCR in cement kilns around the country.[30] In other words, SNCR on cement kilns has achieved varying and sometimes poor success, often due to the injection zone temperatures diverging from optimal. Given the age and type of the GCC Tijeras kilns, maintaining consistent temperatures, let alone those in the ideal temperature range for SNCR, is a critical concern.

In addition to the many technical concerns regarding the use of SNCR at this facility, there are significant risks to the local community that must be considered as well. There are two schools within three blocks of this facility, and the use of significant quantities of ammonia for the mitigation of NO_X emissions poses a risk to those students. These risks come from two sources: possible health risk effects from ambient ammonia concentrations from ammonia slip directly from the SNCR system and safety concerns from the transportation and storage of ammonia. The introduction of ammonia delivery trucks and the storage of large quantities of ammonia adds the risk of an ammonia spill with considerable implications for the health of members of the local community.

6.1.2.3. Catalytic Filters

Catalytic filters represent a relatively lower capital cost alternative to traditional SCR controls. Through the retrofitting of existing baghouses, traditional baghouse filters are replaced with filters that feature a ceramic fiber insert. This insert is embedded with nano-catalysts that allow for reduction efficiencies of NO_X emissions that approach those of SCR. While this technology is a reduction option with a lower initial capital cost than SCR, the capital costs are still significant, and the benefit is offset by high costs for filter replacement.

6.2. STEP 2: ELIMINATE TECHNICALLY INFEASIBLE NO_X CONTROL TECHNOLOGIES

Step 2 of the top-down control review is to eliminate technically infeasible NO_X control technologies that were identified in Step 1.

6.2.1. Combustion Controls

6.2.1.1. Tire Derived Fuels

The facility is currently permitted to use TDF for its two cement kilns but does not actively utilize this fuel. To fully implement the use of TDF at the facility, along with reducing NO_X emissions through this control method, would require a substantial, steady supply of tires to the facility. While feasible for a short time period, the facility in Tijeras would run into a supply issue, as the amount of discarded tires available in the greater Albuquerque area is less than that of a larger metropolitan area. GCC estimates that approximately 1.4 million tires are needed per year to maintain the heat input rate necessary for the substitution of 24% of the total fuel throughput for both kilns—a rate that would result in running out of tire reserves in just 5 years.[31] The structure of the GCC Tijeras kiln necessitates mid-kiln firing of

[30] SNCR control efficiencies as low as 10% have been reported for some European kilns, with efficiencies as high as 85% for other kilns, per EPA, Alternative Control Techniques Document Update – NO_X Emissions from New Cement Kilns. EPA-453/R-07-006 Section 2.6, page 7.

[31] Details of the evaluation of TDF availability are included in Appendix D of this report. This data in Appendix D was obtained by a contractor hired by GCC to inquire about the availability of stock tires in New Mexico. EHD provided data to GCC for the quantity of tires hauled throughout New Mexico in the last year; however, this data is not representative of the tires currently available to GCC – rather the tires that are already claimed by various entities throughout the state.

tire derived fuels, and mid-kiln firing is limited by the rotation of the kiln.[32] This substitution rate represents the firing of one tire per rotation of the kiln. If lower rates are considered, the rate would need to cut in half or one third for one tire per two rotations or one tire per three rotations. There are relatively few major cities in New Mexico, requiring the facility to quickly find its own supply of tires out of state and ship them into the state. The facility would also need to compete with other sites that use TDF in order to attract suppliers to their location. Due to the low initial supply of tires near the facility and the unreliable and costly option of importing tires into New Mexico, the use of TDF in secondary combustion is not readily available and therefore technically infeasible.[33] For completeness and at the request of EHD, cost calculations for TDF firing at a lower heat substitution rate are included in this analysis.

GCC kilns do not use any solid waste fuels. 40 CFR Part 241, Solid Wastes Used as Fuels or Ingredients in Combustion Units provides a procedure for characterizing alternative fuels as a Non-Hazardous Secondary Materials (NHSM) under the provisions of 40 CFR 241 Subpart B, Identification of Non-Hazardous Secondary Materials that are Solid Wastes When Used as Fuels or Ingredients in Combustion Units. The NHSM Rule also includes certain categorical exemptions for NHSMs under 40 CFR 241.4(a); an NHSM under any of these categories is not considered to be a solid waste, but rather a non-waste fuel, and no further analysis is required.

The categorial exemption for TDF under 40 CFR 241.4(a)(1) is: "*Scrap tires that are not discarded and are managed under the oversight of established tire collection programs, including tires removed from vehicles and off-specification tires.*"

For NHSMs that do not fall under any categorical exemptions, the NHSM Rule states that a fuel which is produced from the "sufficient processing" of discarded NHSMs and which meets the "legitimacy criteria" of 40 CFR 241.3(d)(1) is not considered to be a solid waste, but rather a non-waste fuel. Therefore, in order for the alternative fuels to be classified as a non-waste fuel, the alternative fuels must be produced in a manner which constitutes "sufficient processing" under the NHSM Rule and which demonstrates that the "legitimacy criteria" are met.

GCC will mostly receive tires from an established tire management program to ensure the scrap tires are not discarded (i.e., are recycled) and are handled as valuable commodities (i.e., are tracked thoroughly by manifests). As approved by NMED and the EHD for GCC Facility's tire storage and processing O&M plans, the Facility must adequately "process" discarded NHSMs. The definition of "processing" is critical to this determination and is provided below, as defined at 40 CFR 241.2:

> *Processing means any operations that transform discarded non-hazardous secondary material into a non-waste fuel …. Processing includes, but is not limited to, operations necessary to: Remove or destroy contaminants; significantly improve the fuel characteristics of the material, e.g., sizing or drying the material in combination with other operations; chemically improve the as-fired energy content; or improve the ingredient characteristics. Minimal operations that result only in modifying the size of the material*

[32] The only other options for firing TDF would be through shredded tires in a precalciner or by feeding whole tires through the end of the kiln. The GCC Tijeras kilns do not have precalciners, and the chains in the kiln do not allow for tires to be fed from the end; therefore, only mid-kiln firing is available as an option for TDF combustion.

[33] Per the EPA guidelines for BART review, "A technology that is available and applicable is technically feasible." Federal Register Vol. 69, No. 87, Page 25221. https://www.govinfo.gov/content/pkg/FR-2004-05-05/pdf/04-9863.pdf

by shredding do not constitute processing for purposes of this definition.

As listed in the Facility's TDF O&M plans, GCC will ensure tires are sufficiently processed either off-site at the originator, stores, distributors by a third party, or as necessary on-site by GCC. Processing tires will be conducted as necessary to maintain product quality, improve combustion characteristics, or remove contaminants, to ensure stable combustion conditions are maintained in the kiln when utilizing tires. Processing may include, but are not limited to, the following as is necessary:

- Inspect and remove debris
- Physical removal of contaminates (mechanical means to remove dirt and debris)
- Removal of loose scrap metal
- Inspection and removal based on size
- Reject tires and/or loads, as necessary
- Removal of heavy debris through pressure washing or mechanical means

The removal of inert materials and metals constitutes the removal of contaminants as well as improvement of fuel characteristics by removing material with low energy content. Further, the sizing-down of the larger tires, as necessary, will also provide a significant improvement of fuel characteristics. Therefore, the tires will be produced in a manner which will constitute the "processing" of discarded NHSM under 40 CFR 241.3(b)(4).

6.2.1.2. Low-NO_X Burners

LNBs (and the associated significant kiln upgrades) are considered technically feasible for this facility and will be considered further.

6.2.2. Post Combustion Controls

6.2.2.1. Selective Catalytic Reduction

Efficient operation of the SCR process requires constant exhaust temperatures (usually ± 200°F).[34] Fluctuation in exhaust gas temperatures reduces removal efficiency. If the temperature is too low, ammonia slip occurs. Ammonia slip is caused by low reaction rates and results in both higher NO_X emissions and appreciable ammonia emissions. If the temperature is too high, oxidation of the NH_3 to NO can occur. Also, at higher removal efficiencies (beyond 80 percent), an excess of NH_3 is necessary, thereby resulting in higher ammonia emissions. Other emissions possibly affected by SCR include increased PM emissions (from ammonia salts in a detached plume) and increased SO_3 emissions (from oxidation of SO_2 on the catalyst). These ammonia, PM, and ammonia salt emissions contribute negatively to visibility impairment in the region—an effect that is directly counter to the goals of the program. In addition, the emission of ammonia poses significant health risks to the immediate community, including students attending the two schools located within three blocks of the facility.

To reduce fouling the catalyst bed with the PM in the exhaust stream, an SCR unit can be located downstream of the particulate matter control device (PMCD). However, due to the low exhaust gas temperature exiting the PMCD (approximately 350 °F); a heat exchanger system would be required to reheat the exhaust stream to the desired reaction temperature range of between 480 °F to 800 °F. The

[34] USEPA, Office of Air Quality Planning and Standards. Alternative Control Technologies Document – NOx Emissions from Cement Manufacturing. EPA-453/R-94-004, Page 2-11

source of heat for the heat exchanger would be the combustion of fuel, with combustion products that would enter the process gas stream and generate additional NO_X.[35] Therefore, in addition to storage and handling equipment for the ammonia, the required equipment for the SCR system will include a catalytic reactor, heat exchanger and potentially additional NO_X control equipment for the emissions associated with the heat exchanger fuel combustion.

High dust and semi-dust SCR technologies are still highly experimental. A high dust SCR would be installed prior to the dust collectors, where the kiln exhaust temperature is closer to the optimal operating range for an SCR. Since the GCC Tijeras kilns' baghouse inlet temperatures are in the 380-400 °F range, installation and operation of SCR at optimal temperature would pose additional challenges. It requires a larger volume of catalyst than a tail pipe unit, and a mechanism for periodic cleaning of catalyst. A high dust SCR also uses more energy than a tail pipe system due to catalyst cleaning and pressure losses.

A semi-dust system is similar to a high dust system. However, the SCR is placed downstream of an ESP or cyclone.

Only two cement kilns in the U. S. are using SCR for NO_X emissions control (LafargeHolcim's Joppa, IL and Midlothian, TX plants), and the details of the installation, use, and success of SCR at those facilities necessary for a complete analysis of applicability and feasibility at the GCC Tijeras facility remain confidential. While several cement kilns in Europe have installed SCR, the cement industries between Europe and the U.S. differ significantly due to the increased sulfur content found in the processed raw materials in U.S. cement kiln operations. The pyritic sulfur found in raw materials used by U.S. cement plants have high SO_3 concentrations that result in high-dust levels and rapid catalyst deactivation. In the presence of calcium oxide and ammonia, SO_3 forms calcium sulfate and ammonium bisulfate via the following reactions:

$$SO_3 + CaO \rightarrow CaSO_4$$

$$SO_3 + NH_3 \rightarrow (NH_4)HSO_4$$

Calcium sulfate can deactivate the catalyst, while ammonium bisulfate can plug the catalyst. Catalyst poisoning can also occur through the exposure to sodium, potassium, arsenic trioxide, and calcium sulfate.[36] This effect directly and negatively impacts SCR effectiveness for NO_X reduction.

Dust buildup on the catalyst is influenced by site-specific raw material characteristics present in the facility's quarry, such as trace contaminants that may produce a stickier particulate than is experienced at sites where the technology is being demonstrated. This buildup is typical of cement kilns, resulting in reduced effectiveness, catalyst cleaning challenges, and increased kiln downtime at significant cost.[37]

In the EPA's guidance for regional haze analysis, the term "available," one of two key qualifiers for technical feasibility in a BART analysis, is clarified with the following statement:

[35] The fuel would likely be natural gas supplied at the facility through a pipeline while coal will be excluded as it would require an additional dust collector.

[36] Air Pollution Control Cost Manual, Section 4, Chapter 2, Selective Catalytic Reduction, NOx Controls, EPA/452/B-02-001, Page 2-6 and 2-7.

[37] Preamble to NSPS subpart F, 75 FR 54970.

Consequently, you would not consider technologies in the pilot scale testing stages of development as "available" for the purposes of BART review.

The EPA has also acknowledged, in response to comments made by the Portland Cement Association's (PCA) comments on the latest edition of the Control Cost Manual, that:

For some industrial applications, such as cement kilns where flue gas composition varies with the raw materials used, a slip stream pilot study can be conducted to determine whether trace elements and dust characteristics of the flue gas are compatible with the selected catalyst.

Based on these conclusions, SCR is not widely available for use with cement kilns, in large part because the site-specificity limits the commercial availability of systems. For this reason, high-dust and semi-dust SCR's are not considered technically feasible for this facility at this time. The economics of the SCR are included in Section 6.4 for completeness.

6.2.2.2. Selective Non-Catalytic Reduction

Effective SNCR operation is dependent on numerous factors, including NO_X concentration, the temperature range, the amount of oxygen available in the environment, and the amount of ammonia injected into the flue gas. The reactions of ammonia with oxygen and either nitrous oxide or nitrous dioxide are as follows:[38]

$$4NH_3 + 4NO + O_2 \rightarrow 4N_2 + 6H_2O$$

$$4NH_3 + 2NO_2 + O_2 \rightarrow 3N_2 + 6H_2O$$

Sufficient concentration of oxygen and NO_X in the fuel are required to react with ammonia and drive the reactions forward. The presence of other chemicals or low concentrations of oxygen and NO_X will significantly decrease the rate of reaction, drastically reducing the rate of NO_X depletion. The ammonia concentration, in particular, is vital to the successful operation of the SNCR, as too much ammonia will result in unnecessary ammonia slip and too little ammonia will prove insufficient for reaction.[39]

The temperature range is perhaps the most critical factor in the successful implementation of SNCR, with an optimal temperature range of 1,600 ˚F to 1,900 ˚F. If the temperature is too low, the rate of reaction sharply decreases, resulting in too much unreacted ammonia slip. When temperatures at the injection point for this technology exceed 2,100 °F, NO_X generation starts to occur as shown in the reaction below:

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$

This reaction causes ammonia to oxidize and form NO instead of removing NO. When temperatures exceed 2200 °F, NO formation dominates. This scenario would likely be the case if ammonia was

[38] USEPA, Office of Air Quality Planning and Standards. Alternative Control Technologies Document – NOx Emissions from Cement Manufacturing. EPA-453/R-94-004, Page 5-19.

[39] Air Pollution Control Cost Manual, Section 4, Chapter 1, Selective Non-Catalytic Reduction, NOx Controls, EPA/452/B-02-001, Page 1-13 to 1-20.

directly injected into the kiln tube, as high temperatures are required for product quality. Furthermore, at temperatures below the required range, appreciable quantities of un-reacted ammonia will be released to the atmosphere via ammonia slip. This will result in increased visibility impairment and potential adverse health effects.

Even within the temperature range in which SNCR can perform optimally, there is variation in the effectiveness of the controls. While SNCR can be installed at the calciner or the 4th-stage of the preheater on more modern kilns, eliminating the concern for injecting ammonia outside of the appropriate temperature window, the GCC Tijeras kilns do not have either of those components, and would therefore need to install SNCR mid-kiln. Even among the few long dry, kilns that have installed or considered SNCR, the GCC Tijeras kiln is unique in that the length of the kiln is shorter due to the presence of the 2-stage preheater. Therefore, the location where the temperature range falls in the optimal range is unknown. A lack of temperature probes throughout the length of each kiln limits GCC's ability to accurately assess the feasibility of injecting ammonia within the appropriate temperature window for SNCR. The only temperature probes available on the two kilns are as follows:

- There is a temperature probe at the end of each kiln, where the exhaust exits the kiln and the feed material enters (referred to as the exit temperature, as it lies at the opposite end of the burner).
- There is a temperature probe on the burner end of each kiln as well, where the clinker leaves the kiln (referred to as the burning zone).
- Finally, there is a temperature probe just prior to the zone that has chains (on the burner side of the chain section).) on Kiln #2. There are no chain region nor any mid-kiln temperature probes for Kiln #1. The two kilns tend to operate with different temperature profiles; therefore, the kiln #2 chain temperature does not necessarily represent the Kiln #1 chain temperature. Temperature probes cannot be added mid-kiln during operation due to the kiln rotation.

A diagram of Kiln #2 is provided in Appendix E of this report to illustrate where the current temperature probes are located. In the case of the exit temperatures of each GCC Tijeras kiln, the temperature is well below the optimal range, at an average of approximately 1,150 ˚F for Kiln #1 and approximately 1,250 ˚F for Kiln #2. For the burner zone, the temperature is far too high, with an average temperature of approximately 2,000 ˚F for Kiln #1 and 2,250 ˚F for Kiln #2.[40] The temperature probe located in the chain section of the kiln is the probe closest to the most likely region of the kiln with the optimal ammonia injection conditions. Temperature data in this region is limited (only approximately four months have been collected), and temperatures fluctuate significantly (with a standard deviation of approximately 350 ˚F). Temperature data for the kilns are summarized in Table 6-2, below:

[40] In order to determine the average operating temperatures for the burners of each kiln, all data points indicating a burner temperature below 1,000 are excluded. Though this temperature is well below the lower threshold for sufficient heat for clinker formation, it is conservatively used as the exclusion threshold.

Table 6-2. Kiln Temperature Data (2018 – 2019)

Temperature Probe	Average Temperature	Standard Deviation	Data Availability[a]
Kiln #1 Exit	1149	539	100%
Kiln #2 Exit	1264	376	100%
Kiln #1 Burning Zone	1920	688	100%
Kiln #2 Burning Zone	2265	629	100%
Kiln #2 Chain	1529	350	18%

[a] "Data Availability" refers to the percentage of hourly values available from January 1, 2018 through November 18, 2019 (the date at which the temperature data was downloaded).

The only region with temperatures that are expected to approach the correct range for SNCR takes place towards the burner from the location where chains are installed in the kiln. The specific temperature profile in this region of the kiln is not defined at this time, because there are currently no temperature probes installed between the chain section of Kiln #1 and the burning zone and the data in Kiln #2 chain section is limited to only a few months. Temperature probes cannot be installed without a complete halt in operations due to the rotation of the kiln. The temperature data that are available indicate high variability in temperatures. The standard deviation of 350 ˚F at the Kiln #2 chain means that temperatures within one standard deviation (from 1189 ˚F to 1889 ˚F) would only occur approximately 68% of hours, and the remaining 32% of the time temperatures would be outside this range and thus outside the optimal range for SNCR (1,600 ˚F to 1,900 ˚F), and many of the 68% of hours would have a temperature below the optimal range. Installing ammonia injection toward the burner from this probe could bring the average temperature to the middle of the SNCR range (could target a kiln location with 1400 ˚F – 2100 ˚F), but this high variability would still mean that over 32% of the hours would be outside the optimum temperature range. This temperature volatility would result in highly variable NO_X reduction levels, and highly variable emission profile issues (with higher ammonia slip at lower temperatures and NO_X formation from ammonia at higher temperatures).

Additionally, on older kilns such as the GCC Tijeras kilns, instability in kiln operations are inevitable due to flame and temperature variations, shorter kiln lengths, and other operational issues. GCC operates several older kilns around the country, and, based on GCC's experience, achieving strong control efficiencies with SNCR on older kilns without the byproduct of high ammonia slip emissions proves extremely challenging. NO_X reduction of approximately 50% can be achieved in traditional burners or boilers, but that efficiency is not possible for mid-kiln firing. Therefore, SNCR at 50% control efficiency is technically infeasible. However, SNCR with a lower efficiency may be technically feasible for this facility and will be considered further.

6.2.2.3. Catalytic Filters

Catalytic filters are not considered technically feasible for this facility, because GCC Tijeras is not aware of any successful implementations of catalytic filters on cement kilns in the U.S. at this time. Catalytic filters are therefore not considered a commercially-proven control method, and therefore will not be evaluated further.

6.3. STEP 3: RANK OF TECHNICALLY FEASIBLE NOX REDUCTION OPTIONS BY EFFECTIVENESS

Step 3 of the top-down control review is to rank the technically feasible options to effectiveness. Table 6-2 presents available and feasible NO_X control technologies for the kilns and their associated control efficiencies.

The potential control efficiency obtained by mid-kiln firing of TDF is estimated based on the EPA's evaluation of NO_X control technologies for the cement industry, which estimates an overall control efficiency of 33%.[41] This control efficiency is then scaled linearly by the tire substitution rate to determine the control efficiency for firing TDF once per two revolutions and once per three revolutions. Detailed calculations are included with the NO_X cost calculations in Appendix B.

Table 6-3. Ranking of NO_X Control Technologies by Effectiveness

Pollutant	Control Technology	Potential Reduction Efficiency (%)
NO_x	SCR	90[a]
	SNCR	25[b]
	Low NO_x Burner	15[c]
	TDF	10-15[d]
	Good Combustion Practices	Baseline

[a] Reduction efficiency of SCR is determined based on the EPA Air Pollution Control Technology Fact Sheet. https://www3.epa.gov/ttn/catc/dir1/fscr.pdf.
[b] Reduction efficiency of SNCR is determined based on GCC experience at its other facilities, namely the GCC Odessa plant in Texas, which recently underwent an optimization study for SNCR on its cement kiln, which is similar in nature to the GCC Tijeras kiln. Excerpts from the optimization study are provided in Appendix G.
[c] Low-NO_X burner efficiency is obtained from a vendor quote for the GCC Tijeras facility.
[d] TDF control efficiency based on average of 33% at typical substitution rate[41] and is provided as a range dependent on the lower rate of fuel substitution (how frequently tires are fed to the kiln for secondary combustion).

6.4. STEP 4: EVALUATION OF IMPACTS FOR FEASIBLE NO_X CONTROLS

Step 4 of the top-down control review is the impact analysis. The impact analysis considers the:

- Cost of compliance
- Energy impacts
- Non-air quality impacts; and
- The remaining useful life of the source

6.4.1. Cost of Compliance

6.4.1.1. Low NOx Burner Calculations

LNB cost calculations are determined using a vendor quote for the GCC Tijeras cement kilns. The capital cost associated with the installation of a LNB extends well beyond that of just the burner itself. In order to accommodate the change to LNB, the kiln would also need to be converted from a direct-fired to an indirect-fired system. The conversion to an indirect-fired system would require modifications to the coal

[41] Sanders, D. "NOx Control Technologies for the Cement Industry: Final Report." September 2000, EPA-457/R-00-002 https://www3.epa.gov/airquality/ctg_act/200009_nox_epa457_r-00-002_cement_industry.pdf
Calculations assume the tested kilns employed a substitution rate of 24% TDF (rate equivalent to 1 tire per revolution which is the standard practice).

mill, trolley, baghouse, dosing system, and storage bin, on top of the already significant capital cost associated with the burner itself. Conversion of a direct fired to an indirect fired system would represent a complete change to the nature of the current kiln systems, and this upgrade is reflected in the vendor quote.

6.4.1.2. Tire-Derived Fuels Calculations

TDF cost calculations are included at the request of EHD though the supply of tires is limited, and GCC has determined, while TDF usage as a fuel is a technologically possible practice, implementation as an enforceable control technology would limit the operational flexibility of the plant. Requiring the firing of a specific fuel in order to ensure NO_X reduction is problematic because GCC and vendors cannot guarantee a steady supply of TDF and because cement kilns require flexibility to adjust which fuels are fired and at what rates in order to maintain kiln stability and process chemistry.

TDF cost calculations are developed under the assumption that tires are readily available in necessary quantities for the appropriate heat substitution necessary for NO_X control. Capital costs are included for the equipment necessary for supplying tires to the kiln, with capital costs sourced from EPA documentation for TDF cost estimates for mid-kiln firing. Tire processing costs are developed based on the processing costs at another GCC facility. As discussed previously, use of TDF as an alternative fuel requires specific practices for ensuring the fuel qualifies as a non-hazardous secondary material, and not all scrap tires are appropriate for use as TDF in a cement kiln.

Additionally, it is worth noting that inconsistent tire supply has the potential to increase costs for implementation. Maintaining consistent process conditions is not only directly tied to minimizing emissions of NO_X and SO_2, but also minimizing the cost of implementation for control technologies. Tire haul data provided by EHD and the NMED Solid Waste Bureau indicates that there is already substantial demand for tires in New Mexico.[42] There are likely substantial costs associated with acquiring tires in a competitive market sufficient for TDF fuel substitution alone, let alone the substantial costs of acquiring the necessary equipment and annual operating costs for using this fuel. For the purposes of the cost calculations developed in this report, fuel costs are not included – only the capital costs for necessary equipment and anticipated labor costs are included.

As mentioned previously, the supply of tires available is insufficient to feed TDF fuel to the cement kilns at a rate of one tire per rotation; therefore, costs are provided for tire substitution rates of one tire per two rotations (12% substitution of heat input) and one tire per three rotations (8% substitution). Costs are adjusted, where necessary, to 2018 dollars using the Chemical Engineering Plant Cost Index (CEPCI).

6.4.1.3. SCR Cost Calculations

In addition to its lack of widespread commercial availability, there is disagreement regarding the applicability of the U.S. EPA Cost Control Manual for SCR for cement kilns. Though the cost manual does account for high-dust SCR systems, the U.S. EPA agrees that the challenges associated with the installation are site-and industry specific. The PCA compiled cost data from the small sample of European kilns that have successfully introduced the SCR into cement operations, which indicates that

[42] This tire haul data is included in Appendix D, Tire Derived Fuel Availability Analysis. It is worth noting that tire haul data is not representative of available stock tires, only the tires currently in use/transport in the state.

the costs are likely 2.5 to 4.3 times the values supplied by the EPA for SCRs more broadly.[43] Therefore, a factor of 3.4 (the midpoint of the range) is used in developing the capital cost estimate for SCR. In addition, costs are adjusted to 2018 dollars (the latest published complete year for the CEPCI[44].

6.4.1.4. SNCR Cost Calculations

SNCR costs are calculated using the U.S. EPA Cost Control Manual for SNCR. As with the SCR section of the manual, the applicability of these cost calculation methodologies designed for coal boilers to the cement industry is not widely accepted. While the discrepancy in the costs is not believed to be as drastic for SNCR as it is proven to be for SCR, a retrofit factor is still necessary in order to account for the complications associated with installing the equipment on older kilns, particularly because the only feasible location for ammonia to be injected will be in the rotating portion of the kiln. A retrofit factor of 1.1 is used to account for the added costs associated with a more complex injection system. In addition, as with SCR, costs are adjusted to 2018 dollars (the latest published complete year for the Chemical Engineering Plant Cost Index (CEPCI))[45].

6.4.1.5. Cost Effectiveness

The cost effectiveness is determined by dividing the annual control cost by the annual tons reduced. Table 6-4 summarizes the results of the cost effectiveness calculations.

Costs and cost effectiveness considerations at the GCC Tijeras facility should be treated differently than other facilities in the Portland cement industry for multiple reasons. First, complications associated with the older kilns at GCC Tijeras result in inconsistencies in operating conditions causing higher likelihood of unforeseen control costs and higher kiln operating costs. Second, the limitations on the transportation of products, raw material, fuel, and equipment due to the lack of access to rail or water-based transport cause higher plant operating costs. Lastly, in the case of GCC Tijeras, the raw material cost of limestone is also higher. On a dollar per ton clinker produced basis, limestone costs at Tijeras are approximately 2.5 times more expensive when compared to the other GCC facilities (based on a weighted average of costs at other facilities accounting for the production rates at each facility). Therefore, considering higher limestone costs alone, if a cost effectiveness value of $5,000 per ton is used at another cement plant to demonstrate a technology is not cost effective, an equivalent threshold at GCC Tijeras should be at least 2.5 times lower (or $2,000 per ton). While this does not directly impact the individual control costs themselves for each control technology, an accurate assessment of the financial impact of each control technology on the GCC Tijeras operations and whether the technology is cost effective for GCC Tijeras must take into account this substantial difference in the costs of operating at this facility.

[43] USEPA, Office of Air Quality Planning and Standards. Public Comments on the Proposed Revisions to Section 4.2, Chapter 2 (SCR) of the Control Cost Manual, Page 50 to 51. No individual cost estimates or vendor quotes referenced by PCA are used in developing SCR cost estimates for the GCC Tijeras facility.

[44] Access Intelligence LLC, Chemical Engineering, Chemical Engineering Plant Cost Index: 2018 Annual Value, https://www.chemengonline.com/2019-cepci-updates-january-prelim-and-december-2018-final/

[45] Access Intelligence LLC, Chemical Engineering, Chemical Engineering Plant Cost Index: 2018 Annual Value, https://www.chemengonline.com/2019-cepci-updates-january-prelim-and-december-2018-final/

Table 6-4. NO_X Cost of Compliance Based on Emissions Reduction

Control Option	Control Cost ($/yr)	Baseline Emission Level (tons)	NO_X Reduction (%)	Emission Reduction (tons)	Cost Effectiveness ($/ton removed)
SCR	$6,708,694	1,206	90	977[a]	$6,868
SNCR	$710,585	1,206	25	271[a]	$2,619
Low NO_X Burners	$1,981,719	1,206	15	181	$10,955[b]
TDF – 12% Substitution	$1,366,949	1,206	15	179	$7,633
TDF – 8% Substitution	$1,283,340	1,206	10	119	$10,749

[a] Emission reduction assumes a 90% control technology uptime to allow for maintenance, bulk loading and unloading, and unanticipated process interruptions.

[b] Modification for a Low-NO_X burner includes several changes to the fundamental operating nature of the kiln. While some of these changes are incorporated in this cost estimate, GCC Tijeras anticipates that additional costs will be required, particularly given that these costs are not site-specific.

6.4.2. Timing for Compliance

GCC Tijeras believes that reasonable progress compliant controls are already in place. However, if EPA determines that one of the NO_X reduction options analyzed in this report is necessary to achieve reasonable progress, it is anticipated that this change could be implemented within five years of the determination.

6.4.3. Energy and Non-Air Quality Environmental Impacts

The cost of energy required to operate the control devices has been included in the cost analyses found in Appendix B. To operate any of the add-on control devices, there would be decreased overall plant efficiency due to the operation of these add-on controls. At a minimum, this would require increased electrical usage by the plant with an associated increase in indirect (secondary) emissions from nearby power stations. Even though the additional cost associated with the secondary energy impacts may be incorporated in the utility and operating costs for each control technology, the environmental impacts are nevertheless substantial and directly counter to the goals of the regional haze program.

The use of NO_X reduction methods that incorporate ammonia injection leads to increased health risks to the local community from ammonia slip emissions. Additionally, there are safety concerns associated with the transport and storage of ammonia, including potential ammonia spills that can have serious adverse health impacts. This concern is paramount, given the proximity of the two schools located within three blocks of the GCC Tijeras facility.

6.4.4. Remaining Useful Life

The remaining useful life of the kilns does not affect the annualized cost of the add-on control technologies because the useful life is anticipated to be at least as long as the capital cost recovery period, which is 20 years. All control technologies are assumed to have a remaining useful life of 20 years, per EPA guidelines.

6.5. NO_X CONCLUSION

The facility currently has no add-on NO_X control technologies in place on the rotary kilns. While GCC Tijeras has identified low-NO_X burners as a technically feasible reduction method, the technology is not cost effective. There are significant costs associated with modifications to multiple components of the kiln system to allow for the transition from a direct-fired to indirect-fired burner, including the fuel storage and processing, trolley, and baghouse. As a result, LNB is not a cost-effective NO_X reduction option. Use of TDF as an alternative fuel – while technologically possible – has significant availability concerns, as there is a limited supply of tires currently in use in the state of New Mexico and substantial quantities of tires are required to achieve meaningful reductions in NO_X emissions from the GCC Tijeras kilns. Even setting aside concerns of tire availability, the use of TDF is not a cost effective emissions reduction option for the Tijeras cement kilns. SNCR may be a technically feasible control technology for the GCC Tijeras kilns for modest reduction efficiencies; however, there are technical difficulties associated with injecting the ammonia in the rotating portion of the kiln, as well as identifying and verifying the region within the kiln with the optimal temperature range for SNCR NO_X reduction. SCR is not currently widely available for the cement industry, with very limited application in the United States and a need for further pilot testing.

7. CONCLUSION

GCC Tijeras operates two kilns that are unique compared to other cement kilns in the country. Given the age and type of the kilns, operating conditions are less consistent and less stable than in newer kilns. As a result, the installation of many emissions reduction controls or changes to operations incur a variety of technical challenges. These challenges result in control technologies or emission reduction methods that are not cost effective or technically infeasible for the GCC Tijeras site. Cost effectiveness concerns are additionally amplified when taking into consideration the limitations on the transportation of fuel, raw material, products, and equipment to and from the facility. With access only to truck transportation (the facility is landlocked and does not have access to a rail or river), equipment shipping costs and overall plant production costs are greater for the GCC Tijeras facility. As such, control options that may appear to have a reasonable cost for another cement plant, would have outsized impacts on the operating costs of the GCC Tijeras facility.

The following list outlines our findings for each emissions reduction option considered in this four-factor analysis:

SO_2 Reduction Options:

- Wet scrubber: Despite the relatively high reduction efficiencies, this reduction method is not cost effective. Additionally, given several technical challenges related to water usage, treatment, and disposal, among others, this is not considered a possible reduction option.
- Semi-wet/dry scrubber: Semi-dry scrubbing of SO_2 for the GCC Tijeras kilns will require upgrades to the kiln systems. While the use of semi-wet or dry scrubbing is a generally available control technology, it is not a cost-effective emissions reduction option.
- Alternative fuels: Currently the kilns fire coal as their primary fuel source, with natural gas used only during startups. The kilns are already permitted to use tire-derived fuel (TDF) as an alternate fuel for reducing SO_2 emissions, but sustained usage is not feasible because discarded tires are not widely available in New Mexico and importing tires is not cost effective. Furthermore, while switching to entirely diesel or natural gas would lower SO_2 emissions, it would also result in higher NO_X emissions, and the annual fuel cost increase would be substantial, making this option cost ineffective.
- Dry Sorbent Injection: The injection of lime or other dry sorbents is an available and lowest cost option for SO_2 reduction at the GCC Tijeras facility. The potential emission reductions, however, would represent an insignificant fraction of the total SO_2 emissions in the state (the estimated reduction resulting from dry sorbent injection would equal less than 2% of the total state-wide SO_2 emissions for 2017).

NO_X Reduction Options:

- SNCR: SNCR, despite technical concerns specific to the kilns at the GCC Tijeras facility, is considered a technically feasible NO_X emissions reduction. The primary concern, when installing SNCR, is in supplying the ammonia to the process in the optimal temperature window. The GCC Tijeras kilns have two specific issues: length of kilns and instability in operating conditions. Because the GCC Tijeras kilns are shorter in length and pre-heater height, the temperature profile of the kiln is unique, and the location where an appropriate temperature window for ammonia injection may occur is not currently known. Given the age of the kiln, there are additional concerns about the fluctuations in temperature and other operating conditions. Substantial fluctuation in temperature takes place based on the limited temperature data available. Both of these issues create unique challenges for successful SNCR operation on these two kilns. If the temperature is too low, the reaction between the ammonia and the NO_X gases will not take place, resulting in significant ammonia slip and inconsistent NO_X control. If the temperature is too high, then the ammonia can oxidize to form additional NO_X emissions. SNCR technology is not appropriate for this facility due to the high costs, substantial technical complications, and uncertainty in the effectiveness of the technology due to the technical complications.

- SCR: In the case of SCR, there are significant operating costs associated with the catalyst, as constant cleaning is required to accommodate the heavy dust loading of a cement kiln. Constant cleaning and catalyst fouling materials contained in the raw materials necessary for Portland cement production severely limit catalyst life. Even if all these technical concerns could be resolved, the economic factors that result from addressing these issues make the installation of SCR cost ineffective for NO_X reduction on the GCC Tijeras kilns. Furthermore, there is currently only one kiln in the US that has successfully installed and operated this control technology for NO_X emissions control. Considering the age and type of the GCC Tijeras kilns, it will be very difficult to install and operate an unproven control technology.
- Catalytic Filters: Through the retrofitting of existing baghouses, traditional filters can be replaced with ceramic fiber filters embedded with nano-catalysts. The result is the reduction of NO_X at efficiencies approaching those achieved via SCR. As with SCR, however, there are currently no kilns in the US that have successfully installed and operated this control. GCC Tijeras is not currently aware of any cement kilns that have successfully implemented this control technology. Given the age and type of the GCC Tijeras kilns, it will be very difficult to install and operate an unproven control technology, and the reduction method is therefore considered technically infeasible at this time.
- Tire Derived Fuel (TDF): The use of solid, slow burning fuels like TDF is also considered as an alternate method for reducing NO_X emissions. As stated previously, sustained usage is not feasible as discarded tires are not widely available in New Mexico and importing tires is not cost effective when taking into account the emissions reduced. At the request of EHD, cost calculations are included in this report for the use of TDF at lower heat substitution rates to account for availability concerns, and implementing TDF as an emissions reduction option is not cost-effective for these kilns.
- Low-NO_X Burner: Finally, GCC Tijeras considered the installation of low-NO_X burners for a reduction in NO_X emissions from the cement kilns. The installation of the low-NO_X burners will require significant changes to the entire kiln process, including the coal mill. These changes are required for the conversion from direct-fired to indirect-fired burners, and present significant economic and technical challenges. Therefore, low-NO_X burners are not a cost-effective emissions reduction option.

Semi-Wet/Dry Scrubber Cost Calculations

Table A-1. Direct Costs per Kiln

Purchased Equipment Costs			
Semi-wet Scrubber Unit[1]	Equipment Costs (EC)	$	11,038,066.32
Instrumentation[2]	10% of EC	$	1,103,806.63
Sales Tax[2]	3% of EC	$	331,141.99
Freight[2]	5% of EC	$	551,903.32
Subtotal, Purchased Equipment Cost (PEC)		$	13,024,918.25
Total Direct Cost		$	13,024,918.25

Table A-2. Indirect Installation Costs per Kiln[2]

Engineering	10% of PEC	$	1,302,491.83
Construction and Field Expens	10% of PEC	$	1,302,491.83
Contractor Fees	10% of PEC	$	1,302,491.83
Start-up	1% of PEC	$	130,249.18
Performance Test	1% of PEC	$	130,249.18
Contingencies	3% of PEC	$	390,747.55
Total Indirect Cost		$	4,558,721.39

Total Capital Investment (TCI) per Kiln	**$**	**17,583,639.64**

Table A-3. Direct Annual Costs per Kiln

Hours per Year[3]	Kilns run near continuously. Down less than 15% of selected time period		7487.846833
Operating Labor			
Operator[4]	0.5 hr/shift, 3 shifts/day, 365 d/yr, $33.34/hr	$	18,253.65
Supervisor[2]	15% of operator	$	2,738.05
Subtotal, Operating Labor		$	20,991.70
Maintenance			
Labor[4]	0.5 hr/shift, 3 shifts/day, 365 d/yr, $37.94/hr	$	20,772.15
Material[2]	100% of Maintenance Labor	$	20,772.15
Subtotal, Maintenance		$	41,544.30

Table A-4. Utilities per Kiln

Electricity			
Scrubber Electrical Rating[5]	kW		303.88
Cost[6]	$/kW-hr	$	0.05
Subtotal, Electricity		$	114,225.29
Limestone Slurry			
Amount Required[5]	ton/yr		542.10
Cost[7]	$/ton	$	11.90
Subtotal, Lime		$	6,451.04
Water			
Amount Required[8]	gpm		9.4856
Cost[6]	$/1000 gallons	$	0.03
Subtotal, Water		$	127.85
Sludge Disposal			
Amount Generated[5]	tpy		330.07
Disposal Fee	$/ton	$	4.24
Subtotal, Sludge		$	1,399.50
Subtotal, Utilities		$	122,203.67
Total Direct Annual Cost		$	184,739.67

Table A-5. Indirect Annual Costs per Kiln[2]

Overhead	60% of sum of operating, supervisor, maintenance labor & materials	$	37,521.60
Administrative	2% of TCI	$	351,672.79
Property Tax	1% of TCI	$	175,836.40
Insurance	1% of TCI	$	175,836.40
Capital Recovery	20 year life, 4.75% interest	$	1,381,203.11
Total Indirect Annual Cost		$	2,122,070.29

Total Annualized Cost per Kiln	**$**	**2,306,809.97**

1) Semi-dry scrubber unit equipment costs based on vendor quote provided to GCC's Pueblo, CO cement plant for a wet scrubber. Difference between wet and semi-dry scrubber capital cost based on evaluation of other portland cement facilities conducted by Bridge Gap Engineering. Costs are scaled to 2018 dollars using the Chemical Engineeering Plant Cost Index (CEPCI).

2018	603.1
2000	394.1

2) Table 1.3 and Table 1.4 of the EPA Control Cost Manual 6th Edition, Section 5.2, Chapter 1
3) Based on average run time of Kilns #1 and #2 from 2016 to 2018.
4) Labor time and percentages taken from Table 1.4 of the EPA Control Cost Manual 6th Edition, Section 5.2, Chapter 1. Labor costs are specific to GCC.
5) Utility usage rates are determined based on the vendor quote and wet scrubber analysis conducted by GCC Pueblo. Values are scaled based on the total tons of SO_2 reduced.
6) Cost of utilities are site-specific for the GCC Tijeras plant. Costs for sludge disposal are assumed to be equivalent to the solid waste disposal costs to the landfill.
7) Cost of limestone from USGS 2015 mineral yearbook, Crushed Stone, section on prices. Refer to webpage (https://s3-us-west-2.amazonaws.com/prd-wret/assets/palladium/production/mineral-pubs/stone-crushed/myb1-2015-stonc.pdf)

8) Water usage rates are obtained from the vendor quote provided to GCC's Pueblo plant for a wet scrubber. The difference in water usage between a wet scrubber and a semi-dry scrubber is scaled by the difference provided in the "Preliminary Economic Analysis of a Lime Spray Dryer FGD System," U.S. EPA Industrial Environmental Research Laboratory. EPA-600/7-808-050, March 1980. Pages 44, 46. https://nepis.epa.gov/Exe/ZyPDF.cgi/9101FOIG.PDF?Dockey=9101FOIG.PDF. The water usage rates

Wet Scrubber (Limestone Slurry Process):	99670	kgal
Semi-dry Scrubber (Lime Spray Dryer):	74440	kgal

Table A-6. Semi-Dry Scrubber Cost Summary

Variable	Value
Total Capital Cost	
Per Kiln	$17,583,640
Combined	$35,167,279
Total Annual Cost	
Per Kiln	$2,306,810
Combined	$4,613,620
Baseline SO2 Emisisons	357.0
Scrubber Control Efficiency	90%
Total Tons SO_2 Reduced	289
Cost Effectiveness ($/ton)	$15,955

[1] SO_2 reduction takes into account a 90% control technology uptime to account for maintenance and unexpected kiln shutdowns.

Wet Scrubber Cost Calculations

Table A-7. Direct Costs per Kiln

Purchased Equipment Costs			
Wet Scrubber Unit[1]	Equipment Costs (EC)	$	13,160,771.38
Instrumentation[2]	10% of EC	$	1,316,077.14
Sales Tax[2]	3% of EC	$	394,823.14
Freight[2]	5% of EC	$	658,038.57
Subtotal, Purchased Equipment Cost (PEC)		$	15,529,710.23
Total Direct Cost		$	15,529,710.23

Table A-8. Indirect Installation Costs per Kiln[2]

Engineering	10% of PEC	$	1,552,971.02
Construction and Field Expenses	10% of PEC	$	1,552,971.02
Contractor Fees	10% of PEC	$	1,552,971.02
Start-up	1% of PEC	$	155,297.10
Performance Test	1% of PEC	$	155,297.10
Contingencies	3% of PEC	$	465,891.31
Total Indirect Cost		$	5,435,398.58

Total Capital Investment (TCI) per Kiln	**$**	**20,965,108.80**

Table A-9. Direct Annual Costs per Kiln

Hours per Year[3]	Kilns run near continuously. Down less than 15% of selected time period		7487.846833
Operating Labor			
Operator[4]	0.5 hr/shift, 3 shifts/day, 365 d/yr, $33.34/hr	$	18,253.65
Supervisor[2]	15% of Operator	$	2,738.05
Subtotal, Operating Labor		$	20,991.70
Maintenance			
Labor[4]	0.5 hr/shift, 3 shifts/day, 365 d/yr, $37.94/hr	$	20,772.15
Material[2]	100% of Maintenance Labor	$	20,772.15
Subtotal, Maintenance		$	41,544.30

Table A-10. Utilities per Kiln

Electricity			
Scrubber Electrical Rating[5]	kW		320.76
Cost[6]	$/kW-hr	$	0.05
Subtotal, Electricity		$	120,571.14
Limestone Slurry			
Amount Required[5]	ton/yr		572.22
Cost[7]	$/ton	$	11.90
Subtotal, Lime		$	6,809.43
Water			
Amount Required[5]	gpm		13.4061
Cost[6]	$/1000 gallons	$	0.03
Subtotal, Water		$	180.69
Sludge Disposal			
Amount Generated[5]	tpy		348.41
Disposal Fee[6]	$/ton	$	4.24
Subtotal, Sludge		$	1,477.25
Subtotal, Utilities		$	129,038.51
Total Direct Annual Cost		$	191,574.50

Table A-11. Indirect Annual Costs per Kiln[2]

Overhead	60% of sum of operating, supervisor, maintenance labor & materials	$	37,521.60
Administrative	2% of TCI	$	419,302.18
Property Tax	1% of TCI	$	209,651.09
Insurance	1% of TCI	$	209,651.09
Capital Recovery	20 year life, 4.75% interest	$	1,646,819.09
Total Indirect Annual Cost		$	2,522,945.04

Total Annualized Cost per Kiln	**$**	**2,714,519.55**

1) Wet scrubber unit equipment costs based on vendor quote provided to GCC's Pueblo, CO cement plant. Costs are scaled to 2018 dollars using the Chemical Engineeering Plant Cost Index (CEPCI).

2018	603.1
2000	394.1

2) Table 1.3 and Table 1.4 of the EPA Control Cost Manual 6th Edition, Section 5.2, Chapter 1

3) Based on average run time of Kilns #1 and #2 from 2016 to 2018.

4) Labor time and percentages taken from Table 1.4 of the EPA Control Cost Manual 6th Edition, Section 5.2, Chapter 1. Labor costs are specific to GCC.

5) Utility usage rates are determined based on the vendor quote and wet scrubber analysis conducted by GCC Pueblo. Values are scaled based on the total tons of SO_2 reduced.

6) Cost of utilities are site-specific for the GCC Tijeras plant. Costs for sludge disposal are assumed to be equivalent to the solid waste disposal costs to the landfill.

7) Cost of limestone from USGS 2015 mineral yearbook, Crushed Stone, section on prices. Refer to webpage (https://s3-us-west-2.amazonaws.com/prd-wret/assets/palladium/production/mineral-pubs/stone-crushed/myb1-2015-stonc.pdf)

Table A-12. Wet Scrubber Cost Summary

Variable	Value
Total Capital Cost	
Per Kiln	$20,965,109
Combined	$41,930,218
Total Annual Cost	
Per Kiln	$2,714,520
Combined	$5,429,039
Baseline SO2 Emisisons	357.0
Scrubber Control Efficiency	95%
Total Tons SO_2 Reduced	305
Cost Effectiveness ($/ton)	$17,786

[1] SO_2 reduction takes into account a 90% control technology uptime to account for maintenance and unexpected kiln shutdowns.

Table A-13. Dry Sorbent Injection Process Inputs

Variable	Value	Units
Baseline SO_2 Emissions	357	tons/year
SO_2 Removal Efficiency	50%	
Total SO_2 Removed	160.65	tons/year
Lime Injection Rate	500	lb/hr
Annual Operating Time	6739	hours/year

[1] Assumes control technology uptime of 90% for maintenance and unexpected kiln downtime.

Table A-14. Dry Sorbent Injection Costs

Captial Costs[1]		
Equipment Cost	$642,500.00	$
Instrumentation	--	Included in Quote
Sales Tax	$19,275.00	Per EPA Control Cost Manual
Freight	$32,125.00	Per EPA Control Cost Manual
Engineering	$64,250.00	Per EPA Control Cost Manual
Construction and Field Expenses	$64,250.00	Per EPA Control Cost Manual
Contractor Fees	$64,250.00	Per EPA Control Cost Manual
Start-up	$6,425.00	Per EPA Control Cost Manual
Performance Test	$6,425.00	Per EPA Control Cost Manual
Contingencies	$19,275.00	Per EPA Control Cost Manual
Total Capital Investment	$918,775.00	
Direct Annual Costs[1]		
Lime Price[2]	$11.90	$/ton
Annual Lime Cost	$20,048.71	$/year
Operator	$18,253.65	0.5 hr/shift, 3 shifts/day, 365 d/yr, $33.34/hr
Supervisor	$2,738.05	15% of Operator
Maintenance Labor	$20,772.15	0.5 hr/shift, 3 shifts/day, 365 d/yr, $37.94/hr
Maintenance Materials	$20,772.15	100% of Maintenance Labor
Capital Recovery[3]	$0.08	$ Annually/$ Capital Cost
Annualized Capital Cost	$72,170.21	Capital Recovery * Total Capital Investment
Total Annual Cost	$154,754.91	$/year
Cost Effectiveness	$963.30	$/ton

[1] Capital cost obtained from a vendor quote obtained for GCC's Odessa cement plant. Costs related to the construction and implementation of the equipment are obtained from the EPA control cost manual. Because there is no published chapter for Dry Sorbent Injection, both these costs and the direct annual costs for operations and maintenance are obtained from Table 1.3 and Table 1.4 of the EPA Control Cost Manual 6th Edition, Section 5.2, Chapter 1 for Wet Scrubbers.

[2] Cost of limestone from USGS 2015 mineral yearbook, Crushed Stone, section on prices. Refer to webpage (https://s3-us-west-2.amazonaws.com/prd-wret/assets/palladium/production/mineral-pubs/stone-crushed/myb1-2015-stonc.pdf)

[3] Capital recovery calculated based on the methodology provided in the EPA Control Cost Manual, Section 1 Chapter 2, Equation 2.8 and 2.8a on Page 2-22.

Interest	4.75%
Equipment Life	20

GCC Tijeras Kilns - Cost of SO_2 Reduction for Alternative Fuel Scenarios

Fuel Scenario	Fuel	Annual Consumption	Consumption Units	Fuel Cost ($/unit)	Annual Fuel Cost	Annual Fuel Cost Increase	Total Annual SO_2 Emissions (ton)	Total Annual SO_2 Reduction (ton)	Total Cost of SO_2 Reduction ($/ton reduced)
Base	Coal [a]	70,060	tons	34.72	$ 2,432,495				
	Natural Gas [b]	46,700,000	scf	0.00506	$ 236,302				
	Total				$ 2,668,797		357.0		
All Diesel	Diesel [c]	12,587,794	gallons	2.96	$ 37,259,871	$ 34,591,075	243.63	113.37	$ 305,128
All Natural Gas	Natural Gas	1,666,592,100	scf	0.00506	$ 8,432,956	$ 5,764,159	243.55	113.45	$ 50,807

[a] EIA, Average Sales Price of Coal by State and Coal Rank, 2017 - Price of Coal for New Mexico, aggregate of all coal types, is 34.72 $/Ton (https://www.eia.gov/coal/annual/pdf/table31.pdf)

[b] EIA, Natural Gas, New Mexico Natural Gas Industrial Price, Annual - Price of Natural Gas is $5.06/1000 CF (https://www.eia.gov/dnav/ng/hist/n3035nm3a.htm)

[c] EIA, Weekly Retail Gasoline and Diesel Prices, Annual - 2018 Ultra Low Sulfur Diesel for Gulf Coast (Includes New Mexico) is 2.960 $/gal (https://www.eia.gov/dnav/pet/pet_pri_gnd_a_EPD2DXL0_pte_dpgal_a.htm)

Per Kiln Basis		Annual Fuel Cost	Annual Fuel Cost Increase	Total Annual SO_2 Emissions (ton)	Total Annual SO_2 Reduction (ton)	Total Cost of SO_2 Reduction ($/ton reduced)
Base	Coal					
	Natural Gas					
	Total	$ 1,334,398		178.5		
All Diesel	Diesel	$ 18,629,936	$ 17,295,537	121.8	56.68	$ 305,128
All Natural Gas	Natural Gas	$ 4,216,478	$ 2,882,080	121.77	56.73	$ 50,807

GCC Tijeras Kilns - SO_2 Emissions from Alternative Fuel Scenarios (Kiln 1 and Kiln 2 Combined)

Current Scenario

Fuels	Average Combined Fuel Usage [a] ton/yr or scf/yr	Heat Content Btu/lb or Btu/scf	Annual Fuel Heat Usage Btu/yr	Sulfur Content [d,e]	Potential Sulfur Emissions ton/yr	Potential SO2 Emissions ton/yr	Inherent Scrubbing Efficiency	Baseline SO2 Emissions ton/yr
Coal [b]	70,060	12,000	1.68E+12	0.0081	567.49	1134.98	90%	113.5
Natural Gas [c]	46,700,000	1,038	4.85E+10	0.0020	0.01	0.01	90%	0.001
Total			1.73E+12		567.50	1134.99		113.5

[a] Coal usage comes from GCC Tijeras' Annual Emission Inventories, and natural gas consumption is conservatively assumed to be equivalent to the values in the Title V permit.

[b] Heat content of Coal used at GCC Tijeras is 24 MMBtu/Ton based on Annual Emission Inventory reports

[c] EIA, Monthly Energy Review July 2019, Table A5. Approximate Heat Content of Natural Gas (Page 209) - 2018 Heat content of Natural Gas for End-Use Sectors is 1,038 Btu/SCF (https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf)

[d] Sulfur content of coal is from the GCC Tijeras Title V permit, issued by the Albuquerque - Bernalillo County AQCB

[e] EPA, AP-42 Section 1.4.3 - Natural gas sulfur content is 2000 gr/MMscf - https://www3.epa.gov/ttnchie1/ap42/ch01/final/c01s04.pdf

Substitute Diesel for Coal & Natural Gas

Fuels	Usage gal/yr	Heat Content [b] Btu/gal	Annual Fuel Heat Usage Btu/yr	Sulfur Content [c]	Potential Sulfur Emissions [a] ton/yr	Potential SO_2 Emissions ton/yr	Inherent Scrubbing Efficiency	SO_2 Emissions ton/yr
Diesel	12,587,794	137,429	1.73E+12	0.0015%	1	1	90%	0.13

[a] EPA, AP-42 Table 1.3-12, Default CO2 Emission Factors for Liquid Fuels - Density of Diesel = 7.05 lb/gal (https://www3.epa.gov/ttnchie1/ap42/ch01/final/c01s03.pdf)

[b] EIA, Monthly Energy Review July 2019, Table A3. Approximate Heat Content of Petroleum Consumption and Fuel Ethanol (Page 208) - 2018 Heat content of Distillate Fuel Oil is 5.772 MMBtu/Barrel (https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf)

[c] EPA, Nonroad Diesel Fuel Standards - Ultra Low Sulfur Content Diesel Fuel (Sulfur Content = 15 ppm) (https://www.epa.gov/diesel-fuel-standards/diesel-fuel-standards-and-rulemakings#nonroad-diesel)

Substitute Natural Gas for Coal & Natural Gas

Fuels	Usage scf/yr	Heat Content [a] Btu/scf	Annual Fuel Heat Usage Btu/yr	Sulfur Content [b] gr/scf	Potential Sulfur Emissions ton/yr	Potential SO_2 Emissions ton/yr	Inherent Scrubbing Efficiency	SO_2 Emissions ton/yr
Natural Gas	1,666,592,100	1,038	1.73E+12	0.002	0.24	0.48	90%	0.05

[a] EIA, Monthly Energy Review July 2019, Table A4. Approximate Heat Content of Natural Gas (Page 209) - 2018 Heat content of Natural Gas for End-Use Sectors is 1,038 Btu/SCF (https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf)

[b] EPA, AP-42 Section 1.4.3 - Natural gas sulfur content is 2000 gr/MMscf - https://www3.epa.gov/ttnchie1/ap42/ch01/final/c01s04.pdf

Scenario	Total SO_2 Emissions ton/yr	Reduction vs Baseline %
Baseline (Coal & Natural Gas)	113.50	0.00%
All Diesel	0.13	99.9%
All Natural Gas	0.05	99.96%

Scenario	Total SO_2 Emissions ton/yr	Reported Baseline Emissions ton/yr	Non-Fuel Emission Rate ton/yr	Adjusted Emission Rate ton/yr	Reduction vs Baseline, Adjusted %
Baseline (Coal & Coke)	113.50	357.00	243.50	357.00	0.0%
All Diesel	0.13	357.00	243.50	243.63	31.8%
All Natural Gas	0.05	357.00	243.50	243.55	31.8%

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RE: Cost Effectiveness of Wet Scrubbers for SO_2

Gentlemen,

As a response to your telephone request for substantiation of Jerry Young's statements in respect to capital costs, and cost effectiveness, we submit the following information:

1. Using a typical 3000 stpd calciner kiln system, the following operating data presented in Table 1 were assumed. Please note that operating temperatures of approximately 100°C are expected. Due to temperature excursions of the kiln system, which may occasionally occurs, however, the inlet temperatures could peak up to 250 –270°C. Please also note that the system's effluent pH is expected to be 6.5 and sometimes lower.

Table 1 – Typical DynaWave Process Parameters for a 3000 stpd Calciner Kiln System

Inlet gas flow rate	200,000 Nm^3/hr	118,000 scfm (@32°F)
Inlet gas temperature	100°C	212°F
Inlet SO_2 content	400 – 900 ppm	400 – 900 ppm
Outlet gas temperature	55°C	131°F
System pH (approx.)	6.5	6.5
Gas side pressure drop	450 mm W.G.	18 inches W.G.

In some cases, scrubber effluent can be purged by using it in the kiln exhaust gas conditioning tower or in water sprays in the roller mill, which would result in no scrubber

\\PENTA-NT4-F51\PROJECTS\FSRPT\20000317\Project\Correspd\Client\081700mcgill-medina.doc effluent or sludge disposal. However, if chlorides are present, the captured chloride compounds must be removed from the kiln system and disposed of. When calcium sulfate/sulfite (reaction products from the example above) are processed through a cement kiln, a substantial portion will normally partition to clinker, depending on several factors including alkali to sulfur molar ratio. The clinker, consequently, serves as the valve or outlet for the captured sulfur. This does not occur with chloride compounds. Chloride compounds will volatilize and build an ever-increasing recirculating load of chlorides until an outlet is provided or until kiln operating problems occur.

2. In an effort to establish ranges for the cost effectiveness of SO_2 removal utilizing wet scrubbing, we evaluated SO_2 emission data from the U.S. Cement Industry. We found that SO_2 emissions vary considerably with typical values between 0.5 and 5 lb SO_2/st of clinker. With these emission rates we established the cost effectiveness for the high and low SO_2 emissions rate, as given in the following tables 2 and 3.

Tables 2 and 3 below present a summary of the calculated cost effectiveness for a Monsanto DynaWave wet SO_2 scrubber, in US dollars per short ton of SO_2 emissions. Details of the capital cost, operating costs and annual tons of SO_2 removed, and all assumptions made can be provided on August 21, 2000.

Table 2 – Cost Effectiveness for Monsanto DynaWave (High SO_2 Emissions Rate)

Model kiln	Clinker (stph)	SO_2 (lb/st clk)	Capital cost	Annual operating cost ($)	Annual SO_2 removed (stpy)	Cost effectiveness ($/ton SO_2)
Calciner	100	5	8,600,000	2,852,000	1,688	1,700
Calciner	150	5	9,900,000	3,277,000	2,531	1,300
Calciner with bypass	150	5	9,700,000	3,201,000	2,531	1,300

Table 3– Cost Effectiveness for Monsanto DynaWave (Low SO_2 Emissions Rate)

Model kiln	Clinker (stph)	SO_2 (lb/st clk)	Capital cost	Annual operating cost ($)	Annual SO_2 removed (stpy)	Cost effectiveness ($/ton SO_2)
Calciner	100	0.5	8,600,000	2,911,000	169	17,000
Calciner	150	0.5	9,900,000	3,364,000	253	13,000
Calciner with bypass	150	0.5	9,700,000	3,299,000	253	13,000

The tables clearly show that the cost effectiveness of SO_2 scrubbing is the higher, the lower the SO_2 emissions to be scrubbed will be. Therefore, the wet scrubbing technology could be cost effective for one plant but not cost effective for another one. Each kiln system will

\\PENTA-NT4-FS1\PROJECTS\FSRPT\20000317\Project\Corresp\Client\081700mcgill-medina.doc have to be evaluated individually prior to determining whether or not a wet scrubber should be used.

We hope these data and conclusions are helpful in supporting our previously submitted general statement.

Sincerely,

Penta Engineering Corporation

Michael von Seebach, Ph.D.
Vice President
Process and Environmental Engineering

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GCC PERMIAN, ODESSA PLANT
16501 W. MURPHY ST
ODESSA, TX

DRY SORBENT INJECTION
FLUE GAS DESULFURIZATION

REVISION 1

September 6, 2019

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Subject: **GCC Odessa Cement Flue Gas Desulfurization**
IAC Proposal S082319-03:SN005 REV-1

Dear Pedro:

Attached is Revision 1 to IAC proposal S082319-03.

This revision incorporates to following change to the previous proposal:

- The single-silo option changes the silo to sitting on load cells to measure the silo level. Changes to the original option system include addition of:
  - Internal structure modifications to support silo and skirt on four columns that are interior to the skirt. Each column will sit on a load cell.
  - Sartorius/Intec load cells with mount for extreme lateral and lift off forces.
  - Junction Box and load cell cable to Transmitter.
  - Transmitter with analog output 4/20mA (this can be changed to ethernet if desired).
  - Two days of engineering support for calibration of load cells upon completion of silo installation and prior to first-fill of silo with lime.

Also included is Drawing D19-0009-01 with a preliminary General Arrangement of the equipment internal and external to the silo.

IAC looks forward to having the opportunity to review the proposal with you in detail and if you have any questions, please feel to call.

Very truly yours,
Industrial Accessories Company

Mike Gregory

Business Development-Capital Equipment

Cell: (913) 216-3000
E-Mail: **mgregory@iac-intl.com**

IAC Proposal S082319-03:SN005 REV-1
September 6, 2019

GCC Odessa Cement Plant
Dry Sorbent Injection
Flue Gas Desulfurization

Prepared by:

Mike Gregory
Business Development – Capital Equipment

TABLE OF CONTENTS

1.0 SYSTEM DESCRIPTION

IAC proposes to design and furnish the dry sorbent injection (DSI) system for Kiln 1 and Kiln 2 at the GCC Permian Odessa Cement Plant. The system will have a dedicated lime storage silo and lime feed train for each Kiln – each with a loss-in-weight metering system. Each train will inject hydrated lime into a single injection point with carbon steel piping and a single injection lance per Kiln.

The DSI system for Kiln 2 is the equipment currently on-site as the rental system. The DSI system proposed for Kiln 1 is nearly identical. The main differences are a blower sized for this specific application (25 HP instead of 75 HP) and using the existing Kiln 2 system air compressor to provide pulse air for the bin vent filter.

Each proposed silo has a capacity of 2,000 ft3 and is designed to accommodate 25 tons (50,000 pounds) of hydrated lime. It is 10' x 10' square, welded steel silo with metering equipment located below the hopper. The blowers and heat exchangers will be located outside the silo support steel.

The silo hopper will have a single 12" outlet with a manual isolation knifegate valve. Flow of hydrated lime is controlled using the speed of the rotary valve. This rotary valve will have a custom reduced-capacity rotor to produce a feed rate of 75 – 500 lb/hr.

The silo will be equipped with a bin vent filter to prevent dust escape during pneumatic filling of the silo. The hopper is designed with 60° side angle and equipped with a bin activator to facilitate continuous flow from the silo.

Hydrated lime will be injected into the ductwork from a single lance. This proposal is based on a 4" hose connection to the port. The transport pipe to each level will be 4" carbon steel pipe. (Note that the hose for the existing Kiln 2 system will be replaced with 4" pipe for a permanent system.)

The electrical and control system will include a PLC, motor starters, instrumentation, and VFD's. The PLC will be connected to each motor starter and the loss-in-weight gravimetric feed system. It will also serve to communicate between the Plant's control room and the provided equipment. The new Kiln 1 train will have a 25 HP positive displacement blower while Kiln 2 will continue to use the existing 75 HP blower. These blowers are powered through a VFD to allow for speed control. During startup, the blower speed will be set to the minimum value that still allows adequate flow and proper injection of the lime into the flue gas. The value of lowest possible flow is to minimize the pressure in the transfer line, thereby minimizing the leakage of air across the rotary valve. This provides numerous benefits: 1) to extend the life expectancy of the rotary valve, 2) maximize accuracy of the gravimetric feed system, 3) reduce wear on transfer line elbows and injection points. Once set at startup, it is not expected that this setting will have to be changed (blower speed will not be an operational variable). Plant operators will have the ability to turn the blower on & off, change the lime feed rate of each train, and monitor measurements such as blower pressure, blower temperature, and silo level.

This electrical and control equipment will be installed in one panel per system. This proposal is based on these panels being installed near their respective system, but if desired, they can be located in the Plant's electrical room.

2.0 SCOPE OF SUPPLY

IAC will provide the following equipment and services. All external, non-insulated, mild steel surfaces will receive surface preparation in accordance with SSPC-SP3/6 and one coat primer; all steel surfaces that will be insulated, will not be painted nor receive any surface preparation. All standard buy-out items will be furnished with manufacturer's recommended coating/painting.

Kiln 1 DSI Scope Summary (New Equipment):

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OPTION: Single Silo w/Two Trains (New Equipment):

As an option, IAC proposes to design and furnish the dry sorbent injection (DSI) system for Kiln 1 and Kiln 2 at the GCC Permian Odessa Cement Plant. The system will have a single lime storage silo with two lime feed trains – each with a dedicated loss-in-weight metering system. Each train will inject hydrated lime into a single injection point (the same point used by existing injection system).

The proposed silo has a capacity of 4,800 ft3 and is designed to accommodate 60 tons (120,000 pounds) of hydrated lime. It is 14' diameter, welded steel silo with metering equipment located in the skirted area under the storage portion of the silo. The blowers and heat exchangers will be located outside the silo skirt.

The silo hopper will have a single 12" outlet with a "Y" that will feed the weigh hopper of each train. The silo outlet will include a manual isolation knifegate valve and automated butterfly valves in each leg.

The silo will be equipped with a bin vent filter to prevent dust escape during pneumatic filling of the silo. The hopper is designed with 70° side angle and equipped with air fluidizers to facilitate continuous flow from the silo.

Hydrated lime will be injected into the ductwork from an existing port. Testing has shown that SO2 removal can be accomplished with existing port, although alternative injection locations are available. This proposal is based on a 4" hose connection to the port. The transport pipe to each level will be 4" carbon steel pipe.

The electrical and control system will include a PLC, motor starters, instrumentation, and VFD's. The PLC will be connected to each motor starter and the loss-in-weight gravimetric feed system. It will also serve to communicate between the Plant's control room and the provided equipment. Each train will have a 25 HP positive displacement blower. These blowers will be powered through a VFD to allow for speed control. During startup, the blower speed will be set to the minimum value that still allows adequate flow and proper injection of the lime into the flue gas. The value of lowest possible flow is to minimize the pressure in the transfer line, thereby minimizing the leakage of air across the rotary valve. This provides numerous benefits: 1) to extend the life expectancy of the rotary valve, 2) maximize accuracy of the gravimetric feed system, 3) reduce wear on transfer line elbows and injection points. Once set at startup, it is not expected that this setting will have to be changed (blower speed will not be an operational variable). Plant operators will have the ability to turn the blower on & off, change the lime feed rate of each train, and monitor measurements such as blower pressure, blower temperature, and silo level.

This electrical and control equipment will be installed in two panels. This proposal is based on these panels being installed in the Plant's electrical room near the silo. If this is not feasible, IAC can provide an optional price for a stand-alone enclosure for the panels.

Confidential Business Information

SCOPE OF TWO-TRAIN SILO OPTION:

SORBENT CONVEY PIPING:

Kiln 1:

a. 4" Dia, Sch 40 CS Piping (Blow Thru Adapter to Lance);
b. Morris-couple connections; no expansion joints required.
c. Horizontal – 127', Vertical – 15', Elbows – 3 x 90° + 4 x 45°

Kiln 2:

a. 4" Dia, Sch 40 CS Piping (Blow Thru Adapter to Lance);
b. Morris-couple connections; no expansion joints required.
c. Horizontal – 185', Vertical – 22', Elbows – 3 x 90° + 3 x 45°

SILO & ACCESSORIES:

SILO DESIGN:	QTY:	1
LIME CONSUMPTION FOR SILO DESIGN:	[redacted]	[redacted]
LIME VOLUMETRIC BULK DENSITY:	lbs/cu.ft.	25
LIME STRUCTURAL BULK DENSITY:	lbs/cu.ft.	60
SILO CAPACITY [redacted]	[redacted]	[redacted]
SILO STRAIGHT-WALL CAPACITY:	Cu.Ft.	4,280
SILO DIAMETER:	FT	14
SILO SSH:	FT	28
SILO HOPPER HEIGHT:	FT	8
SILO HOPPER SIDE SLOPE:	Degree	70
SILO NET CAPACITY:	Cu.Ft.	4,600
	Tons	56
LOCATION OF INJECTION:		
NO. OF INJECTION PORTS (PER KILN):		1
LANCE DIAMETER:	IN	2

Hydrated Lime Bulk Density:

Volumetric:	25 PCF
Structural:	65 PCF
Angle of Repose:	30 Degree

Silo Dimensions:	Skirted Design
Diameter:	13'-11"
SSH (For Product):	28'-0"
Hopper Angle:	70 Degree
Hopper Discharge Diameter:	1'-0"
Roof Angle:	10 Degree

Useable Capacity:	4,800 CF.
Tank Design:	Load-Cell Supported
Tank	Commercial Quality Carbon
Material Characteristics:	Mass Flowing Material
Material Name	Hydrated Lime; 15 microns
Internal Friction	22 Degree
Pressure Coefficient:	.59
Tank Loads:	
Seismic Code	IBC 2006; ASCE 7-05
Seismic Group	ll
Seismic Category:	B
Wind Load:	130 MPH Wind Load (Exposure C)
Material Load (Live Load)	334,000 lbs. @ 60 Lbs./Cu.Ft.
Tank Weight (Dead Load)	46,000 lbs. (approx.)
Design Pressure	0.38 PSI (Internal)
Design Pressure	0.03 PSI Vac. (External)
Grounding Rods & Connectors:	By Others
Personnel Door at Grade:	One 3'-6" x 6'-8"
	Anchor Bolts not Included.
Cleaning & Finishing Standards:	
Exterior:	Epoxy primer & Finish; 4 mils DFT.
Silo Interior, Product side:	Epoxy Primer; 2 mils DFT.
Silo skirt interior:	Epoxy Primer; 2 mils DFT.
Silo Fittings & Accessories:	
Platform	Full Mezzanine Platform
Exterior Access to Roof:	Ladder
Roof Handrails; Kick-plates:	One Lot around Roof
Roof Top Access Door:	24" Manway combo w/PVR
PVR Valve:	One (1)
Target Box:	One (1); for 4" Feed line
Bin Vent Flange:	45" Square
Gasket Material:	EPDM
Bin Vent Baghouse	One (1)
IAC Baghouse Model:	39PE-BVT-25:S6; Style 2; Non-Hopper; Top Load Access with 2 Top Doors.
Clean Air Plenum:	12 Gage A-36 HRS
Dirty Air Plenum:	3/16" A36 HRS
Tube-sheet:	3/16" A36 HRS
Design Pressure:	+/- 20 inwg.
Plan View:	45" x 45"
Height:	42"; (Low Profile Design)
Weight:	798 lbs.
Access to Pleated Elements:	Two (2) roof Top Doors.

Pleated Element:	25; Polyester; 39” Long.
Filter Area:	431 sq.ft.
Compressed Air Use:	8.5-17 CFM @ 90–100 PSIG; Clean & Dry
Cleaning & Finishing Standards:	
Interior Cleaning:	None
Interior Paint:	None
Exterior Cleaning:	SP1 / SP3
Exterior Paint:	Prime & Finish Enamel; 3-4 mils D.F.T.
Pulse Valves:	5; ¾” Mecair Diaphragm Pulse Valves
Panel Enclosure:	Nema 4; Asco Solenoid Valves; 120V
Magnahelic Gage:	0-15 inwg; Dwyer Model 2015
Outlet Opening:	8”; ¼” Flange to mate w/side-mounted Fan
Air Header:	CS w/1” Sir Filter/Regulator
Winterizing Kit:	Insulated Steel enclosure around air header and pulse valves w/heat tape and thermostat controller
Bin Vent Filter Fan & Motor	
Model:	CGI 126; radial blade; side mounted
Static Pressure:	6 inwg
Arrangement:	4
Drive:	Direct
RPM	3,600
Motor:	3 HP
Fan Platform:	Located ~ 3’-0” above Silo Deck Plate
Silo Hopper Fluidization	
Number of Fluidizers	9
Compressed Air	2.8 cfm per fluidizer; Timer control
Air Pressure:	40 psig; instrument quality; clean and dry
Silo Hopper Discharge Valve:	Manual Slide Gate; 12”
Isolation/Feed Valve	
Size:	12”; Manual Valve
Chute to Weigh Hopper:	
Quantity:	2
Size:	12” Diameter
Flex Connector:	
Quantity:	2
Size:	12” Diameter; 12” long
Weigh Hopper	
Quantity:	2
Capacity:	~ 10 cu.ft.

Construction:	304 SST
Inlet:	12”
Outlet;	8”
Support Legs:	4; C.S. with 4” x 4” mounting pads
Inspection Door:	16”; roof mounted
Vibrators:	2; ball style pneumatic; air operated.
Weigh Hopper Filter	
Quantity:	2
IAC Baghouse Model:	18TB-FRT-4; Style 2; No-Hopper
Filter Bag:	16 oz./sq.yd. Polyester Felt w/PTFE
Bag Installation:	Top Load
Cleaning Air:	1.5-5.3 CFM @ 80-100 psig; Filtered & Dry
Solenoid Valve:	1; ASCO; 3/8”; Nema 4; Manual Operator
Platform Scale & Instrument	
Quantity:	2
Size:	60” x 60”x 4.5” tall
Load Scale Range:	200 to 3000 lbs/hr.
Electrical Panel:	NEMA 4; Ethernet/IP communication
Support Table for Weigh Hopper:	
Quantity	2
Construction:	CS
Paint:	SP1/SP3 Epoxy; 2 coats; 3-4 mils D.F.T.
Screw Feeder:	
Quantity:	2
Size:	2” Diameter
Drive:	VFD
Motor:	Inverter Duty; 1 HP
Turndown:	1000 to 1 (Design)
Weigh Hopper Feed Chute	
Quantity:	2
Construction:	MS
Inlet:	8”
Outlet:	8”
Weigh Hopper Outlet Flex Connector:	
Quantity:	2
Size:	8” connection; rubber isolation sleeve
Height:	6”
Clamping:	Two (2) 12” Hose style double band clamps
Surge Hopper	
Quantity:	2
Construction:	MS

Inlet:	8”
Outlet:	8”
Height:	24”

Surge Hopper Filter

Quantity:	2
IAC Baghouse Model:	18TB-FRT-2; Style 2; No-Hopper
Filter Bag:	16 oz./sq.yd. Polester Felt w/PTFE
Bag Installation:	Top Load
Cleaning Air:	1.5-5.3 CFM @ 80-100 psig; Filtered & Dry
Solenoid Valve:	1; ASCO; 3/8”; Nema 4; Manual Operator

Rotary Valve Feeder

Quantity:	2
Size:	8”
Motor:	1 HP

Blow Thru Adapter

Quantity:	2
Inlet	8” Diameter
Convey Pipe Connection:	4” Inlet; 4” Outlet
Construction;	MS

PD Convey Blower:

Quantity:	2
Manufacturer:	Roots Model 45URAI-J
Connection:	Inlet & Outlet flexible rubber Expansion Joints
Motor:	25 HP, VFD for speed control
Accessories:	Inlet Air Filter; Pressure Gage-liquid filled; Pressure Relief Valve, set at 9.5 psig.

PD Blower Instruments:

Pressure Transmitter:	4-20 mA analog signal; 0-30 psig; Rosemount 30515
Temperature Transmitter:	4-20 mA analog signal; Rosemount 3144P

Level Indicators:

Silo:	One (1) Bin Master 3D-Level Scanner; Two (High and Low) Level Indicators (Rotary Paddle Type)
Weigh Hopper;	Rotary Paddle; Two (2); 1 low; 1 high

Clean Air Piping

Quantity:	2
Size:	4”
Material:	Sch 40; CS
Length:	10’-0”
Elbows;	One (1) SR

Compression Couplings:	6; 4” size
Flange;	One (1) 4”; 150 lb flange & gasket

Product Convey Piping

Quantity:	See Above
Elbows;	See Above
Size:	4”
Material:	Sch 40; CS
Compression Couplings:	4” size

Conveying Air Isolation Valves:

Quantity:	2; Manual
Size:	2 x 4”; @ port isolation

Heat Exchanger

Quantity:	Two (2); Xchanger Model AA-500; Cool inlet temperature of up to 150F to 110F; 2 HP Motor; 460V-3pH-60Hz.
Inlet:	4” Diameter
Outlet:	4” Diameter

DSI Electrical

PLC:	
Quantity:	One (1) with HMI screen.
Motor Starter Panel:	
Quantity:	2 panels – One for PLC and one for starters and VFD’s.
Enclosure:	
Quantity:	N/A –but can be added as option

Silo Load Cells

Load Cells:	Four (4) @ 110 ton each
Mounting Kit:	Four (4) Extreme duty seismic mount
Communications:	One (1) each of Junction Box & Transmitter

3.0 WORK BY OTHERS

The following items are not included and are to be furnished by others.

1. Foundations and anchor bolts.
2. Complete erection (See Option for IAC Installation) .
3. Pipe supports.
4. 480V/3 PH/200A Electrical Supply to each Control Panel.
5. Local Disconnects for all Motors if desired.
6. Sub-grade electrical grid and lightning protectors, as needed.
7. Area lighting, transformers & panel boards, as needed.
8. Welding receptacles, as needed.
9. Initial equipment lubrication.
10. All items specifically not included.

4.0 TIME LINE SCHEDULE

DOCUMENTS FOR APPROVAL	DAYS AFTER ORDER
General Arrangement Drawings:	15
Foundation Loading Diagrams:	30
Project Schedule (delivery & construction):	30
Process Flow Diagram:	30
Single Line (Electrical):	30

NOTE: The above is a preliminary schedule.

DOCUMENTS FOR INFORMATION

O&M Manuals:	With Engineering Completion
Spare Parts List:	With Engineering Completion

PROJECT DELIVERY SCHEDULE

ACTIVITY	DATE
Award/Release	11/1/19 (Basis of schedule)
Equipment Delivery:	4/15/20

Note:

1. Detailed schedule will be provided after contract signing.

5.0 PRICING

IAC will design, fabricate, and deliver the Lime Injection System as described herein, for the prices as indicated below:

DSI Silo & Injection System

KILN 1:	
DSI Silo & Accessories	
Lime Metering	
25 HP Convey Air Blower	
Heat Exchangers for Convey Line	
PLC, Electrical Panels and Control System:	$183,000
KILN 2: (Purchase of Existing Injection System Equipment)	
DSI Silo & Accessories	
Lime Metering	
75HP Convey Air Blower	
Heat Exchangers for Convey Line	
PLC, Electrical Panels and Control System	
Air Compressor:	$195,000
Multi-System Discount for Purchase of Both Systems:	- $10,000
	========
TOTAL FOR KILN 1 & KILN 2 DSI INJECTION SYSTEMS:	**$368,000**

Optional Equipment (not included in the Base above):

1.	Mechanical Construction Services	$14,600
	a. Crane, Extended Boob Forklift & Manlift by others	
2.	Site Services (Lump sum Basis):	Per Diem
3.	Freight to Jobsite:	$25,000

<u>OPTIONS</u>

OPTION PRICE FOR SINGLE SILO W/TWO TRAINS DESCRIBED ABOVE:

DSI Silo & Injection System

Base Price for DSI Silo & Accessories:
Exterior Ladder to Mezzanine & Roof Level w/
Interior Ladder to for equipment access:
Load Cells w/Internal Support Structure:
Two (2) Heat Exchangers for Convey Line:
PLC, Electrical Panels and Control System:
(Enclosure not included) ========

$642,500

Payment Terms:

30% With Purchase Order
10% GA & Engineering Drawings for Approval
55% With Delivery; Progress Payment allowed for equipment delivered.
5% With Start-up, no later than 90 days after completion of delivery

<u>All payments Net 30 days from date of Invoice.</u>

Bid Validity: October 1, 2019.

6.0 FIELD SERVICE RATE SHEET *Effective 1/1/18*

The rates below are effective from the date shown above and are subject to change without notice.

Normal working hours are from 8:00 a.m. to 5:00 p.m. Monday through Friday with one (1) hour for lunch. Minimum billing will be four (4) hours plus any incurred expenses.

U.S. Service Work Daily and Hourly Rates - U.S. Dollars				
	Mechanical Work		**Electrical Work**	
	Daily (8 hrs)	Hourly	Daily (8 hrs)	Hourly
Monday - Friday After 8 & up to 12 hours (Over 12 hours)	$1,080.00	$135.00 $197.00 $253.00	$1,336.00	$167 $212 $283
Saturday (up to 12 hours) (Over 12 hours)	$1,576.00	$197.00 $253.00	$1,696.00	$212 $283
Sunday & Holidays Per hour - 4 hr. minimum		$253.00		$283

Travel Time:
The buyer shall pay for travel time incurred as a result of service work. Travel time is defined as actual time spent by our Service Personnel while traveling to and from the job site for the purpose of doing the contracted work. The rates for travel time shall be the same as the charges noted above. Working time, stand-by time, and travel shall be combined to calculate the total charges.

Travel Expense:
The Buyer shall reimburse the Seller for transportation expenses incurred in traveling to and from the job site. If a company or a personal car is used, travel expenses shall be calculated at $0.50 per mile. If public transportation is used, travel expenses shall be the actual cost of air transportation, bus, taxi, and/or rental car.

Living Expenses:
Meals, lodging, and incidental expenses will be charged at cost.

Stand-By Time:
Stand by time is defined as time during which Seller's personnel is available for work, but is not working because of circumstances beyond Seller's control. The stand by time shall be charged as working time. Local living expenses shall be invoiced to the buyer for normal weekend days when no work is performed and the Seller's personnel is not on call.

Relief Trip:
If the scope of the work requires IAC personnel to remain at the jobsite for extended periods, the service person shall be entitled to one (1) return trip home every third weekend. The Buyer shall be liable for all transportation expenses, but will not be charged for travel time for the relief trip.

7.0 COMMERCIAL TERMS & CONDITIONS

IAC STANDARD TERMS AND CONDITIONS

All equipment or installation services not specifically referenced herein, as supplied by IAC shall be considered to be provided by others.

Equipment, parts, and labor, manufactured by IAC, are warranted to be free of defects in materials and workmanship for a period of one (1) year from date of shipment. IAC MAKES NO IMPLIED WARRANTY OF MERCHANTABILITY, NO IMPLIED WARRANTY OF FITNESS FOR ANY PARTICULAR PURPOSE AND NO OTHER WARRANTY, EITHER EXPRESS OR IMPLIED, CONCERNING ANY COMPONENTS OR PARTS OF THE EQUIPMENT WHICH WERE NOT MANUFACTURED BY IAC. This does not alter or amend any warranty that such manufacturer of the Equipment might have made with respect to the Equipment which PURCHASER might be entitled to assert. To the extent any such warranty has been made, IAC is not a party to that warranty and has no responsibility with respect to it. All warranties offered by the original manufacturers shall be passed on to the customer.

In all cases should a repair or defect in material or workmanship occur on IAC's equipment IAC shall be notified immediately in writing by purchaser; and at that time IAC shall have the sole and exclusive option of either field repairing or requesting that said item(s) be returned to IAC for factory repair or replacement.

The repair or replacement of defective parts or workmanship is purchaser's sole and exclusive remedy against IAC for the breach of IAC's warranty. Purchaser agrees that no other remedy, including but not limited to incidental or consequential damages, shall be available to him. PURCHASER shall indemnity IAC against any loss, claim or damage (including attorney's fees incurred in the defense of any claim) arising out of or in connection with the installation, processing or use by any person of any of the Equipment, in whole or in part, unless such injury is due solely and directly to the negligence of IAC, its employees or agents.

It is understood that all taxes, licenses, and permits required for this project are the responsibility of the PURCHASER.

Note: Call us anytime you have design or engineering requirements for stand-alone equipment all the way up to a "Turnkey" system (new or retrofit) for air pollution control equipment; and pneumatic material conveying and bulk storage systems.

We thank you in advance for your consideration of our equipment proposal and at the same time, we shall look forward to any questions you may have for us.

Respectfully,

Mike Gregory
Industrial Accessories Company

CC: Glenn A. Smith, Jr., Gregg Zoltek, Herb Litke, Luis Castano

Cost Estimate

TCI for Coal-Fired Boilers
For Coal-Fired Boilers:
$TCI = 1.3 \times (SCR_{cost} + RPC + APHC + BPC)$

Capital costs for the SCR (SCR_{cost}) =	$15,565,147	in 2018 dollars
Reagent Preparation Cost (RPC) =	$7,122,951	in 2018 dollars
Air Pre-Heater Costs (APHC)* =	$0	in 2018 dollars
Balance of Plant Costs (BPC) =	$7,337,250	in 2018 dollars
Total Capital Investment (TCI) =	$39,032,951.37	in 2018 dollars

* Not applicable - This factor applies only to coal-fired boilers that burn bituminous coal and emits equal to or greater than 3lb/MMBtu of sulfur dioxide.

SCR Capital Costs (SCR_{cost})
For Coal-Fired Utility Boilers >25 MW:
$SCR_{cost} = 310{,}000 \times (NRF)^{0.2} \times (B_{MW} \times HRF \times CoalF)^{0.92} \times ELEVF \times RF$
For Coal-Fired Industrial Boilers >250 MMBtu/hour:
$SCR_{cost} = 310{,}000 \times (NRF)^{0.2} \times (0.1 \times Q_B \times CoalF)^{0.92} \times ELEVF \times RF$

SCR Capital Costs (SCR_{cost}) =	$15,565,147 in 2018 dollars

Reagent Preparation Costs (RPC)
For Coal-Fired Utility Boilers >25 MW:
$RPC = 564{,}000 \times (NOx_{in} \times B_{MW} \times NPHR \times EF)^{0.25} \times RF$
For Coal-Fired Industrial Boilers >250 MMBtu/hour:
$RPC = 564{,}000 \times (NOx_{in} \times Q_B \times EF)^{0.25} \times RF$

Reagent Preparation Costs (RPC) =	$7,122,951 in 2018 dollars

Air Pre-Heater Costs (APHC)*
For Coal-Fired Utility Boilers >25MW:
$APHC = 69{,}000 \times (B_{MW} \times HRF \times CoalF)^{0.78} \times AHF \times RF$
For Coal-Fired Industrial Boilers >250 MMBtu/hour:
$APHC = 69{,}000 \times (0.1 \times Q_B \times CoalF)^{0.78} \times AHF \times RF$

Air Pre-Heater Costs (APH_{cost}) =	$0 in 2018 dollars

* Not applicable - This factor applies only to coal-fired boilers that burn bituminous coal and emit equal to or greater than 3lb/MMBtu of sulfur dioxide.

Balance of Plant Costs (BPC)
For Coal-Fired Utility Boilers >25MW:
$BPC = 529{,}000 \times (B_{MW} \times HRFx\ CoalF)^{0.42} \times ELEVF \times RF$
For Coal-Fired Industrial Boilers >250 MMBtu/hour:
$BPC = 529{,}000 \times (0.1 \times Q_B \times CoalF)^{0.42}\ ELEVF \times RF$

Balance of Plant Costs (BOP_{cost}) =	$7,337,250 in 2018 dollars

Annual Costs

Total Annual Cost (TAC)

TAC = Direct Annual Costs + Indirect Annual Costs

Direct Annual Costs (DAC) =	$281,387	in 2018 dollars
Indirect Annual Costs (IDAC) =	$3,072,960	in 2018 dollars
Total annual costs (TAC) = DAC + IDAC	$3,354,347	in 2018 dollars

Direct Annual Costs (DAC)

DAC = (Annual Maintenance Cost) + (Annual Reagent Cost) + (Annual Electricity Cost) + (Annual Catalyst Cost)

Annual Maintenance Cost =	0 005 x TCI =	$195,165	in 2018 dollars
Annual Reagent Cost =	m_{sol} x $Cost_{reag}$ x t_{op} =	$44,965	in 2018 dollars
Annual Electricity Cost =	P x $Cost_{elect}$ x t_{op} =	$24,316	in 2018 dollars
Annual Catalyst Replacement Cost =		$16,941	in 2018 dollars
For coal-fired boilers, the following methods may be used to calcuate the catalyst replacement cost			
Method 1 (for all fuel types):	n_{scr} x Vol_{cat} x ($CC_{replace}$/R_{layer}) x FWF	* Calculation Method 1 selected.	
Method 2 (for coal-fired industrial boilers):	(Q_B/NPHR) x 0.4 x $(CoalF)^{2.9}$ x $(NRF)^{0.71}$ x ($CC_{replace}$) x 35 3		
Direct Annual Cost =		$281,387	in 2018 dollars

Indirect Annual Cost (IDAC)

IDAC = Administrative Charges + Capital Recovery Costs

Administrative Charges (AC) =	0 03 x (Operator Cost + 0.4 x Annual Maintenance Cost) =	$4,970	in 2018 dollars
Capital Recovery Costs (CR)=	CRF x TCI =	$3,067,990	in 2018 dollars
Indirect Annual Cost (IDAC) =	AC + CR =	$3,072,960	in 2018 dollars

Cost Effectiveness

Cost Effectiveness = Total Annual Cost/ NOx Removed/year

Total Annual Cost (TAC) =	$3,354,347	per year in 2018 dollars
NOx Removed =	488	tons/year
Cost Effectiveness =	$6,868	per ton of NOx removed in 2018 dollars

Table B-1. SCR Cost Summary

Variable	Value
Total Capital Cost	
Per Kiln	$39,032,951
Combined	$78,065,903
Total Annual Cost	
Per Kiln	$3,354,347
Combined	$6,708,694
Total Tons NO_X Reduced	977
Cost Effectiveness ($/ton)	$6,868

Low-NO_X Burner and Upgraded Coal Mill Cost Calculations

Table B-2. Direct Costs per Kiln

Purchased Equipment Costs			
Upgraded Coal Mill[1]	Equipment Costs (EC)	$	[redacted]
Sales Tax[2]	[redacted] of EC	$	[redacted]
Subtotal, Purchased Equipment Cost (PEC)		$	[redacted]

Table B-3. Indirect Installation Costs[2]

Installation[3]	Vendor Quote	--	
Start-up[2]	1% of PEC	$	231,750.00
Performance Test[2]	1% of PEC	$	231,750.00
Contingencies[2]	3% of PEC	$	695,250.00
Total Indirect Cost		$	1,158,750.00

Total Capital Investment (TCI)	**$**	**24,333,750.00**

Table B-4. Direct Annual Costs per Kiln

Hours per Year[4]	Kilns run near continuously. Down less than 15% of selected time period		7487.85
Electricity			
ATOX Coal Mill[5]	kW		114
Fan[5]	kW		73
Cost[6]	$/kW-hr		0.0502
Subtotal, Electricity		$	70,291.41
Total Direct Annual Cost		$	70,291.41

Table B-5. Indirect Annual Costs per Kiln[2]

Capital Recovery	20 year life, 4.75% interest	$	1,911,427.43
Total Indirect Annual Cost		$	1,911,427.43

Total Annualized Cost per Kiln	**$**	**1,981,718.85**

[1] Cost of one burner per vendor quote provided by FLS. Costs for each burner includes the trolley, hoses, and burner, as well as the primary air fan.

[2] Table 1.3 and Table 1.4 of the EPA Control Cost Manual 6th Edition, Section 5.2, Chapter 1

[3] Installation cost estimate included in vendor cost provided by FLS. "Installation" as quoted by the vendor is assumed to account for engineering, construction, and contractor services.

Based on average run time of Kilns #1 and #2 from 2016 to 2018.

[5] Electricity ratings for components included in PFDs attached to the vendor quote from FLS.

[6] Cost of electricity is site-specific for the GCC Tijeras facility based on 2018 power costs.

Table B-6. Low-NO_X Burner Cost Summary

Variable	Value
Total Capital Cost	$24,333,750
Total Annual Cost	$1,981,719
Baseline NOX Emisisons	1206
Anticipated Control Efficiency	15%
Total Tons NOX Reduced	180.9
Cost Effectiveness ($/ton)	$10,954.78

[1] Based on vendor quotes provided by FLSmidth for the upgrade of the coal mill and installation of JETFLEX Low-NO_X burners on each kiln.

Cost Estimate

Total Capital Investment (TCI)

For Coal-Fired Boilers:

$$TCI = 1.3 \times (SNCR_{cost} + APH_{cost} + BOP_{cost})$$

For Fuel Oil and Natural Gas-Fired Boilers:

$$TCI = 1.3 \times (SNCR_{cost} + BOP_{cost})$$

Capital costs for the SNCR ($SNCR_{cost}$) =	$987,220	in 2018 dollars
Air Pre-Heater Costs (APH_{cost})* =	$0	in 2018 dollars
Balance of Plant Costs (BOP_{cost}) =	$1,379,070	in 2018 dollars
Total Capital Investment (TCI) =	$3,076,177	in 2018 dollars

* Not applicable - This factor applies only to coal-fired boilers that burn bituminous coal and emits equal to or greater than 0.3lb/MMBtu of sulfur dioxide.

SNCR Capital Costs ($SNCR_{cost}$)

For Coal-Fired Utility Boilers:

$$SNCR_{cost} = 220{,}000 \times (B_{MW} \times HRF)^{0.42} \times CoalF \times BTF \times ELEVF \times RF$$

For Fuel Oil and Natural Gas-Fired Utility Boilers:

$$SNCR_{cost} = 147{,}000 \times (B_{MW} \times HRF)^{0.42} \times ELEVF \times RF$$

For Coal-Fired Industrial Boilers:

$$SNCR_{cost} = 220{,}000 \times (0.1 \times Q_B \times HRF)^{0.42} \times CoalF \times BTF \times ELEVF \times RF$$

For Fuel Oil and Natural Gas-Fired Industrial Boilers:

$$SNCR_{cost} = 147{,}000 \times ((Q_B/NPHR) \times HRF)^{0.42} \times ELEVF \times RF$$

SNCR Capital Costs ($SNCR_{cost}$) =	$987,220	in 2018 dollars

Air Pre-Heater Costs (APH_{cost})*

For Coal-Fired Utility Boilers:

$$APH_{cost} = 69{,}000 \times (B_{MW} \times HRF \times CoalF)^{0.78} \times AHF \times RF$$

For Coal-Fired Industrial Boilers:

$$APH_{cost} = 69{,}000 \times (0.1 \times Q_B \times HRF \times CoalF)^{0.78} \times AHF \times RF$$

Air Pre-Heater Costs (APH_{cost}) =	$0	in 2018 dollars

* Not applicable - This factor applies only to coal-fired boilers that burn bituminous coal and emit equal to or greater than 3lb/MMBtu of sulfur dioxide.

Balance of Plant Costs (BOP_{cost})

For Coal-Fired Utility Boilers:

$$BOP_{cost} = 320{,}000 \times (B_{MW})^{0.33} \times (NO_xRemoved/hr)^{0.12} \times BTF \times RF$$

For Fuel Oil and Natural Gas-Fired Utility Boilers:

$$BOP_{cost} = 213{,}000 \times (B_{MW})^{0.33} \times (NO_xRemoved/hr)^{0.12} \times RF$$

For Coal-Fired Industrial Boilers:

$$BOP_{cost} = 320{,}000 \times (0.1 \times Q_B)^{0.33} \times (NO_xRemoved/hr)^{0.12} \times BTF \times RF$$

For Fuel Oil and Natural Gas-Fired Industrial Boilers:

$$BOP_{cost} = 213{,}000 \times (Q_B/NPHR)^{0.33} \times (NO_xRemoved/hr)^{0.12} \times RF$$

Balance of Plant Costs (BOP_{cost}) =	$1,379,070	in 2018 dollars

Annual Costs

Total Annual Cost (TAC)

TAC = Direct Annual Costs + Indirect Annual Costs

Direct Annual Costs (DAC) =	$112,121	in 2018 dollars
Indirect Annual Costs (IDAC) =	$243,172	in 2018 dollars
Total annual costs (TAC) = DAC + IDAC	$355,293	in 2018 dollars

Direct Annual Costs (DAC)

DAC = (Annual Maintenance Cost) + (Annual Reagent Cost) + (Annual Electricity Cost) + (Annual Water Cost) + (Annual Fuel Cost) + (Annual Ash Cost)

Annual Maintenance Cost =	0.015 x TCI =	$46,143	in 2018 dollars
Annual Reagent Cost =	q_{sol} x $Cost_{reag}$ x t_{op} =	$49,961	in 2018 dollars
Annual Electricity Cost =	P x $Cost_{elect}$ x t_{op} =	$2,360	in 2018 dollars
Annual Water Cost =	q_{water} x $Cost_{water}$ x t_{op} =	$8,719	in 2018 dollars
Additional Fuel Cost =	ΔFuel x $Cost_{fuel}$ x t_{op} =	$4,338	in 2018 dollars
Additional Ash Cost =	ΔAsh x $Cost_{ash}$ x t_{op} x (1/2000) =	$600	in 2018 dollars
Direct Annual Cost =		$112,121	in 2018 dollars

Indirect Annual Cost (IDAC)

IDAC = Administrative Charges + Capital Recovery Costs

Administrative Charges (AC) =	0.03 x Annual Maintenance Cost =	$1,384	in 2018 dollars
Capital Recovery Costs (CR)=	CRF x TCI =	$241,788	in 2018 dollars
Indirect Annual Cost (IDAC) =	AC + CR =	$243,172	in 2018 dollars

Cost Effectiveness

Cost Effectiveness = Total Annual Cost/ NOx Removed/year

Total Annual Cost (TAC) =	$355,293	per year in 2018 dollars
NOx Removed =	136	tons/year
Cost Effectiveness =	$2,619	per ton of NOx removed in 2018 dollars

Table B-7. SNCR Cost Summary

Variable	Value
Total Capital Cost	
Per Kiln	$3,076,177
Combined	$6,152,354
Total Annual Cost	
Per Kiln	$355,293
Combined	$710,585
Total Tons NO_X Reduced	271
Cost Effectiveness ($/ton)	$2,619

Table B-8. TDF Cost Calculation Summary

Emission Unit ID	TDF Cost Effectiveness ($/ton removed)	Total Annualized Cost ($/year)	Total Pollutant Removed (tons)
Tire per 2 Revolutions	$7,633	$1,366,949	179.09
Tire per 3 Revolutions	$10,749	$1,283,340	119.39

Table B-9. Process Inputs

Variable	Value		Unit
Tire per 2 Revolutions	2	3	revolutions
Tire per 3 Revolutions	6,778	6,778	kcal/kg
Coal fuel throughput	[redacted]	[redacted]	metric tons/day
Tire substitution rate [2]	0.50	0.33	tires/rotation
	12%	8%	% substitution
Tire heating value (HHV)	13,500	13,500	Btu/lb
	7,485	7,485	kcal/kg
Tire mass	10	10	kg/tire

[1] Coal higher heating value is specific to the GCC Tijeras facility and coal mine.

[2] Calculated using a kiln rotation rate of 90 rotations per hour.

Table B-10. Annual Tire Usage Calculation

Variable	Value		Unit
Current heat input	[redacted]	[redacted]	
Tire heat input	162,021,312	108,014,208	kcal/day
Tire throughput[1]	2,165	1,443	tires/day
Tire Throughput (Both Kilns):	711,087	474,058	tires/year

[1] Assumes TDF is used for 90% of the year, due to fluctuating tire availability and kiln maintenance or downtime

Table B-11. Cost Calculation Input Data

Variable	Value		Unit
Baseline NO_X Emissions	1,206	1,206	tons/year
NO_X Control Efficiency [1]	14.85%	9.90%	
Interest Rate [2]	4.75%	4.75%	
Estimated Equipment Life [3]	20	20	years
Chemical Engineering Plant Cost In			
2019	607.5	607.5	
1997	386.5	386.5	

[1] Assumed control efficiency of 33% at a tire substitution rate of 1 tire per rotation, scaled linearly.
Sanders, D. "NOx Control Technologies for the Cement Industry: Final Report." September 2000, EPA-457/R-00-002
https://www3.epa.gov/airquality/ctg_act/200009_nox_epa457_r-00-002_cement_industry.pdf
Annual average control efficiency accounting for 90% uptime.

[2] Bank prime loan rate obtained from the Federal Reserve. https://www.federalreserve.gov/releases/h15/

[3] Default value provided in the EPA's Control Cost Manual and associated template calculation workbook for various control technologies.

Table B-12. TDF Direct Capital Costs

Cost	Value	Value	Notation
Tire per 2 Revolutions			
Ti TDF Equipment Cost	$1,490,000	$1,490,000	A
Instrumentation	Incl.	Incl.	0.1 * A
Sales Tax	$44,700.00	$44,700.00	0.03 * A
Freight	$74,500.00	$74,500.00	0.05 * A
Subtotal, Purchased Equipment Cost	$1,609,200	$1,609,200	PEC
Direct Installation Costs [1]	$670,000	$670,000	DI
Total Direct Cost	**$2,279,200**	**$2,279,200**	DC = PEC + DI

[1] TDF equipment cost and direct installation costs obtained from "NOx Control Technologies for the Cement Industry: Final Report" (EPA, 2000). Costs are presented in 1997 dollars.
https://www3.epa.gov/airquality/ctg_act/200009_nox_epa457_r-00-002_cement_industry.pdf

Table B-13. TDF Indirect Capital Costs

Cost	Value	Value	Notation
Overhead & Contingencies	$491,000	$491,000	
Engineering	Incl.	Incl.	
Construction & Field Expenses	Incl.	Incl.	
Contractor Fee	Incl.	Incl.	
Start-Up	Incl.	Incl.	
Performance Testing	Incl.	Incl.	
Contingencies	$298,000	$298,000	
Total Indirect Cost	**$789,000**	**$789,000**	

[1] TDF indirect installation and contingency costs obtained from "NOx Control Technologies for the Cement Industry: Final Report" (EPA, 2000). Costs are presented in 1997 dollars.
https://www3.epa.gov/airquality/ctg_act/200009_nox_epa457_r-00-002_cement_industry.pdf

Total Capital Investment (TCI) (1997 $)	**$3,068,200**	**$3,068,200**

Table B-14. TDF Direct Annual Costs

Variable	Value	Value	Units
Hours per Year	7884	7884	hours
Days per Year	328.5	328.5	days
Operating Labor [1,3]			
Operator Hours	15,768	15,768	hours
Operator Wages	[redacted]	[redacted]	[redacted]
Subtotal, Operator Cost	[redacted]	[redacted]	[redacted]
Maintenance Labor [2,3]			
Maintenance Hours	492.75	492.75	hours
Maintenance Wages	[redacted]	[redacted]	[redacted]
Subtotal, Maintenance Cost	[redacted]	[redacted]	[redacted]
Tire Processing Costs [4]			
Cost Per Ton of Tires	[redacted]	[redacted]	
Subtotal, Tire Processing Cost	[redacted]	[redacted]	
Total Direct Annual Costs (2019 $)	[redacted]	[redacted]	

[1] Assumes a total of 4 full time operators will be required to run the equipment.
Operators work a total of 12 hours per shift.
[2] Assumes maintenance hours of 0.5 hours per 8 hour shift, consistent with various emission control technologies in the EPA Control Cost Manual.
[3] Operator and maintenance staff wages are site-specific to the GCC Tijeras cement plant.
[4] [redacted]

Table B-15. TDF Indirect Annual Costs

Cost	Value	Value	Notation
Administrative Charges	$61,364	$61,364	0.02 * TCI
Insurance	$30,682	$30,682	0.01 * TCI
Property Tax	$30,682	$30,682	0.01 * TCI
Capital Recovery [1]	$241,009	$241,009	CRF * TCI
Total Indirect Annual Cost (2015 $)	**$363,737**	**$363,737**	

[1] Formula for capital recovery obtained from the EPA Control Cost Manual, Section 1, Chapter 2, Equation 2.8a.
https://www3.epa.gov/ttncatc1/dir1/c_allchs.pdf

Table B-16. TDF Cost Summary

Variable	Value	Value	Units
Total Annualized Cost	$1,366,949	$1,283,340	2019$/year
Emission Rate Prior to Burner Replacement	1,206	1,206	tons NO_X/yr
Pollutant Removed	179	119	tons NO_X/yr
Cost Per Ton of Pollutant Removed	$7,633	$10,749	$/ton

Proposal
Volume 1
10 October 2019

FLSMIDTH

GCC Tijeras

Coal grinding circuit

Tijeras, NM

Budget offer for a ATOX 13.5 coal grinding circuit

Tender No.: TBD

FLS Proposal No.: Budget

One Source

FLSmidth Inc.
2040 Avenue C • Bethlehem, PA 18017-2188 • USA
Tel +1 610 264 6011 • Fax +1 610 264 6170
www.flsmidth.com

FLSMIDTH

October 10th, 2019

GCC PUEBLO
11783 State HWY 337 South
Tijeras NM, 87059

Attention: Ms. Samantha Kretz
Environmental Engineer

Subject: GCC Tijeras coal mill budget price

Dear Ms. Kretz,

Thank you for your interest in a new coal mill system for the GCC Tijeras plant. We understand that your current grinding circuit has some operating challenges with the direct firing setup. To modernize this part of the plant we are offering GCC an ATOX 13.5 circuit. To help with your capital budgeting we have estimated the coal grinding on an installed basis, for the equipment shown on the flow sheet. Our budget cost is:

ATOX 13.5 coal mill circuit with two JETFLEX burners – EPC [redacted]

We have included a sample process operating diagram for a generic coal grinding circuit. The assumptions we have taken based on our knowledge of the Tijeras plant are:

[redacted]

[redacted]

FLSmidth has supplied over 150 ATOX coal mills around the world including one recently at the GCC Dakotah plant. Throughout our 137 years of FLSmidth's existence, we have taken great pride in our experience, our people, our leading and innovating technology and our customer service. FLSmidth has complete capabilities and personnel to support this project and future needs through our major Project Center located in Bethlehem, PA. We can help your plant achieve sustainable productivity enhancements with our diverse experience and intimate knowledge of the markets. For FLSmidth our people and relationships are our greatest strength which we leverage to help our clients reach their goals. We hope that you find this proposal informative and complete. Should you need any additional information please contact me at 412 951 6473 or via email at srdan.nisic@flsmidth.com

Best regards,

Srdan Nisic
FLSmidth Inc.
Products and Upgrades Sales Manager
Cement Division

Confidential Business Information

FLSMIDTH CPD-P Coal mill system Operating Case 1	Project			Project number	Edition
	Generic operating values			TBD	3
	Made by	Checked by	Approved by	Project status	Date
	WRM			Prelim. Budget	10/6/2011
	Barometric pressure	Ambient temperature	Relative humidity	Water temperature	Electrical frequency
	751 mm Hg	32 °C	70 %	20 °C	50 Hz

Product	
Coal meal	[redacted]
Other material	
Temperature	
Moisture	
Fineness	

[redacted]

Template: CMv, release 8.17.0 of 20100126. Program: 8.20.11.7.6.24.99.33.6.23.15.10.0 of 20110504

All massflows are on dry basis

[redacted]

Confidential Business Information

Draft

Scale:	Drawn	Appr.	Appr. Date	Zone/Descr.:
1:1	WGSO		nuldate	Reference No. with Q see legend No.

GCC
2000
400 E Clinker production

Flow Diagram

Plan No. 3

FLSmidth No.: 10367460 Ver.: 1.0

[redacted]

Draft

Confidential Business Information

Scale:	Drawn	Appr.	Appr. Date	Zone/Descr.:
1:1	WGSO		nulldate	Reference No. with Q see legend No.

GCC
2000
400 G Clinker production

Flow Diagram

Plan No. 4

FLSmidth

No.: 10367462

Ver.: 1.0

[redacted]

Draft

Confidential Business Information

1:100

0 5 10 m

Proposal no. 1454543_100

Scale:	Drawn	Appr.	Appr. Date	Zone/Descr.:
1:100	JESSO		nulldate	

Industria Nacional Del Cemento – Puerto Vallemi, PAR
2000
461 Coal mill

Proposal drawing

Plan No. 2

FLSMIDTH

No.: 10368459 Ver.: 1.0

[redacted]

Draft

Proposal no. 1454543_100

Scale:	Drawn	Appr.	Appr. Date	Zone/Descr.:
1:100	JESSO		nulldate	

Industria Nacional Del Cemento – Puerto Vallemi, PAR
2000
461 Coal mill

Proposal drawing

Plan No. 3

FLSMIDTH

No.: 10368460 Ver.: 1.0

1:100
0 5 10 m

[redacted]

Draft

Confidential Business Information

Proposal no.	1454543_100			
Scale:	Drawn	Appr.	Appr. Date	Zone/Descr.:
1:100	[illegible]		[illegible]	

Industria Nacional Del Cemento – Puerto Vallemi, PAR
2000
461 Coal mill

Proposal drawing

Plan No. 4

1:100
0 5 10 m

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No.: 10368461

Ver.: 1.0

APPENDIX C – RBLC DATABASE SEARCH RESULTS

RBLC Search Results

RBLC ID	FACILITY NAME	CORPORATE OR COMPANY NAME	FACILITY STATE	AGENCY NAME	PERMIT NUMBER	PERMIT ISSUANCE DATE	PROCESS NAME	PRIMARY FUEL	POLLUTANT	CONTROL METHOD DESCRIPTION
IN-0312	LEHIGH CEMENT COMPANY LLC	LEHIGH CEMENT COMPANY LLC	IN	INDIANA DEPT OF ENV MGMT, OFC OF AIR	093-40198-00002	6/27/2019	Kiln	Natural Gas, Coal, Coke, Fuel Oils	Nitrogen Oxides (NOx)	Low NOx Burners and Selective Non-Catalytic Reduction (SNCR)
TX-0822	CEMENT PLANT	CAPITOL AGGREGATES, INC.	TX	TEXAS COMMISSION ON ENVIRONMENTAL QUALITY (TCEQ)	7369, PSDTX120M4, AND GHGPSDTX	6/30/2017	Portland Cement Kiln - Kiln KL-870	Coal	Nitrogen Oxides (NOx)	Good Combustion Practices, SNCR
*KS-0031	ASH GROVE CEMENT COMPANY	ASH GROVE CEMENT COMPANY	KS	KANSAS DEPT. OF HEALTH & ENVIRONMENT, BR. OF AIR & RADIATION, KS	C-13894	7/14/2017	Portland Cement Manufacturing (kilns, mills, clinker cooler, conveyors)	Coal and/or Petroleum Coke, etc.	Nitrogen Oxides (NOx)	Fabric filters are specified in the PSD permit.
IL-0111	UNIVERSAL CEMENT	UNIVERSAL CEMENT	IL	ILLINOIS EPA, BUREAU OF AIR	8120011	12/20/2011	Kiln with In-Line Raw Mill	Coal, Petcoke, Scrap Tires	Nitrogen Oxides (NOx)	Staged Combustion and SNCR
GA-0136	CEMEX SOUTHEAST, LLC	CEMEX, INC.	GA	GEORGIA DEPARTMENT OF NATURAL RESOURCES	3241-153-0003-V-04-3	1/27/2010	Main Kiln Stack K218	Coal	Nitrogen Oxides (NOx)	Staged & Controlled Combustion (SCC), SNCR, Low NOx Burner and Indirect Firing.
TX-0822	CEMENT PLANT	CAPITOL AGGREGATES, INC.	TX	TEXAS COMMISSION ON ENVIRONMENTAL QUALITY (TCEQ)	7369, PSDTX120M4, AND GHGPSDTX	6/30/2017	Portland Cement Kiln - Kiln KL-870	Coal	Sulfur Dioxide (SO2)	Good Combustion Practices
IL-0111	UNIVERSAL CEMENT	UNIVERSAL CEMENT	IL	ILLINOIS EPA, BUREAU OF AIR	8120011	12/20/2011	Kiln with In-Line Raw Mill	Coal, Petcoke, Scrap Tires	Sulfur Dioxide (SO2)	Absorption in Clinker and Kiln Dust and an Add-On Circulating Fluidized Bed Absorber or Equivalent.
GA-0136	CEMEX SOUTHEAST, LLC	CEMEX, INC.	GA	GEORGIA DEPARTMENT OF NATURAL RESOURCES	3241-153-0003-V-04-3	1/27/2010	Main Kiln Stack K218	Coal	Sulfur Dioxide (SO2)	Judicious selection/use of raw materials and, as necessary, use of hydrated lime injection.
*KS-0031	ASH GROVE CEMENT COMPANY	ASH GROVE CEMENT COMPANY	KS	KANSAS DEPT. OF HEALTH & ENVIRONMENT, BR. OF AIR & RADIATION, KS	C-13894	7/14/2017	Portland Cement Manufacturing (kilns, mills, clinker cooler, conveyors)	Coal and/or Petroleum Coke, etc.	Sulfur Oxides (SOx)	Fabric filters are specified in the PSD permit.
TX-0736	MIDLOTHIAN PORTLAND CEMENT PLAN	HOLCIM (TEXAS) LIMITED PARTNERSHIP	TX	TEXAS COMMISSION ON ENVIRONMENTAL QUALITY (TCEQ)	8996, PSDTX454M4	5/12/2015	Oxidation Control for Portland Cement Kilns	natural gas	Particulate matter, total (TPM)	Wet Scrubbers, Continuous Opacity Monitoring, Proper operation of Oxidation Control Units
TX-0736	MIDLOTHIAN PORTLAND CEMENT PLAN	HOLCIM (TEXAS) LIMITED PARTNERSHIP	TX	TEXAS COMMISSION ON ENVIRONMENTAL QUALITY (TCEQ)	8996, PSDTX454M4	5/12/2015	Oxidation Control for Portland Cement Kilns	natural gas	Sulfuric Acid (mist, vapors, etc)	Low sulfur fuels, Wet scrubbers

[1] There are no verified cost effectiveness values associated with the above RBLC entries.

[2] Note that fabric filters are not expected to provide control of NO_X or SO_2 emissions. It is assumed that the control method description was applied to all of the pollutants for Ash Grove more broadly.

APPENDIX D - TIRE DERIVED FUEL AVAILABILITY ANALYSIS

Table 1. Process Inputs

Variable	Value	Unit
Coal heating value (HHV)	6,778	kcal/kg
Coal fuel throughput	[redacted]	[redacted]
Tire substitution rate	24%	% substitution
Tire heating value (HHV)	13,500	Btu/lb
	7,485	kcal/kg
Tire mass	10	kg/tire

Table 2. Annual Tire Usage Calculation

Variable	Value	Unit
Current heat input	[redacted]	[redacted]
Tire heat input	324,042,624	kcal/day
Tire throughput[1]	4,329	tires/day
Tire Throughput (Both Kilns):	1,422,174	tires/year

[1] Assumes TDF is used for 90% of the year, due to fluctuating tire availability and kiln maintenance or downtime

Table 3. Renewable Tire Availability

Location	Total
Albuquerque	714,622
Roswell	83,750
Wagon Mound	50,000
Los Lunas	45,000
Espanola	33,057
San Miguel County	31,000
Santa Fe	26,600
Thoreau	25,000
Silver City	19,900
Deming	15,000
Taos	13,800
Los alamos	10,314
Socorro County	6,000
Bernalillo County	5,872
Logan	2,800
Raton, NM	2,500
Santa Rosa	2,018
Las Vegas	1,031
Tucumcari	567
Mora	10
Total	**1,088,841**

Table 4. Reserves Tire Availability

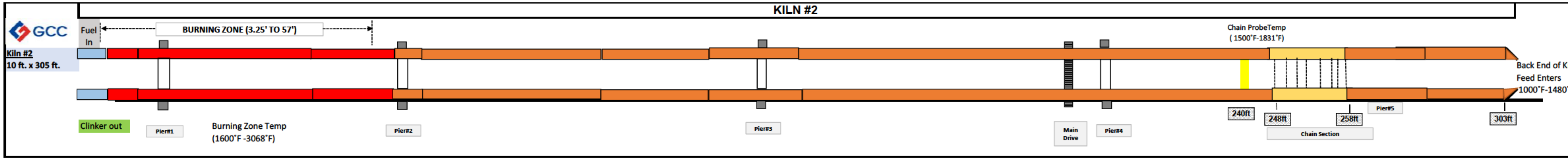
Location	Total
Thoreau	1,000,000
Cuba	800,000
Deming	230,000
Moriarty	75,000
Silver City	52,500
Socorro County	43,200
Logan	15,000
Raton	15,000
Taos Landfill	13,000
Albuquerque	10,000
Las Vegas	8,000
Los Lunas	500
Santa Ana Pueblo	350
Total	**2,262,550**

Table 5. Annual Tire Use and Reserves Depletion

Variable	Year 1	Year 2	Year 3	Year 4	Year 5
Renewable Tire Use[1]	871,073	871,073	871,073	871,073	871,073
Reserve Tire Use	551,101	551,101	551,101	551,101	58,145
Total Tires Used	1,422,174	1,422,174	1,422,174	1,422,174	929,218
Reserve Tires Remaining	1,711,449	1,160,348	609,246	58,145	0

[1] It is assumed that 80% of the currently available renewable tires will be available for a given year.

APPENDIX E – KILN #2 DIAGRAM WITH TEMPERATURE PROBE LOCATIONS


KILN #2
GCC
Kiln #2
10 ft. x 305 ft.
Fuel In
BURNING ZONE (3.25' TO 57')
Clinker out
Pier#1
Burning Zone Temp
(1600˚F -3068˚F)
Pier#2
Pier#3
Main Drive
Pier#4
Chain ProbeTemp
(1500˚F-1831˚F)
240ft
248ft
258ft
Chain Section
Pier#5
303ft
Back End of Kiln
Feed Enters
1000˚F-1480˚F

APPENDIX F – STACK TEST RESULTS

Table 1. Stack Test Data

Year	Pollutant	Run:	Run #1	Run #2	Run #3	Average
2014	SO2	Historic Emission Factor (lb/ton)				**0.14**
	NOX	Historic Emission Factor (lb/ton)				**5.25**
2016	SO_2	Clinker Production (tons/hr)	55.7	59.1	52.7	55.8
		Emission Rate (lb/hr)	22.3	19.0	20.5	20.6
		Calculated Emission Factor (lb/ton)	0.4	0.3	0.4	**0.4**
	NO_X	Clinker Production (tons/hr)	55.7	59.1	52.7	55.8
		Emission Rate (lb/hr)	302.1	257.4	244.6	268.0
		Calculated Emission Factor (lb/ton)	5.4	4.4	4.6	**4.8**
2017	SO_2	Clinker Production (tons/hr)	52.0	51.0	50.0	51.0
		Emission Rate (lb/hr)	66.1	76.3	124.0	88.8
		Calculated Emission Factor (lb/ton)	1.3	1.5	2.5	**1.7**
	NO_X	Clinker Production (tons/hr)	52.0	51.0	50.0	51.0
		Emission Rate (lb/hr)	245.3	310.0	345.6	300.3
		Calculated Emission Factor (lb/ton)	4.7	6.1	6.9	**5.9**
2018	SO_2	Clinker Production (tons/hr)	54.6	51.9	52.2	52.9
		Emission Rate (lb/hr)	26.2	30.0	38.3	31.5
		Calculated Emission Factor (lb/ton)	0.48	0.58	0.73	**0.60**
	NO_X	Clinker Production (tons/hr)	54.6	51.9	52.2	52.9
		Emission Rate (lb/hr)	204.5	200.1	208.8	204.5
		Calculated Emission Factor (lb/ton)	3.75	3.86	4.00	**3.87**

Table 2. Production

Year		Jan-May Production (tons)	June-Dec production (tons)	Total Production (tons)
2016		160,736	249,851	410,587
2017		167,271	237,403	404,674
2018		147,973	263,084	411,057

Table 3. Calculated Emissions

Year	Pollutant	Jan-May Emissions (tons)	June-Dec Emissions (tons)	Total Emissions (tons)
2016	SO_2	20.5	46.3	66.8
	NO_X	404.1	600.5	1004.6
2017	SO_2	31.0	207.6	238.6
	NO_X	402.0	700.6	1102.7
2018	SO_2	129.4	78.6	208.0
	NO_X	436.7	508.7	945.4
		Baseline Emissions (tpy)	SO_2	171.1
			NO_X	1017.6

Table 4. Baseline Annual Emissions for Report

	2016	2017	2018	Average
Average Clinker Production (tpy)	410,587	404,674	411,057	408,773
SO_2 (tpy)	359	354	359	357
NO_X (tpy)	1212	1194	1213	1,206

APPENDIX G - GCC ODESSA SNCR OPTIMIZATION

The following excerpt is taken from the SNCR optimization study conducted at GCC's Odessa, TX cement plant, which outlines the baseline conditions for the study:

> *In order to determine emission levels of NO_X and NH_3 prior to NH_3 injection during this optimization period, May 9 through May 12 was used as a baseline period for normal Kiln 1 operations with no NH_3 injection. Results from this period are summarized in Table 4-2.*
>
> **Table 4-2. Summary of Emissions and Other Key Variables During No NH_3 Injection Period**
>
> | Variable | Data |
> |---|---|
> | Clinker Production Range | [redacted] |
> | Operating Hours and Injection Temperature Between [redacted] | [redacted] [redacted] |
> | Operating Hours and Injection Temperature Between [redacted] | [redacted] [redacted] |
> | Operating Hours and Injection Temperature [redacted] | [redacted] [redacted] |
> | Average NO_X | 294 ppm |
> | Average NO_X lb/ton | 5.3 |
> | Average NH_3 | 5.8 ppm |
>
> *As shown in the table, the kiln mostly operated in the production range of [redacted]. In this production range, average NH_3 and NO_X emissions were 294 ppm and 5.8 ppm, respectively. Additionally, temperature at NH_3 injection points were also in the optimal SNCR zone in this production range.*

As a result of the optimization study, GCC Odessa concluded the following:

> *NH_3 injection rate of under 1 gpm [gallons per minute] provided maximum NO_X reductions with minimal NH_3 slip to the extent demonstrated in the 60 day optimization period. GCCP will strive to operate the SNCR with injection rates lower than 1 gpm as feasible to continue demonstrating compliance with the NO_X emissions limits.*

The daily average data collected in the study is summarized below. For the purposes of the evaluation of SNCR for the GCC Tijeras kiln, data collected for an injection rate of less than 0.2 gpm is conservatively excluded. Per the study, "during a clinker production range of [redacted] [tons per hour], by injecting NH_3 in the range of an average of 0.2 - 0.43 gallon per minute (gpm), NO_X emissions are controlled at 137 - 251 ppm and NH_3 emissions at 12-16 ppm." This injection rate range was identified as one that maximized NO_X control while limiting NH_3 slip. Data collected for an injection rate of greater than 1 gallon per minute is also excluded based on the conclusions referenced above.

Table G-1. GCC Odessa Optimization Study Results

Variable	Value	Units
Average Clinker Production Rate	29.80	ton/hr
Average NO_X Emission Rate	136.36	lb/hr
Calculated NO_X Emission Factor	4.58	lb/ton
Average Ammonia Injection Rate[a]	0.40	gpm
Average Ammonia Slip	18.00	ppm

[a] Average injection rate of daily average values obtained within the range of 0.2-1.0 gpm.

Based on these results, the calculated emission factor of 4.56 lb NO_X per ton of clinker represents a SNCR control efficiency of approximately 14% compared to the baseline emission rate of 5.3 lb NO_X per ton of clinker. This value is significantly lower than the control efficiencies achieved in more modern kilns and is indicative of the expected control efficiency for the GCC Tijeras kilns, which are similar in age and type to those at GCC Odessa. For the purposes of this analysis a control efficiency of 25% is conservatively assumed.