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**GREENHOUSE GAS BEST AVAILABLE CONTROL TECHNOLOGY
(BACT) ANALYSIS - REVISED**

**GREENHOUSE GAS BEST AVAILABLE CONTROL
TECHNOLOGY ANALYSIS**

Prepared for:

Carolinas Cement Company LLC
Castle Hayne, NC Plant

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SECTION 1

INTRODUCTION

1.1 Project Description

Carolinas Cement Company LLC (CCC) is proposing to construct a modern Portland cement manufacturing facility at the site of an existing cement storage terminal operated by Roanoke Cement Company near Castle Hayne, North Carolina. The plant will include a multi-stage preheater-precalciner kiln with an in-line raw mill, coal mill, alkali bypass and clinker cooler venting through the main stack. Production is expected to be 6000 tons per day (tons/day) and 2,190,000 tons per year (tons/yr) of clinker and 2,407,000 tons/yr of cement. Fuels may include coal, petroleum coke, biomass fuels (organic material that is available on a renewable or recurring basis), and distillate fuel oil. Coal and petroleum coke will be the primary fuels. Biomass will be utilized to the extent practical depending on performance, availability, and economic viability. Fuel oil will be used mainly for kiln startup.

The raw materials for clinker production may include limestone/marl, clay, quarry spoils, bauxite, slag, fly ash/bottom ash, sand, and/or mill scale. Synthetic gypsum or natural gypsum and limestone will be milled with the clinker to produce cement. Associated processes will include mining, crushing, blending, grinding, material handling, storage for raw materials, fuels, clinker, and finished cement, and cement packing and bulk loadout. Cement will be shipped by rail and truck. The project will also include a diesel emergency generator set.

The Castle Hayne area is in attainment with all the National Ambient Air Quality Standards (NAAQS). The existing Roanoke Cement terminal is considered a minor source under North Carolina's Prevention Significant Deterioration (PSD) rules at 15A NCAC 02D.0530 for all PSD pollutants. A modification to a PSD minor source is subject to PSD if the modification itself exceeds the major source threshold for any PSD regulated pollutant. In the case of Portland cement plants, the major source threshold for criteria pollutants is 100 tons/yr, which includes all quantifiable fugitive emissions.

As shown elsewhere in the permit application, the emissions from the project of particulate matter (PM), PM less than 10 microns in diameter (PM₁₀), PM_{2.5} sulfur dioxide (SO₂) carbon monoxide (CO), nitrogen oxides (NO_x), and volatile organic compounds (VOC) will exceed the PSD major source emission rate and CCC must comply with all applicable requirements under North Carolina's PSD rules.

1.2 Cement Manufacturing

Portland cement is used in almost all construction applications including homes, public buildings, roads, industrial plants, dams, bridges, and many other structures. Therefore, the quality of Portland cement must meet very demanding standards. The manufacture of a high quality Portland cement begins with the use of a cement rock containing calcium carbonate material (i.e., marl or limestone) and the production of a high quality cement clinker.

In the Portland cement manufacturing process, raw materials such as limestone, bauxite, iron ore, and other additive materials are heated to their fusion temperature, typically 1,400° to 1,500°C (2,550° to 2,750°F), in a refractory lined kiln by burning various fuels such as coal, coke, and natural gas. Burning (or heating) an appropriately proportioned mixture of raw materials at a suitable temperature produces hard fused nodules called "clinker," which are cooled and then mixed with calcium sulfate (gypsum) and limestone, and ground to a desired fineness. Different types of cements are produced by using appropriate kiln feed composition, blending the clinker with the desired additives, and grinding the product mixture to appropriate fineness. Manufacture of cements of all types involves the same basic high temperature fusion, clinkering, and fine grinding process.

There are four primary types of refractory lined kilns used in the Portland cement industry: long wet kilns, long dry kilns, preheater kilns, and preheater/precalciner kilns. The long wet, long dry, and most preheater kilns have only one fuel combustion zone, whereas the newer preheater kilns with a riser duct and the preheater/precalciner kilns have two or more fuel combustion zones. These newer designs of dry pyroprocessing systems increase the overall energy efficiency of the cement plant. The energy efficiency of the cement making process is important as it determines the amount of heat input needed to produce a unit quantity of cement clinker. Use of a modern preheater/precalciner kiln with a high thermal efficiency, such as is

proposed for CCC, leads to less consumption of heat and fuel, with correspondingly lower emissions.

1.3 Regulatory Requirements for Greenhouse Gases

On June 3, 2010, the U.S. EPA published final rules for permitting sources of Greenhouse Gases (GHG's) under the prevention of significant deterioration (PSD) and Title V air permitting programs, known as the GHG Tailoring Rule. The rules require that between January 2, 2011 and June 30, 2011, only sources that are currently subject to PSD and Title V permitting would be subject to permitting for GHG's (i.e., no sources would be subject to the Clean Air Act permitting due solely to GHG emissions). During this time, only GHG increases of 75,000 tons per year (tons/yr) or more would be subject to a Best Available Control Technology (BACT) analysis of GHG's under the PSD program. There is no "grandfathering" of PSD applications in process as of January 2, 2011 (i.e., a BACT analysis would be required for GHG emission increases greater than 75,000 tons/yr for any PSD permit issued after that date).

After July 1, 2011, new sources emitting more than 100,000 tons/yr of GHG's and modifications increasing GHG emissions more than 75,000 tons/yr would be subject to PSD review, regardless of whether PSD was triggered for other pollutants. Facilities that emit at least 100,000 tons/yr would be subject to Title V permitting requirements. EPA plans additional rulemaking that would govern permitting after June 2013.

Because the CCC project is subject to PSD review as a result of a significant increase in a number of other PSD-regulated pollutants and the project will increase GHG emissions by more than 75,000 tons/yr, a GHG BACT analysis is needed.

1.4 Best Available Control Technology (BACT) Requirements

BACT is defined as "an emission limitation, including a visible emission standard, based on the maximum degree of reduction of each pollutant subject to PSD review that the reviewing authority on a case-by-case basis, taking into account energy, environmental, and economic impacts, and other costs, determines is achievable through application of production processes and available methods, systems, and techniques (including fuel cleaning or treatment or innovative fuel combustion techniques) for control of such pollutant." If the reviewing authority

also determines that technological or economic limitations on the application of measurement methodology to a particular part of a source or facility would make the imposition of an emission standard infeasible, a design, equipment, work practice, operational standard or combination thereof, may be prescribed instead to satisfy the requirement for the application of BACT. Such standard shall, to the degree possible, set forth the emissions reductions achievable by implementation of such design, equipment, work practice, or operation. Each BACT determination shall include applicable test methods or shall provide for determining compliance with the standard(s) by means that achieve equivalent results.

The EPA has consistently interpreted the statutory and regulatory BACT definitions as containing two core requirements that the agency believes must be met by any BACT determination. First, the BACT analysis must include consideration of the most stringent available technologies, i.e., those which provide the "maximum degree of emissions reduction." Second, any decision to require a lesser degree of emissions reduction must be justified by an objective analysis of "energy, environmental, and economic impacts" contained in the record of the permit decision. It should be noted that if an option is judged to be technically infeasible, no further analysis is needed.

The minimum control efficiency to be considered in a BACT analysis must result in an emission rate less than or equal to any applicable new source performance standards (NSPS) emission rate or National Emission Standards for Hazardous Air Pollutants (NESHAP). In this case, there are no applicable NSPS/NESHAP for GHG's from cement plants.

In a BACT analysis, the most effective technically feasible controls should be evaluated based on an analysis of energy, environmental, and economic impacts. As part of the analysis, several control options for potential reductions in GHG pollutant emissions were identified. The control options are usually identified by:

- (1) Researching the RACT/BACT/LAER Clearinghouse (RBLC)
- (2) Drawing from previous engineering experience
- (3) Surveying available literature
- (4) Review of PSD permits for Portland cement plants.

Because the requirement for a GHG BACT analysis is new, there is little or no information available in the RBLC or in PSD permits issued for other sources.

In November 2010, EPA issued for public comment general guidance for PSD permitting of GHGs ("PSD and Title V Permitting Guidance for Greenhouse Gases"). In addition, EPA

also issued a “white paper” providing GHG BACT guidance specific to the Portland cement industry (“Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from the Portland Cement Industry”) which was reviewed, but not solely relied upon, in preparing this document. The guidance is non-binding, and all final BACT determinations for this project are made by the North Carolina Department of Environment and Natural Resources (NCDENR), Division of Air Quality (DAQ).

SECTION 2

SUMMARY OF GHG EMISSIONS

For purposes of the GHG BACT analysis, the GHG emissions to be considered are those directly emitted by the on-site stationary sources and thus do not include mobile sources such as cars, trucks, and trains. However, the document also qualitatively addresses off-site emissions from electricity consumed by the plant.

GHGs are emitted from two stationary combustion sources at the plant, the kiln system and the emergency generator. Although GHG emissions from the generator are relatively small and are exempt from EPA's annual GHG reporting requirements, both the kiln system and the emergency generator are vented through the main kiln stack. The GHGs consist chiefly of carbon dioxide (CO₂) with small quantities of other GHG pollutants (methane and nitrous oxide) included in the CO₂-equivalent (CO_{2-e}) estimate.

The potential direct GHG emissions from the proposed plant are summarized in Table 1; the detailed calculations are presented in Appendix A. It should be noted that this estimate is based on optimum production with limited kiln start-up events. Under periodic market conditions such as occurring now in the U.S. that force inventory outages, there could be additional fuel used per unit of production for more frequent startups. For these conditions, the estimated total annual CO_{2-e} production would be less than the amount in Table 1, but the estimated CO_{2-e} per ton of clinker basis could be slightly higher.

TABLE 1. SUMMARY OF DIRECT GHG EMISSIONS

Tons CO_{2-e}/yr	Tons CO_{2-e}/ton of clinker
1,895,000	0.87

EPA documentation indicates that the average direct, on-site GHG emissions from US cement production in 2006 was 0.98 tons CO_{2-e} per ton of clinker. Thus, the estimated direct emissions from the CCC plant, under optimal conditions, will be 11 percent lower than the industry average.

SECTION 3

ENERGY IMPROVEMENTS AND POTENTIAL CONTROL TECHNOLOGIES

3.1 Reducing Clinker Content of Cement

The cement-to-clinker ratio for Portland cement is limited by the chemistry and current industry and market specifications required for cement products. Materials or cement admixtures could potentially be used as a partial replacement for clinker in the cement manufacturing process. **The extent to which clinker can be replaced at the cement plant is limited in the U.S. by technical specifications and market acceptance, and to the extent that in the U.S. cement substitutes are usually added at the concrete batching plant. Such industry and market limitations are beyond the control of the cement plant, and while reducing the clinker content is desirable, it cannot be specified as BACT.**

Reductions in GHG emissions from this type of project result when less clinker is needed to produce a given quantity of cement. Process CO₂ emissions are reduced as a result of reduced limestone calcination, and thermal and electrical energy used in the production of clinker. Reducing the amount of clinker in cement would also reduce GHG emissions from upstream sources associated with the extraction and transportation of coal. Cement produced with 30 percent admixtures, or additives used to lower the clinker-to-cement ratio, where allowed by specification, building codes, or market acceptance, has been shown to produce 27 percent less CO₂ than conventional cement produced without admixtures.¹ Cement admixtures may be of natural origin (limestone or pozzolanic rock), or industrial origin (waste products from other industries, such as slag from steel-industry blast furnaces or fly ash from coal-fired power plants). These waste products have hydraulic binding properties similar to clinker.

Gypsum is added to clinker primarily as a setting additive for cement, but it is also an effective strength and performance booster. Based upon expected sulfur content (expressed as SO₃) in clinker, optimum SO₃ in cement and the SO₃ content of gypsum that is currently available, the CCC Plant will produce cement with approximately 5 percent gypsum admixtures.

¹ Source: http://www.CCC.com/wps/portal/4_3_6-Ecologie_industrielle

One of the ways to reduce carbon footprint for cement plants is to maximize the non-clinker component in cement. The non-clinker components are gypsum, limestone, CKD and other hydraulically active materials like pozzolona, fly ash, slag, etc. These can reduce the carbon intensity of cement as these are either mined or already processed materials.

In addition to gypsum, the CCC Plant plans to incorporate up to 5 percent “interground limestone” in the cement manufacturing process. The American Society of Testing and Materials (ASTM) C150, the standard specification for Portland cement, limits limestone admixtures to a maximum of 5 percent based upon performance criteria and limitation on the Loss of Ignition (LOI) and Insoluble Residue (IR). Limestone addition is also limited by insoluble residue (non-cementing material which is present in Portland cement that affects the compressive strength properties of cement).² The CCC Plant could potentially use up to 5 percent limestone admixture in cement, depending on the chemical/physical characteristics of the product. Small quantities of CKD may also be used in the finished cement.

Blended hydraulic cements are produced by intimately blending two or more types of cementitious material. Primary blending materials are Portland cement, ground granulated blast-furnace slag, fly ash, natural pozzolans, and silica fume. These cements are commonly used in the same manner as Portland cements. The use of blended cement types also reduces the clinker-to-cement ratio. Common cement blends contain other feedstock such as pozzolans (volcanic ash), fly ash or granulated blast furnace slag. While producing cement blends reduces energy consumption in the kiln and avoids the GHG emissions that stem from clinker production, the availability of waste slag is limited, and pozzolans can be obtained only in certain locations. Moreover, long-distance transportation of cement or cement feedstock would result in significant additional energy use, which is not an attractive option given the low value of the product. Therefore, significant blending of clinker substitutes typically occurs when the concrete is mixed, rather than at the time of cement production.

² Source: <http://www.dot.ca.gov/hq/esc/Translab/ClimateActionTeam/limestone-in-cement.html>

The use of hydraulically active pozzolonas, blast furnace slag and fly ash in cement is common in most parts of the world other than North America. Because of strict product standards, cement manufacturers in North America are constrained from providing cement with similar performance but with lower energy intensity and CO₂ footprint. In North America, these materials are typically added at the concrete batch plants, where the addition of these hydraulically active materials may be sub-optimal.

If allowed by specification, building codes, or market acceptance, the expansion of the production of blended cement may require the following equipment additions/modifications:

- Storage, handling, and proportioning equipment for additive materials, such as hoppers, feeders, conveyors, and cement grinding aid.
- Additionally, the grinding mills used to grind the clinker would need to be modified because slag is abrasive and much harder to grind and the operation and maintenance of grinding mills used in slag cement plants is more challenging than in ordinary Portland cement grinding plants. Increasing the percentage of slag in the cement increases the wear rate, requiring the equipment to be replaced more frequently.

The acceptance of high blend cement is not common practice in the Mid-Atlantic region. Portland cement is perceived as being stronger than slag cement. This is due to the lower early strength of slag cement compared to Portland cement. The grey-white color of slag cement also creates doubts in the marketplace due to the difference in color between Portland and slag cement. Doubt about use of blended cement is evident in the marketplace because government departments typically specify that only Portland cement be used in major construction projects, even when slag cement would be appropriate. The ability to use blended cement to achieve GHG reductions is wholly dependent on the demand for such cement.

3.2 Alternate Fuels

Coal is the predominant fuel currently planned to be used at the facility, although other fuels including petroleum coke and fuel oil may also be used as supplemental fuels. The expected amount of fuel (on a dry coal basis) is 238,100 tons per year. It is estimated that the CCC plant would operate at an energy consumption efficiency of 2.72 million Btu of fuel per short ton of clinker.

The primary GHG emitted from cement manufacturing is CO₂. There are two main emission sources of CO₂ in the cement manufacturing process: calcination/pyro-processing, and fuel burning. Each of these is described below:

- Calcination/pyro-processing: This is generally the largest source of GHG emissions from a cement manufacturing facility resulting from the conversion of calcium carbonate/limestone to calcium oxide/clinker ($\text{CaCO}_3 + \text{heat} = \text{CaO} + \text{CO}_2$).
- Fuel burning in pyro-processing: This is the second-largest source of GHG emissions in a cement manufacturing facility resulting from the burning of fossil fuels to heat the kiln feed to the temperature necessary for its conversion to clinker.

3.2.1 Natural Gas

Natural gas is not included as a fuel for the CCC project. The use of natural gas (if feasible) would fundamentally redefine the project. As such, fuel switching to natural gas is not warranted in the BACT analysis.

3.2.2 Biomass

The substitution in cement kilns of conventional fossil fuels (principally coal) with biomass fuels can result in some apparent reductions of greenhouse gas emissions. Presumably, the CO₂ emissions from burning biomass are the result of carbon that has relatively recently been removed from the atmosphere through uptake by plants, and would be returned to the atmosphere upon the plant's decay. Therefore, biomass could be considered to be a carbon-neutral fuel, although the EPA has not provided a definitive determination on the status on biomass. If determined to be carbon-neutral, biomass would then not have the global warming impact that burning fossil fuel has.

The feasibility of using biomass for CCC cannot be evaluated at this time as sources and costs cannot be secured at this stage of the plant development. **While there may be potential opportunities in the future to incorporate biomass fuels, due to the technical feasibility, availability uncertainty, and cost, CCC believes that biomass substitution cannot be specified as BACT for GHGs.** CCC will actively pursue the use of biomass to the extent that can be safely managed during the transport, storage and reuse, and based upon their availability, current economics, and regulatory constraints.

Several different types of biomass are burned in cement kilns around the world including:

- Animal droppings
- Animal grease
- Animal meal
- Dry sewage sludge
- High Btu non-hazardous liquids (e.g., glycerin, citrus solvents, etc.)
- Municipal waste
- Paper waste
- Rice husks
- Sawdust
- Seeds
- Wood chips.

These biomass materials may be burned in conjunction with conventional fossil fuels, namely coal. The substitution of fossil fuels with biomass fuels at cement kilns may require various changes, depending on the type of fuel used. Fuels preparation is a significant consideration. Shredding/crushing/pulverizing and drying of solid biomass fuels may be needed. If a separate dryer is needed, an additional GHG source is created, as well as increasing the energy requirement to process the fuels. In general, separate processing, storage and handling facilities will be needed for the biomass fuels. Changes may also be required to the burners used in the kiln depending on the type of biomass used. According to a supplier of cement kiln burners, pulverized dry biomass can be handled like pulverized coal in a pneumatic conveying system and blown through a conventional burner—a concentric annular channel surrounding a flame stabilizer—provided the waste fuel is not sticky. If the alternative fuel is lumpy, fluffy, or fibrous, however, a great risk of developing deposits and plugging of the burner system results. Therefore, it will be feasible for CCC to utilize some forms of biomass with the current equipment and configuration as presented in the permit application. Other types of biomass could require additional equipment that will need to be added through a permit modification if new emission sources are created.

Biomass fuels do not produce the same flame intensity (luminously) as a coal flame, which is necessary to produce quality clinker. The higher hydrogen content of biomass fuels lower the lower heat value (LHV) of the fuel, and the water vapor produced decreases available heat. Thus, more biomass fuel heat input would be required than coal to produce each ton of clinker.

In addition, using default figures for EPA's October 30, 2009 GHG Reporting Rules, the CO₂ emission factor for solid biomass fuels ranges from 93.8 kg/mm Btu (wood) to 118.7 (agricultural byproducts), compared to bituminous coal of 93.4 kg/mm Btu. Thus no CO₂ reduction benefit is expected when using solid biomass fuel in place of coal.

The economics of burning biomass in cement kilns depends on the difference in delivered cost between the biomass fuel and the coal being displaced, and the cost of any changes needed at the plant to allow the biomass fuels to be burned. The estimated delivered cost of coal to CCC is \$4.20 per MM Btu (\$105/ton). Because solid biomass has heating values that typically range from 4000 to 9000 Btu per pound on a dry basis, as compared to 12,500 Btu per pound for coal, more biomass is needed to provide the same heating value as a given weight of coal. Using the figures cited above, 1.39 to 3.13 dry tons of biomass would be needed per ton of coal displaced. Therefore, the delivered cost of the biomass would have to be between \$33.55 and \$75.54 per ton on a dry basis to be competitive with the delivered cost of coal. The lower price would apply to biomass waste with a heat content of 4000 Btu/lb and the higher price to biomass with a heat content of 9000 Btu/lb, both on a dry weight basis. These prices for fuel do not include the capital costs for plant modifications, if needed, to burn the solid biomass. A cost-effectiveness analysis is not possible for solid biomass fuel since no CO₂ reduction is expected.

The estimated cost for fuel at the CCC plant is approximately \$27.6 million per year, based on a unit price of \$105/ton for coal. The nationwide average price for biodiesel, [20% blend with 80% diesel (B20)] is reported in the USDOE Clean Cities Alternative Fuel Price as being \$24.18 per MM Btu. The cost of biodiesel is almost 6 times that of coal on a per Btu basis. Based on the above costs and default CO₂ emission factors for coal and biodiesel from EPA's GHG Reporting Rule, the cost/effectiveness is \$92.60 per ton of CO₂ reduced. Thus, replacing coal with biodiesel fuel cannot be considered as BACT. In addition to technical, cost and availability issues, there may be severe regulatory restrictions that may preclude the use of certain alternate fuels and raw materials. EPA proposed rules³ that seek to clarify which non-hazardous secondary materials are, or are not, solid wastes when used as ingredients and burned in combustion units. Under the proposed rules, units that burn by-products and/or non-hazardous secondary materials that are considered solid waste under the Resource Conservation and

³ Federal Register: June 4, 2010 (Volume 75, Number 107) 40 CFR Part 241- Identification of Non-Hazardous Secondary Materials That Are Solid Waste; Proposed Rule

Recovery Act (RCRA) will be subject to section 129 Clean Air Act (CAA) incinerator requirements and units that burn non-hazardous secondary materials that are not considered solid waste under RCRA would be subject to the section 112 CAA Maximum Achievable Control Technology (MACT) requirements. This proposal significantly narrows the current universe of non-hazardous by products and secondary materials that when burned in combustion units would be available for use by CCC. Until these rules are finalized and the regulated community has had time to develop programs and policies that will be compliant, changing the plant design or modifying the processes to incorporate alternative raw materials or fuels is not feasible because of regulatory constraints and uncertainty.

3.3 Plant Design Optimization

Energy efficiency is achieved by selecting a plant design based on the modern efficient dry process preheater-precalciner kiln technology as well as the use of less energy intensive equipment and practices. Several technologies exist that can reduce the energy intensity of the various stages of cement production. Cement production involves the chemical combination of calcium carbonate (limestone), silica, alumina, iron and small amounts of other materials to form clinker. The clinker is blended with additives and then finely ground to produce different cement types. Cement manufacturing involves the following unit operations:

- Mining
- Crushing
- Raw meal grinding
- Pyro-processing
- Cement blend and grinding
- Material storage
- Loading, packing and shipping.

Raw material preparation involves crushing of the quarried material, and blending and grinding the raw materials. The specific electrical energy consumption in raw materials preparation accounts for a significant part of overall electrical energy consumption. The major raw material for cement manufacture is limestone, which is mined in the quarry and then transported to the primary crusher. The mined limestone is conveyed to the secondary crusher through belt conveyors. The crushed limestone is blended with additives and dried and ground into fine meal. CCC will use a vertical roller mill (VRM) for raw meal grinding which is the most energy efficient, consuming only 65 percent of the energy consumption of a ball mill.

Pyro-processing takes place in the kiln system. The kiln is a major consumer of both the electrical and thermal energy in a cement plant. The kiln system will be a modern 5-stage preheater/precalciner system with in-line raw mill and kiln gas drying of coal in the coal mill for maximum heat recovery and energy efficiency. The clinker which is produced in the kiln is then cooled and ground along with about 5 percent gypsum and up to 5 percent limestone or other additives such as CKD to produce Portland cement. The CCC plant will also use VRM technology in the finish grinding process.

CCC is committed to using high efficiency systems. The energy efficient equipment planned includes:

- Modern preheater cyclones
- Multi-channel burner
- Expert kiln control system
- Vertical roller mills with high efficiency separators for grinding raw materials, clinker, and fuel.

3.4 Electrical Systems Optimization

CCC will use energy efficient electric equipment and controls where feasible to reduce power consumption. These will include the following:

- Variable frequency drives for motors that are frequently operated at less than 75 percent of nominal rating
- High efficiency motors
- High efficiency fans when practical
- Kiln feed bucket elevator in lieu of pneumatic conveying.
- All other conveying systems will be mechanical or air slides, where practical and pneumatic systems will only be used where necessary for very fine material (e.g., finished cement product)

Waste heat from cement kilns and clinker cooler systems may be used for drying raw meal and/or coal. The amount of heat energy required depends on the raw material moisture content, and the number of cyclone stages affects the heat available. At adequate energy levels the waste heat could be used to generate steam, and the steam could be used to turn a turbine that generates electricity. Although the steam turbine is the best known technology, the relatively low temperature level of the waste heat in a cement plant limits efficiency to approximately 25 percent. Generally, only long dry kilns produce exhaust gases with temperatures high enough to make heat recovery for power economical. Heat recovery for power may not be possible at

facilities with in-line raw mills where the waste heat is used to dry the raw materials; it is usually more economic and efficient to use the exhaust heat to reduce the moisture content of raw materials with very high moisture, which is the case at CCC. Thus, heat recovery for electrical power generation is not practical or economically feasible for the CCC plant.

3.5 Low Carbonate Alternate Raw Materials

The first step in the Portland cement manufacturing process is obtaining raw materials. Generally, raw materials consisting of combinations of limestone, shells or chalk, and shale, clay, sand, or iron ore are mined from a quarry near the plant or are plentiful from nearby sources. Portland cement consists essentially of compounds of lime (calcium oxide, CaO) fused with silica (silicon dioxide, SiO₂) and alumina (aluminum oxide, Al₂O₃). The lime is obtained from a calcareous (lime-containing) raw material, and the other oxides are derived from clayey material. Additional raw materials such as silica sand, iron oxide (Fe₂O₃), and bauxite [containing hydrated aluminum, Al(OH)₃] are used to get the desired composition.

The main methods of using alternative raw materials in cement manufacturing are using industrial byproduct materials in place of traditional raw materials. Substituting alternative materials that have already been partially or fully calcined will reduce the CO₂ emissions associated with the ingredients.

Blast furnaces slags, electric arc furnaces slag, cement kiln dust (CKD), steel mill scale, feldspar, and power plant fly ash each contain a number of minerals that make them possible additive materials for cement manufacturing. Slags and CKD in particular have high lime and fly ash has high alumina content. An added benefit of using these materials is that they are usually dry and already calcined and only limited amount additional energy is needed to remove the entrained moisture and preheat the material. This cuts down on processing and energy costs. CKD from the main baghouse will be recirculated as kiln feed. Dust from the alkali bypass baghouse cannot be recirculated as kiln feed due to high chloride/alkali content, but may be used in the finish mills.

The versatility of the cement making process enables the safe use of by-products and secondary materials from cement manufacturing pyro-processes and other industries as ingredients containing beneficial quantities of constituents used to make cement. These materials must meet strict quality specifications to ensure that the cement will meet customer performance

specifications. The use of these alternative materials also contributes to sustainability by reducing landfill space requirements and GHG emissions and by preserving valuable natural and non-renewable resources.

The selection of low carbonate alternate raw materials must also consider the amount of uncombined carbon in the form of unburned fuel and/or organic material. These components oxidize in the kiln to form CO₂, which releases heat. The evolved heat may in some cases reduce heat input to the kiln and be CO₂ neutral, but can also produce unreasonable heat in the flue gases which does not displace primary fuel.

CCC will seek to use these alternative raw materials to the maximum extent possible, consistent with product quality considerations, economics at the time, and future regulatory constraints (see discussion in Section 3.2.2). However, at this time, specific alternate raw materials cannot be specified as BACT for GHG.

3.6 Carbon Capture and Sequestration Systems

EPA guidance indicates that carbon capture and sequestration (CCS) should be included in the BACT analysis for GHGs, although it is recognized that at this time the technology development is in early stages and case-specific factors, such as the technical feasibility and cost of CCS technology for the specific application, size of the facility, proposed location of the source, and availability and access to transportation and storage opportunities would be anticipated to eliminate CCS as BACT.

CCS begins with the separation and capture of carbon dioxide (CO₂) from plant flue gas and other stationary CO₂ sources. The next step is to sequester (store) the CO₂. Capturing CO₂ without a place to safely store or use the gas is unacceptable because both must occur in order to be effective in reducing CO₂.

In general, CO₂ capture technologies can be categorized into three approaches – pre-, post-, and oxy-combustion. Precombustion systems are designed to separate CO₂ from H₂ and other constituents. Post-combustion systems are designed to separate CO₂ from the flue gas – primarily nitrogen (N₂) – produced by fossil-fuel combustion in air. Oxy-combustion separates the O₂ from N₂ (via an air separation unit) before coal combustion takes place. Removing the N₂ from the oxidant stream before combustion results in a CO₂ concentrated flue gas stream that, after purification, is sequestration ready.

The following experimental CCS technologies have been identified. The test for technical feasibility of any control option is whether it is both commercially available and applicable to reducing GHG emissions. Technically infeasible options will be eliminated from further discussion. Infeasible technologies include those that are conceptual, pilot scale, or not commercially available. Potentially feasible technologies include those that are commercially available and have been demonstrated on a cement plant of similar design and/or demonstrated at another industry with similar emission characteristics.

- Pre-combustion capture is mainly applicable to gasification plants, where coal is converted into gaseous components by applying heat under pressure in the presence of steam and sub-stoichiometric O₂. By carefully controlling the amount of O₂, only a portion of the fuel burns to provide the heat necessary to decompose the remaining fuel and produce syngas, a mixture of H₂ and carbon monoxide (CO), along with minor amounts of other gaseous constituents. To enable pre-combustion capture, the syngas is further processed in a water-gas shift (WGS) reactor, which converts CO into CO₂ while producing additional H₂, thus increasing the CO₂ and H₂ concentrations. An acid gas removal system can then be used to separate the CO₂ from the H₂. Because CO₂ is present at much higher concentrations in syngas (after WGS) than in flue gas, and because the syngas is at higher pressure, CO₂ capture should be easier to achieve and therefore less expensive for pre-combustion capture than for post-combustion capture. After CO₂ removal, the H₂ is used as a fuel. There are approximately 58 power plants (5 USA) using pre-combustion solvent based technology to reduce their CO₂ emissions. Although these systems are large scale operations (4,000 tons/day CO₂ separation) for synthetic natural gas production, petroleum refining, and natural gas purification, it has not been integrated into a coal-based electricity generating power plant or into any cement manufacturing facilities. The end products of this technology are hydrogen based gaseous fuel and a rich stream of CO₂ suitable for compression and transportation to a suitable sequestration location. This technology has not been demonstrated at cement plants and it is not commercially available for the application needed. **This technology is not transferable to cement manufacturing. Precombustion technologies are not technically feasible.**
- Post-combustion capture refers to removal of CO₂ from combustion flue gas prior to discharge to the atmosphere. In a typical coal-fired plant, fuel is burned with air. Flue gas consists mostly of N₂ and CO₂. The CO₂ capture process would be located downstream of the conventional pollutant controls. Chemical solvent-based technologies are currently used in petroleum refineries, fertilizer manufacturing plants, pharmaceutical manufacturing, and food and beverage applications. The chemical solvent process requires the generation of a relatively large volume of low pressure steam, which decreases the amount of heat available for process and cogeneration purposes. The steam is required for release of the captured CO₂ and regeneration of the solvent. Separating CO₂ from this flue gas is challenging for several reasons: a high volume of gas must be treated because the CO₂ is dilute; the flue gas is at low pressure; trace impurities (particulate matter [PM], sulfur oxides [SO_x], nitrogen oxides [NO_x], hydrogen chloride, ammonia, etc.) can degrade the CO₂ capture materials (i.e., solvents, sorbents, membranes); and compressing captured CO₂ from near atmospheric

pressure to operating pipeline or tank storage pressure (about 2,200 psia) requires a large auxiliary power load.

- Alkanolamines and ammonia based solvents have been used as decarbonization solvents in the gas processing, chemicals, and petroleum industries for more than 50 years. The upstream flue gas cleaning system cools and removes particulates, SO_x, ammonia, and hydrogen chloride (HCl), etc. Next, the cooled and cleaned flue gas enters the absorption tower, where it makes contact with the liquid solvent in countercurrent flow. The flue gas enters the absorber at its bottom, flows up, and leaves at the top. The solvent enters the top of the absorber, flows down, and emerges at the bottom. CO₂ is chemically bound to the solvent by the exothermic reaction of the gas with the amine in the solvent. The liquid amine CO₂-rich solvent then leaves the bottom of the absorber and passes into the stripping tower via a cross heat exchanger. In the CO₂ stripper, the mixture is heated with steam to liberate the CO₂ from the solvent as the acid gas. This step is carried out at lower pressure than the previous absorption step, to enhance desorption of CO₂ from the liquid. The amine processes generate a relatively pure CO₂ gas stream, saturated with water within a 70° to 100°F inlet temperature range at pressures of 15.0 psia to 21.9 psia. Ammonia-based capture processes can also generate a relatively pure CO₂ stream, but at elevated pressures of between 30 psia and 300 psia; the inlet temperature is nominally 100°F. The CO₂ is now ready for the further steps of compression, transport from the plant site to a storage site, and sequestration. Amine absorption has been practiced at large scale in the natural gas processing industry to remove hydrogen sulfide (H₂S) and CO₂ from the natural gas. Adapting the technique to flue gas decarbonization is problematic, for two reasons. First, CO₂ is present in large quantities in flue gas, but H₂S is only an impurity to be removed from natural gas. Second, decarbonization of natural gas must address the presence of H₂S—but there is no H₂S in flue gas. This technology was demonstrated at the California Portland Cement Plant in February 2008. Reportedly, 45-90 percent CO₂ removal rates were achieved⁴. However, no more information detailing the results of the trials was found. Global Shell Solutions the owner of the Cansolv technology indicates that they expect to have pilot plant capabilities by 2011. **This technology is not commercially available for the application needed. Post combustion technologies using liquid solvents are not technically feasible.**
- In October 2009, the U.S. Department of Energy announced the selection of 12 projects intended to capture carbon dioxide from industrial sources for storage or beneficial use. The funded projects included one where a cement plant was selected to demonstrate a dry sorbent CO₂ capture technology. The technology developer will design and construct a dry sorbent CO₂ capture and compression system, pipeline (if necessary), and injection station. If successful, this commercial-scale carbon capture and sequestration demonstration project will remove up to 1 million tons of CO₂. The developer has indicated that they do expect their technology to be commercially available until 2015. Information concerning the status of this demonstration project

⁴ J.Sarlis, D. Shaw: Cansolv Activities and Technology Focus for CO₂ Capture. Presentation at the 11 meeting of the International Post-Combustion CO₂ Capture network, 21-22 May 2008, Vienna

has not been released by the technology developer. **This technology has not been demonstrated at cement plants and it is not commercially available for the application needed. Post combustion technologies using dry sorbents are not technically feasible.**

- Membrane-based post-combustion CO₂ capture uses permeable or semi-permeable materials that allow for the selective separation of CO₂ from flue gas. While membranes are more advantageous for separating CO₂ in high-pressure applications, such as coal gasification, highly-selective and permeable membrane systems designed specifically for CO₂ separation from low partial pressure, post-combustion flue gas streams are not commercially available. Membranes potentially could be a more cost effective technology option for post-combustion CO₂ capture than solvents or sorbents that require a large amount of regeneration energy to separate the CO₂. Membranes constructed of polymeric materials are currently used in a number of industrial gas separation processes including air separation; hydrogen recovery from ammonia; dehydration of air; and CO₂ separation from natural gas. Post-combustion membranes that are durable, have acceptable permeability and selectivity, are thermally and physically stable, tolerant of contaminants in combustion flue gas and can operate under low pressure and high packing density are not commercially available. This technology has not been demonstrated at cement plants and it is not commercially available for the application needed. **This technology is not transferable to cement manufacturing. Post combustion technologies using membranes are not technically feasible.**
- Oxy-combustion systems for CO₂ capture rely on combusting coal with relatively pure O₂ diluted with recycled CO₂ or CO₂/steam mixtures. Under these conditions, the primary products of combustion are water (H₂O) and CO₂, with the CO₂ separated by condensing the H₂O. Oxy-combustion overcomes the technical challenge of low CO₂ partial pressure normally encountered in coal combustion flue gas by producing a highly concentrated CO₂ stream (approximately 60%), which is separated from H₂O vapor by condensing the H₂O through cooling and compression. Flue gas recycle is necessary for oxy-combustion to approximate the combustion and heat transfer characteristics of combustion with air. An additional purification stage for the highly concentrated CO₂ flue gas may be necessary to remove other minor gas constituents such as N₂, O₂, and argon in order to produce a CO₂ stream that meets pipeline and storage requirements. Unlike pre- and post-combustion CO₂ capture technologies; there is significantly less experience with oxy-combustion with only a few pilot-scale applications in operation worldwide. **This technology has not been demonstrated at cement plants and it is not commercially available for the application needed. This technology is not transferable to cement manufacturing. Oxy-combustion systems are not technically feasible.**
- Chemical looping is an advanced technology similar to oxy-combustion in that it relies on combustion/gasification of coal in a N₂-free environment. However, rather than using an air separation unit (ASU), chemical looping involves the use of a metal oxide or other compound as an O₂ carrier to transfer O₂ from the air to the fuel. Subsequently, the products of combustion (primarily CO₂ and H₂O) are kept separate from the rest of the flue gases.

Chemical looping can be applied in either coal combustion or coal gasification processes. Chemical looping combustion and chemical looping gasification are in the early stages of process development. Bench- and laboratory-scale experimentation is currently being conducted. Projects in this pathway are advancing the development of chemical looping systems by addressing key issues, such as solids handling and O₂ carrier capacity, reactivity, and attrition. **This technology has not been demonstrated at cement plants and it is not commercially available for the application needed. This technology is not transferable to cement manufacturing. Combustion technologies using combustion gasification of coal and nitrogen free environments are not technically feasible.**

- Dehydration, compression/liquefaction and transport are required once the CO₂ is separated from the flue gas. The CO₂ gas must be reduced to a supercritical liquid phase prior to pipeline transport and/or permanent storage in deep geologic formations. Either CO₂ is compressed to the desired pressure using a gas compressor or is liquefied at lower pressures by using refrigeration systems and then pumped to the desired pressure. The underlying premise of the liquefaction approach is that liquid pumps require significantly less power to raise pressure and are considerably less expensive than gas compressors. CO₂ compressors are responsible for a large portion of the enormous capital and operating cost penalties expected with any carbon capture and sequestration (CCS) system. Final pressure around 1,500 to 2,200 psia for pipeline transport or re-injection to geologic formations is required. Compressor technology is mature and commercially available. The base line system would include a conventional centrifugal 16-stage compressor with air-cooling streams between stages operating at 60 percent efficiency. **Because a feasible GHG capture technology is not available, compression technology is not needed and will not be evaluated further.**
- Storage is achieved by deep underground injection into suitable geologic formations or by terrestrial carbon sequestration. Geologic sequestration involves taking the CO₂ that has been captured from the plants stationary sources and storing it in deep underground geologic formations in such a way that CO₂ will remain permanently stored. Geologic formations such as oil and gas reservoirs, un-mineable coal seams, and underground saline formations are potential options for storing CO₂. Terrestrial sequestration involves the fixation of the CO₂ into vegetative biomass and soils. The majority of geologic formations considered for CO₂ storage, deep saline or depleted oil and gas reservoirs, are layers of porous rock underground that are “capped” by a layer or multiple layers of non-porous rock above them. Sequestration practitioners drill a well down into the porous rock and inject pressurized CO₂. Under high pressure, CO₂ turns to liquid and can move through a formation as a fluid. Once injected, the liquid CO₂ tends to be buoyant and will flow upward until it encounters a barrier of non-porous rock, which can trap the CO₂ and prevent further upward migration. Coal seams are another formation considered a viable option for geologic storage, and their storage process is a slightly different. When CO₂ is injected into the formation, it is adsorbed onto the coal surfaces, and methane gas is released and produced in adjacent wells.

The U.S. Department of Energy National Energy Technology Laboratory (NETL) has published a Carbon Sequestration Atlas of the United States and Canada. Production of this Atlas was the result of cooperation and coordination among carbon sequestration experts from local, State, and government agencies, as well as industry and academia. This Atlas

presents information on carbon storage potential across the majority of the U.S. and portions of western Canada. DOE investigated five types of underground formations for geologic sequestration, each with different challenges and opportunities for CO₂ sequestration: 1) mature oil and natural gas reservoirs, 2) deep un-mineable coal seams, 3) deep saline formations, 4) oil- and gas-rich organic shale, and 5) basalt formations.

Geologic sequestration involves taking the CO₂ that has been captured from stationary sources and storing it in deep underground geologic formations in such a way that CO₂ will remain permanently stored. Geologic formations such as oil and gas reservoirs, un-mineable coal seams, and underground saline formations are potential options for storing CO₂. Storage in basalt formations and organic rich shale is also being investigated. Current assessments indicate that there is no potential for storing GHG in oil, gas, coal and shale formations within the State of North Carolina. Current assessment also shows that the saline formations off the coast of North Carolina have the potential to store approximately 1,352 million metric tons of CO₂.

Saline formations are layers of porous rock that are saturated with brine. They are much more extensive than coal areas or oil- and gas-bearing rock and represent a significant potential for CO₂ geologic storage. However, less is known about saline formations because they lack the characterization experience that industry has acquired through resource recovery from oil and gas reservoirs and coal seams. Therefore, there is an amount of uncertainty regarding the suitability of saline formations for CO₂ storage.

The distance between stationary source and geologic storage formation is calculated as the shortest straight-line distance from each point. While these results do not give a complete picture of the transportation and infrastructure requirements, it does give a first-order interpretation of the magnitude of the requirements. The distance between the Castle Hayne Plant and other terrestrial based formations is greater than 500 miles. The distance between the plant and the off shore federally controlled saline formations is greater than 22 miles. Approximately 12 miles of this distance is under the Atlantic Ocean. There are no pipelines or ocean going ships capable of transporting and injecting the GHG into the off shore saline formations. **Given that GHG storage facilities and transport means have not been developed in this area, GHG storage technology not a technically feasible option.**

- Terrestrial sequestration increases the amount of carbon that plants and soils naturally store. For example, trees planted to reforest abandoned mines would use CO₂ as they grow, and changing agricultural practices to include no-till farming would keep CO₂ in the soil that would otherwise be released when the land is tilled. The type of tree (hardwood or conifer) and its age determines the amount of carbon it can sequester. For instance, according to the U. S. Department of Energy's Method for Calculating Carbon Sequestration by Trees in Urban and Suburban Settings, a 1-year old fast-growing hardwood (e.g., *Ulmus americana* (American elm) sequesters 4.0 lbs (1.8 kg) carbon/tree/year; whereas, for an equivalent conifer (e.g., *Taxodium distichum* (bald cypress) the rate is 2.2 lbs (1 kg) carbon/tree/year. A 50-year old fast-growing hardwood sequesters 122.7 lbs (55.8 kg) carbon/tree/year and the equivalent conifer sequesters 106.3 lbs (48.3 kg) carbon/tree/year. Carbon-info.org has a generic model for the CO₂ absorption for a young tree (0 to 5 years) that uses 5.5 lbs (2.5 kg)

CO₂/tree/year and for a mature tree (45 to 50 years) the CO₂ absorption is 30.8 lbs (14 kg) CO₂/tree/year. In the Regional Greenhouse Gas Initiative (RGGI), The Western Climate Initiative (WCI), and the Midwestern Greenhouse Gas Reduction Accord (MGGR) trading schemes participating States allow regulated facilities to use offsets to meet their compliance obligations. North Carolina has not joined any of the existing regional consortiums and there is not a Southeast or Mid Atlantic GHG consortium.

A terrestrial sequestration project could consist of a tree plantation planted on land that is not committed for industrial process uses. Assuming 100 acres could be set aside as a forest reserve, this acreage would support approximately 1,000 trees. At maturity these trees would sequester 15 tons per year or approximately 1155 tons over the expected 75 year life time of the trees or 5.1E-6 tons per ton of clinker. Yellow poplars, scarlet oaks, and sweet gums are fast-growing hardwoods that require little maintenance and have proved to be solid carbon absorbers in tests. Each of these grows readily in the Wilmington area. The 3-foot seedling tree retails for approximately \$30 each and the planting costs would be approximately \$5.00 per tree. This plantation would not be managed and natural succession will keep the reserve functioning for the foreseeable future. Hence the total project cost would be approximately \$31,500 plus the cost of land. The cost effectiveness is \$2, 100 per ton of CO₂ sequestered not including land value, or \$25,000 per ton of CO₂ sequestered including the estimated land value (\$344,000). **Therefore, it is not cost-effective to implement this terrestrial sequestration technology as BACT for GHG.** Furthermore, the amount of CO₂ sequestered is relatively minuscule and the CO₂ taken up by trees will eventually be released as the trees die or in the event of a forest fire.

- Algae Sequestration is a novel and developing process that captures CO₂ from the flue gas by pushing the flue gas through a bioreactor that grows algae. The algae would be used to manufacture biodiesel fuel and fertilizers that are sold on the open market. **This technology has not been demonstrated and is not commercially available for the application needed. Post combustion technologies using bioreactors are not technically feasible.**

SECTION 4

PROPOSED GHG BACT DETERMINATION

CCC proposes as BACT for GHG's the use of a modern efficient preheater/precalciner kiln design with in-line raw mill technology and use of energy-efficient electrical/mechanical components.

CCC proposes as BACT for GHG's the following emission limit:

Kiln system and emergency generator direct emissions shall not exceed 0.91 tons CO_{2-e} per ton of clinker, calendar 12-month average. Compliance shall be determined in accordance with the procedures used by CCC in reporting their GHG emissions pursuant to 40 CFR Part 98. This recommended limit accounts for uncertainties in future fuels and raw materials and the fact that the new kiln has not been constructed and no actual operating data are available.

Furthermore, CCC proposes work practices for electrical efficiency as BACT consisting of the following:

- Using Vertical Roller Mills (VRMs) with high efficiency separators for grinding raw materials, clinker and fuel
- Installing variable frequency drives (VFDs) for motors in applications that frequently require less than 75% of the motor's nominal output.
- Using NEMA Premium Efficiency motors or better for low voltage applications for 200 HP or less applications.
- High efficiency fans when practical.
- Using bucket elevators, air slides, belt conveyors and other mechanical systems wherever practical and avoiding dilute phase pneumatic conveying except in the case of fine materials, fuel injection or dust avoidance.

APPENDIX A
CALCULATION OF MAXIMUM GHG
EMISSIONS

GHG EMISSIONS ESTIMATE - CAROLINAS CEMENT

	PROPOSED	UNITS	BASIS
CLINKER RATE	6,000	TON/DAY	CCC Design
ANNUAL PRODUCTION	2,190,000	ST/YR	
	1,986,755	METRIC T/YR	
LOI KILN FEED	35.16	%	FLS
VIRGIN KILN FEED	3,415,743	T/YR	
CO2 FROM FEED	1,200,975	T/YR	
CKD DISCHARGED-BYPASS	26,072	T/YR	FLS 2.7 mtph 15% byp
CKD DISCHARGED-PH (RM OFF)	0	T/YR	All recirculated
CKD DISCHARGED-TOTAL	26,072	T/YR	
CKD-PH LOI	33	%	Estimate
CKD LOSS FREE	0	T/YR	
CKD-BYPASS LOI	5	%	Estimate
CKD LOSS FREE	24,768	T/YR	
KILN FEED TO PRODUCE CKD	38,199	T/YR	Includes kiln & bypass dust
CO2 FROM CALCINATION - CKD	1,304	T/YR	
CO2 FROM CALCINATION (Total)	1,202,279	T/YR (1)	
KILN HEAT INPUT	2.72	MMBTU/TON CLK	
	755	kcal/kg clinker	Estimate w/bypass
HHV FUEL(DRY BASIS)	12,500	BTU/LB	CCC coal data
LHV COAL	6,944	kcal/kg	
FUEL DRY BASIS	238,097	T/YR	
	216,000	tonnes/yr	
CARBON FUEL	75	%	Coal data
CO2 FROM FUEL	653,576	T/YR (2)	
ORGANIC CARBON IN FEED	0.27	%	Assume same as tested limestone
CO2 FROM RAW MATERIALS	33,816	T/YR (3)	Using EPA Part 98 Equation H-5
TOTAL CO2	1,889,671	T/YR	

Continued

GHG EMISSIONS ESTIMATE - CAROLINAS CEMENT

	PROPOSED	UNITS	BASIS
CH4 EMISSION FACTOR	1.10E-02	kg/mmBtu	EPA Part 98 Table C-2
N2O EMISSION FACTOR	1.60E-03	kg/mmBtu	EPA Part 98 Table C-2
BTU INPUT FROM FUEL	5,952,420	mmBtu/yr	
CH4 EMISSIONS	72	T/YR	
N2O EMISSIONS	10	T/YR	
CO2 Global Warming Potential	1		EPA Part 98 Table A-1
CH4 Global Warming Potential	21		EPA Part 98 Table A-1
N2O Global Warming Potential	310		EPA Part 98 Table A-1
CH4 CO2e	1,516	T/YR	
N2O CO2e	3,254	T/YR	
TOTAL CH4 & N2O CO2e	4,770	T/YR (4)	
EMERGENCY GENERATOR			
DIESEL FIRING RATE	57.2	gal/hr	
OPERATING HOURS	500	hrs/yr	
MAXIMUM FUEL FIRED	28,600	gal/yr	
HHV FUEL	137,000	Btu/gal	
BTU INPUT	3,918	mmBtu/yr	
CO2 EMISSION FACTOR	165	lb/mmBtu	EPA AP-42 Table 3.4-1
CO2 EMISSIONS	323	T/YR (5)	
TOTAL CO2e EMISSIONS	1,894,764	T/YR	
CO2e/TON CLINKER	0.87	T/TON	
	1730	LB/TON	