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U.S. Environmental Protection Agency

Cement Sector

Trends in Beneficial Use of Alternative Fuels and Raw Materials

Revised Draft

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US EPA ARCHIVE DOCUMENT

US EPA ARCHIVE DOCUMENT

Contents

DRAFT

DRAFT

US EPA ARCHIVE DOCUMENT

List of Tables

DRAFT

US EPA ARCHIVE DOCUMENT

Executive Summary

Objective

This report analyzes recent trends in beneficial use of alternative fuels and raw materials (AFR) in cement production. The overall objective of the study is to promote increased utilization of beneficial use materials in cement kilns by identifying trends and cost, technical, supply/logistics, and regulatory barriers to increased utilization of these materials. Alternative fuels considered in this study include petroleum refinery spent catalyst and clarified slurry oil sediments (CSOS), scrap paper/wood, construction and demolition (C&D) debris, scrap tires, wastewater treatment sludge (biosolids), plastics, and emerging materials including scrap carpet and automobile shredder residue (ASR). Alternative raw materials considered in this study include spent foundry sand and steel slag used as a cement kiln raw material. Slag used as a clinker additive is outside the scope of this report.

Alternative Fuels and Raw Materials Included in this Report

- Automobile shredder residue
- Plastics
- Refinery waste/clarified slurry oil sediment/refinery spent catalyst
- Scrap carpet
- Scrap paper / wood
- Construction/demolition debris
- Scrap tires
- Spent foundry sand
- Steel slag
- Wastewater treatment sludge

Approach

To analyze trends in beneficial use of alternative fuels and raw materials, EPA Sector Strategies Program (SSP) interviewed cement plant contacts, regulatory agency contacts, and AFR suppliers concerning use of AFR in cement kilns. Initial contacts were identified through discussions with the Portland Cement Association (PCA). PCA and EPA also coordinated a meeting with API representatives to discuss technical and regulatory issues related to clarified slurry oil sediments issues. State and local regulatory agency contacts were identified through the telephone interviews with cement plant contacts and petroleum refinery contacts. Cement plant contacts and regulatory agency contacts identified suppliers of AFR, including contacts at the cement companies' wholly-owned subsidiaries and independent alternative fuel suppliers.

SSP developed topics of discussion to address the initially prioritized beneficial use materials of spent foundry sand, steel slag, scrap paper/wood, C&D debris, and refinery spent catalyst and clarified slurry oil sediment. The interview guides aided in telephone interviews with cement plant, regulatory agency, and AFR supplier contacts. Specific areas of discussion included the types of beneficial use materials utilized by the plant, the sources of those materials, past and anticipated trends in the supply of materials and the plant's utilization of materials, and the technical and regulatory issues associated with the utilization of materials. Agency contacts discussed state and local regulatory issues, permitting and performance testing issues, public perception issues, economic programs in the states, and other issues that arose during discussions.

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The topics of discussion expanded as the telephone interviews progressed. In some cases follow-up calls were made to specific cement plant contacts to obtain additional information concerning issues that arose in other interviews or to obtain additional cement plant contacts, regulatory agency contacts, or AFR supplier contacts. These discussions led to the identification of "emerging issues," concerning alternative fuels that are either in use or being investigated by the cement plants. For these additional alternative fuel materials, SSP developed material-specific analysis and "emerging issue" case studies based on interviews with cement plant contacts and state and local regulatory agency contacts. These "emerging" materials include:

- Wastewater Treatment Sludge (biosolids)
- Plastics
- Automobile Shredder Residue (ASR)

Emerging issues concerning utilization of scrap tires in cement kilns were also identified by cement plant and regulatory agency contacts. Therefore, additional analysis of scrap tires was conducted for this report, and case studies were developed for utilization of scrap tires.

SSP also conducted research into specific regulatory issues concerning alternative fuels and conducted meetings with SSP counterparts for other Industry Sectors to obtain additional perspective on sector-specific issues.

On the usage of the Term "Waste"

Beneficial use of industrial materials (referred to in the cement sector as coprocessing) involves transferring industrial byproducts from one industrial sector to another. Such transfers can reveal differences in perspectives between industry sectors concerning the definition of the industrial byproducts involved. Industrial byproducts have historically been referred to as "wastes," even in cases where such products are recovered, rather than disposed of, and used as alternative fuels or alternative raw materials. "Waste oil," which may be burned for energy recovery, is one example of such terminology. Both the cement industry and other industry sectors have adopted the terminology "alternative fuels and raw materials" (AFRs) to refer to industrial byproducts used as alternative fuels and as alternative raw materials, however these materials are still referred to as "wastes" in cement sector and other industry sector documents. For example, the Portland Cement Association (PCA) Annual Labor and Energy Report [1] refers to "waste, oil," "waste, solvents," and "waste, other solids" as fuel type categories, and the U.S. Geological Survey Minerals Yearbook for Cement refers to "liquid waste" as a fuel type category. [2] Other key documents that use the term "waste" in this context include EU Directive 94/67/EC, and the World Business Council for Sustainable Development (WBCSD) Cement Sustainability Initiative (CSI) "Guidelines for the Selection and Use of Fuels and Raw Materials in the Cement Manufacturing Process Cement Sustainability Initiative" (December 2005).[3]

The generators of industrial byproducts (e.g., petroleum refineries) may be more inclined to refer to these industrial byproducts as "raw materials," "feedstocks," or "products" than are the users of the industrial byproducts (e.g., cement kilns). This is in part because the cement sector and other industry sectors have historically been paid fees to accept such "wastes" from generators, while the petroleum refineries and other industrial byproduct generators have been paid to deliver their facilities "products" to customers. More recently, suppliers of alternative fuel to cement kilns, including cement company wholly-owned subsidiaries and private companies, have adopted terms such as "engineered fuel" when referring to fuels derived from many different industrial byproduct streams. The preparation process used to produce this fuel adjusts for the technical and administrative specifications of cement, and guarantees that environmental standards are met independent of the specific industrial byproduct streams used in its production.[4]

Also note that the terminology of "waste" and specific regulatory definitions of "waste" (e.g., "hazardous waste;" "solid waste;" "municipal solid waste") date back several decades. The term "waste" has therefore come into general usage as applied to industrial byproducts even in cases where the material is not defined by regulation as a waste.

EPA generally has regulated units that process materials (waste or otherwise) for energy recovery under the Clean Air Act (CAA) Section 112, Maximum Achievable Control Technology (MACT) standards, such as the Portland Cement Kiln MACT, Industrial Boiler MACT, and the Pulp and Paper MACT. However, the DC Circuit recently vacated and remanded two EPA rules promulgated under the CAA – the Commercial and Industrial Solid Waste Incineration (CISWI) definitions rule, issued under section 129 of the Act, and the Boiler MACT, issued under section 112 of the Act. The court concluded that EPA erred by excluding units that combust solid waste for purposes of energy recovery from the CISWI rule and including such units in the Boiler rule.

In response to the court's decision, EPA is currently examining the use of various materials by industries, including the cement industry, and is in the process of conducting a rulemaking to determine which materials are solid wastes under RCRA, subtitle D. EPA also is establishing new standards under both 112 and 129 for the various units subject to each section, as the community of units regulated under each section will change as a result of the ruling. A separate MACT Standard for hazardous waste combustors (HWCs) applies to cement kilns that burn hazardous waste. In general, cement kilns operate under Title V Operating Permits issued by state regulatory agencies implementing Clean Air Act programs.

Specific types of "waste" are defined in the Resource Conservation and Recovery Act (RCRA) and other statues and regulations. For example, RCRA Hazardous Waste Code K170 waste is defined as: Clarified Slurry Oil (CSO) storage tank sediment and/or in-line filter/separation solids from petroleum refining operations. [5] This material is referred to in this document as Clarified Slurry Oil Sediments (CSOS). This material is categorized as a "RCRA hazardous waste."

Lastly, EPA's Office of Solid Waste and Emergency Response (OSWER) is currently considering organizational changes that, among other things, reflect the growing trend to view waste management as resource recovery and reuse opportunities, as appropriate. The cement and other industries are finding new ways to use materials that have historically been discarded or treated as wastes. Industrial facilities are reusing byproducts or waste

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materials in their own operations or sending them elsewhere for reuse as a substitute fuel or raw material. EPA values such beneficial reuse, and recognizes the many opportunities associated with converting waste products into valuable commodities.

The term "waste" in this document is not intended to connote any regulatory classification except when the term "waste" is used in phrases such as "RCRA hazardous waste;" "solid waste;" and "municipal solid waste," which are terms defined in EPA regulations. Other uses of the term "waste" (e.g., "waste oil") in this document are derived directly from the terminology used in the source documents (e.g., the PCA *Labor and Energy Report*; the USGS Cement Minerals Yearbook) and do not and are not intended to connote any regulatory classification of the material.

AFR Utilization in Cement Production

Table ES-1 provides a summary of utilization of conventional and alternative fuels in cement production in the U.S. in 2006. Data are provided in mass units and energy (BTU) units for conventional fuels and in energy units for alternative fuels. Note that available data for utilization of alternative fuels in cement production do not identify the specific type of alternative material (e.g., biosolids, wood) but rather identifies "Waste Oil;" Waste Solvents;" "Waste Other Solids;" and "Waste Miscellaneous" as separate general categories of alternative fuel materials. In general, utilization of alternative fuels other than solvents (including hazardous waste solvents) and scrap tires in cement kilns is relatively low. Alternative fuels other than scrap tires and solvents collectively represented approximately 2.5 percent of the total energy (BTU) input to cement kilns in 2006; scrap tires represented approximately 3.6 percent of the total energy input to cement kilns in 2006. According to USGS data, approximately 400,000 metric tons of scrap tires were used as alternative fuel in cement production in 2005. Tire derived fuel represents 52 percent of scrap tires generated.[1] The cement sector represents 38 percent of the market for tire-derived fuel, according to the Rubber Manufacturers Association (RMA).

Table ES-1 Energy Derived from Fuels Used in Cement Production			
Fuel Type	**Quantity Used in Cement Production**	**Btus (billions) Used in Cement Production**	
Coal	9,997,231 tons	226,539.64	64.05%
Petroleum Coke	2,560,737 tons	74,900.71	21.18%
Natural Gas	12,723 million cu. ft.	12,939.29	3.66%
Middle Distillates	20,766,405 gallons	2,875.66	0.81%
Residual Oil	3,534,995 gallons	523.99	0.15%
Gasoline	1,485,385 gallons	185.61	0.05%
LPG	950,379 gallons	81.81	0.02%
Waste Oil	--	1,008.72	0.29%
Waste Solvents	--	14,026.48	3.97%
Tire Derived Fuel	--	12,622.12	3.57%
Other Solids	--	2,686.92	0.76%
Waste - Miscellaneous		5,311.63	1.50%

[1] For 2005, the Rubber Manufacturers Association reports that 728,000 metric tons of scrap tires were used as alternative fuel in cement production in 2005, representing 18% of total quantity generation, and 37% of total quantity used for fuel.

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US EPA ARCHIVE DOCUMENT

Total		353,702.58	100.00%
Source: PCA, U.S. and Canadian Labor-Energy Input Survey 2006			

Table ES-2 summarizes generation, and onsite and offsite management of CSOS. In 2005, only 24 short tons of CSOS were reported to be sent to cement kilns for energy recovery, representing only 0.15 percent of the approximately 16,000 short tons of CSOS generated by petroleum refineries managed offsite. This is as compared to approximately 5,000 short tons of CSOS sent to cement kilns for energy recovery in 2001 (16 percent of total) and 700 short tons (2 percent of total) in 2003.

Table ES-2 Beneficial Use of CSOS in Cement Production

Year	CSOS sent to cement kilns (Short Tons)	Total CSOS Managed Offsite (Short Tons)	Percent of Total
2001	4,949.60	30,909	16.01%
2003	698.10	32,408	2.15%
2005	24.31	16,376	0.15%
Source: EPA Hazardous Waste Reporting System (2006)			

Utilization of alternative raw materials (i.e., spent foundry sand, steel slag) in cement production is also relatively low. As shown in Table ES-3, utilization of spent foundry sand in "other" beneficial use applications, which includes use as a raw material in cement production, represented only approximately 11 percent of beneficial use. Utilization of steel slag and other slag as raw material in cement production represented approximately 5 percent of overall sales of slag for beneficial use.

Table ES-3 Beneficial Use of Raw Materials in Cement Production

Material Type	Beneficial Use Metric tons (2005)	Percent of Total Beneficial Use
Spent Foundry Sand		
Not specified/Other (including use as a raw material in cement production)	292,928	11.07%
Total Beneficial Use	2,645,427	100%
Steel Slag and Other Slag		
Steel Slag	500,000	2.5%
Other Types of Slag	500,000	2.5%
Total Slag used as raw material in cement production	1,000,000	5.0%
Total Beneficial Use	20,300,000	100%
Source: American Foundry Society Bench Marking Survey (2007)		

Conventional and Alternative Fuel Characteristics

Table ES-4 summarizes the energy content of conventional and alternative fuels used in cement production. Many alternative fuels used in cement production have lower energy content than coal, the primary conventional fuel used in cement production, or require further processing to increase the energy content to the approximate energy content of

US EPA ARCHIVE DOCUMENT
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US EPA ARCHIVE DOCUMENT

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coal. This means that for some types of alternative fuels, e.g., biosolids, 1.5 tons or 2 tons of the alternative fuel may be needed to replace one ton of coal. This is a factor in both the operation of the cement kiln and in the transportation cost of the alternative fuel. Also, use of alternative fuels for energy recovery, replacing conventional fuels, reduces emissions of greenhouse gases (specifically carbon dioxide) from cement production, particularly where the alternative fuel is a "carbon neutral" material such as biosolids or scrap paper/wood.

Table ES-4: Lower Heating Value (LHV) of Conventional/Alternative Fuels

Fuel Type	Btu/Pound	Notes
Coal	11,300	
Petroleum Coke	14,600	
Paint Residues	7,000	
Plastics	18,700	Polyethylene
	12,000	Mixed non-chlorinated
Refuse-derived Fuel	6,500-7,000	Post-processing
Scrap Carpet	7,300 – 12,000	Nylon; Polypropylene
	12,000 – 15,000	Post-processing
Scrap Tires	14,000	Tire-derived fuel
Automobile Shredder Residue	7,000	Pre-processing
	10,000	Post-processing
Clarified Slurry Oil Sediments	8,000 - 9,000	Centrifuged
Biosolids	7,000-8,000	Class A Dry
Paper/Cardboard	8,500	Dry
Sawdust	7,000	Dry
Wood	6,500 – 7,500	Dry
Engineered Fuel	10,000	[processed Wet Kiln Fuel]
	6,500-8,000	[processed Dry Kiln Fuel]
Sources: Cement Industry Contacts; Murray, A.E., and Price, L., 2008.		

Pros and Cons of Alternative Fuel and Raw Material Use in Cement Kilns

Table ES-5 summarizes the benefits, barriers, technical drawbacks, and other issues related to AFRs included in this report.

US EPA ARCHIVE DOCUMENT

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Table ES-5. Summary of Alternative Fuel and Raw Material Benefits, Barriers, Technical Drawbacks, and Other Issues				
AFR	**Benefits**	**Barriers**	**Technical Drawbacks**	**Other Issues**
Automobile shredder residue (ASR)	High calorific value; after processing, energy content similar to coal. ASR has raw material value; silicates, calcium, aluminum, and iron content would replace the need for mined material High availability because almost all ASR is landfilled. Lowers landfill demand.	TSCA regulations categorize ASR as a “PCB Waste.” This represents a regulatory barrier to use of ASR for energy recovery, therefore most ASR is landfilled. ASR can contain mercury (within mercury switches), lead, and copper from content of scrap automobiles; these elements can affect cement kiln air emissions.	Technologies to upgrade the quality of ASR for suitable use within a cement kiln may not be cost effective. Treatment technologies that separate ASR into higher value high-purity plastics may compete with ASR use as alternative fuel, depending upon waste management hierarchy	Modification of regulatory TSCA waste classification applicable to ASR may facilitate the use of ASR as an alternative fuel in cement kilns. According to cement sector contacts, EPA Region VI is interpreting EPA regulation “Disposal of PCB bulk product waste” in a way that automobile shredders that generate ASR cannot certify compliance. Performance testing and air permit modifications generally required; continuous emissions monitoring system (CEMS) installation may also be required prior to initiating AFR use; these represent added cost
Plastics	High calorific value; energy content similar to coal. Recycling reduces landfill gas emissions. Represents new use for unrecyclable plastics categories (b and c) that would otherwise go to landfill.	Difficult to generate consistent quantities of material; plastics waste from multiple generators may need to be consolidated. Recyclable plastics are often sent to post-consumer plastic recyclers; cement plants do not want to compete with recyclers or conflict with waste management hierarchy. Use of chlorinated plastics can	Difficult to manage the quality of the material if commingled with general MSW stream, other non-plastic materials, and chlorinated plastics. Segregation of materials requires additional capital and labor costs. Generators (local governments) may need to install equipment and establish procedures to adequately segregate plastics in	Performance testing and air permit modifications are generally required for plants to initiate AFR use; CEMS installation may also be required prior to initiating AFR use. These represent additional cost.

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Table ES-5. Summary of Alternative Fuel and Raw Material Benefits, Barriers, Technical Drawbacks, and Other Issues				
AFR	**Benefits**	**Barriers**	**Technical Drawbacks**	**Other Issues**
	Lowers landfill demand.	increase emissions of PCDD/PCDFs and also affect clinker quality.	the MSW and supply the plastic for use in cement kilns.	
Refinery spent catalyst / clarified slurry oil sediments (CSOS)	Calorific value of CSOS; after processing, somewhat lower than coal CSOS has raw material value; CSOS alumina and silica content would replace the need for mined material Most CSOS is treated onsite by refineries or treated offsite for disposal; beneficial use would recover energy and raw material value. Refinery spent catalyst has raw material value, replacing the need for mined material.	CSOS can only be managed by offsite facilities with hazardous waste facility permits; utilization is constrained by the logistics and geographic relationship of CSOS generators and RCRA permitted cement kilns and other facilities. CSOS is not generated on a continuous basis; one refinery would not generate sufficient material to continuously supply a cement kiln; material from several refineries may need consolidation.		Refineries pursing reclassification of CSOS so the material would be regulated as a refinery product rather than a hazardous waste. The number of cement kilns permitted to combust hazardous waste has decreased nationwide because of public perception issues, EPA enforcement and regulatory requirements, and related costs. Onsite management/reuse of CSOS by refineries avoids regulatory classification as hazardous waste or TRI reporting as an offsite transfer, but use as AFR material at cement kilns would be a more optimal disposition.
Scrap carpet	Calorific value; after processing, scrap carpet energy content is similar to that of coal. Scrap carpet has raw material value; calcium carbonate would reduce demand for mined material. High potential availability	Difficult to generate consistent quantities of material; scrap carpet from multiple generators may need to be consolidated. Centralized collection of material is difficult, as there are large numbers of small generators of scrap carpet. Using scrap carpet as an AFR has the potential to affect cement kiln	Preprocessing is needed to make alternative fuel from scrap carpet. Carpet is made to be highly durable, making scrap carpet difficult to shred. Separating scrap carpet from other debris at point of generation involves labor costs; small scale carpet installers require training in preventing	Permit modifications and performance testing are generally required prior to initiating AFR use; CEMS installation may also be required prior to initiating AFR use. These represent additional cost.

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Table ES-5. Summary of Alternative Fuel and Raw Material Benefits, Barriers, Technical Drawbacks, and Other Issues

AFR	Benefits	Barriers	Technical Drawbacks	Other Issues
	because almost all scrap carpet is landfilled. Lowers landfill demand.	NO_x emissions because of nitrogen content of the scrap carpet.	contamination with materials such as scrap wood, nails.	
Scrap paper / wood	Calorific value, but relatively low as compared to coal. Quantities are available because some material is currently landfilled. Lowers landfill demand. Use of "CO_2 neutral" alternative fuels lowers greenhouse gas emissions from cement production.	Difficult to generate consistent quantities of materials; wood and scrap paper from multiple generators may need to be consolidated. Recyclable scrap paper is often sent to post-consumer paper recyclers; cement plants do not want to compete with recyclers, and plants do not want to conflict with waste management hierarchy for paper.	Feasibility of processing material into consistent physical condition for conveyance into kiln. Capital cost for equipment to prevent sawdust from becoming wet and prevent fugitive dust emissions.	Permit modifications and performance testing generally required prior to initiating AFR use; CEMS installation may also be required prior to initiating AFR use. These represent additional cost.
Construction and demolition debris	Calorific value, but relatively low as compared to coal. Lowers landfill demand	C&D debris is not generated on a continuous basis; difficult to ensure a consistent supply of C&D debris for use in making alternative fuel. Logistics and transportation of C&D debris use are more difficult than relatively homogenous wood waste material generated by a lumber mill or a landscape services provider.	Variable quality of the C&D debris as generated requires segregation of material to produce C&D debris of consistent quality to make alternative fuel. Onsite segregation of C&D debris involves capital and labor costs. Feasibility of processing C&D debris into consistent physical condition for conveyance into kiln depends on quality of the material as generated.	Several states (including MA, NY) have recently banned disposal of C&D debris in landfills, increasing the potential supply of C&D debris for use in making alternative fuel.
Scrap tires	Calorific value of scrap tires	Increasing competition for scrap	Some cement kiln designs are	Performance testing and air permit

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Table ES-5. Summary of Alternative Fuel and Raw Material Benefits, Barriers, Technical Drawbacks, and Other Issues				
AFR	**Benefits**	**Barriers**	**Technical Drawbacks**	**Other Issues**
	similar to coal; scrap tires also have raw material (iron) value Use of scrap tires can reduce cement kiln NO_x emissions. Iron recovered from tires reduces the quantity of iron needed from mined sources. Use of scrap tires reduces landfilling, and reduces health and environmental concerns from piled scrap tires; this can be integral part of state government scrap tire programs.	tires from other beneficial users. Waste management hierarchy interpretation may affect the perception of use of scrap tires for energy recovery as opposed to recycling scrap tires into other uses. Some state and local regulations allow scrap tires to be disposed in non-hazardous solid waste landfills; this affects the available supply of scrap tires. Potential public perception and communications issues associated with scrap tire use in cement kilns.	not able to use whole scrap tires and would need to use chipped tires; chipping tires is costly and is not always cost effective.	modifications are generally required for plants to initiate AFR use; CEMS installation may also be required prior to initiating AFR use. These represent additional cost.
Spent foundry sand	Spent foundry sand has raw material value; specifically silica. Silica content of spent foundry sand substitutes for mined raw material. Lowers landfill demand	In some states this material is being stockpiled or landfilled; this affects the available supply of the material. Cost and technical issues related to quality of the material as generated. Cement plants (or generators) must screen lower quality spent foundry sand to remove metal and other extraneous materials, making lower quality spent foundry sand not as desirable as mined raw material. Spent foundry sand can be used as a	Phenolic resin binder content of the spent foundry sand may not be compatible with preheater/precalciner kiln design and can affect carbon monoxide emissions from cement kilns. Spent foundry sand can be more difficult to grind that mined sand; extraneous material can damage grinding equipment. Some cement plants have an inexpensive supply of mined raw	Some states do not have active regulatory management programs for spent foundry sand, permitting the material to be landfilled.

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Table ES-5. Summary of Alternative Fuel and Raw Material Benefits, Barriers, Technical Drawbacks, and Other Issues				
AFR	**Benefits**	**Barriers**	**Technical Drawbacks**	**Other Issues**
		construction material; competing uses for spent foundry sand, including construction fill, are less sensitive to the material's quality.	material containing silica and therefore would not need to use spent foundry sand, even if the material was readily available.	
Steel slag	Steel slag has raw material value; specifically silicates. Silicate content of steel slag would substitute for mined material; reducing demand for mined material.	Competition from concrete batch plants using steel slag as an additive in cement production may affect the market for steel slag use as a cement kiln raw material.	Requires particular quality of slag for use in kiln. Some cement plants have an inexpensive supply of mined raw material containing silica and therefore would not need to use steel slag, even if the material was readily available.	
Wastewater treatment sludge	Calorific value, but relatively low as compared to coal even after drying the material. Lowers landfill demand. Material is potentially widely available in metropolitan areas; large supply and continuously available. Use of "CO_2 neutral" alternative fuels lowers greenhouse gas emissions from cement production.	Potential public perception and communications issues associated with biosolids use in cement kilns. Existing infrastructure for biosolids management is largely based on land application of the biosolids. Requires drying the biosolids material before use in kiln.	Biosolids as generated contain pathogens. Classification of biosolids is based on pathogenic organisms content of material; some jurisdictions limit cement plants' use of the material to Class A material that has been heat processed to remove pathogens; this can effectively reduce the net amount of energy recovered from the material.	Performance testing and air permit modifications are generally required for plants to initiate AFR use; CEMS installation may also be required prior to initiating AFR use. These represent additional cost.

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Key Findings

This analysis produced the following key findings:

- Primarily driven by cost considerations, the principal focus of cement plants' beneficial use of alternative fuels rather than on the beneficial use of alternative raw materials.

- Most cement plants noted that use of alternative fuels is important to the continued competitiveness of their plants.

- Technical considerations regarding materials handling arose frequently during interviews, and affected key decisions on plants' uses of materials. Often, for instance, a decision to use one alternative fuel or raw material precludes the use of another material because of materials handling system limitations.

- State agency contacts generally indicated that agencies are promoting beneficial use at a relatively low level; cement plant and state agency contacts indicated that the market has been more efficient than state agencies at matching alternative fuel and raw material suppliers and users.

- There is a growing commercial market for brokers that may consolidate quantities of materials into larger shipments to cement plants and may process the material prior to shipment.

- Significant differences exist in the corporate management of beneficial use of materials. Some corporations set benchmarks for their cement plants and the plants may work on pilot projects, while other companies contain plants acting more autonomously.

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Key Opportunities and Options

Much of AFR being used in cement kilns provide natural synergies between the cement sector and other SSP sectors, including:

- Automobile Manufacturing: Automobile Shredder Residue
- Automobile Parts Manufacturing: Plastics
- Oil and Gas: CSOS, Refinery Spent Catalyst
- Metal Casting: Spent Foundry Sand

Partnerships between the cement sector and other SSP sectors could leverage the strong interest expressed in interviews in collaboratively examining the issues associated with distribution and use of alternative fuels and raw materials. Also, partnerships between sectors and state agencies with active beneficial use promotion programs could promote establishment and expansion of such programs. Note that regional differences, as well as state and local regulatory frameworks, play a key role in the factors of cost, quantity, and quality of AFR. Approaches to further actions would be most efficient when informed by such differences.

Recommendations for further actions are based on conclusions (observations) concerning beneficial use materials supply and demand and cost, technical, and regulatory issues; potential health effects of beneficial use of materials is outside of the scope of this report; however, the use of AFR at cement kilns would be subject to the full suite of safety, health, environmental, and transportation regulations applicable to any commercial fuels and raw materials used at those locations. Potential public perception and associated public communications issues related to beneficial use of materials are also outside of the scope of this report. The potential for health effects and public perception/communications will need to be considered in evaluating and implementing recommendations for further actions.

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1. Introduction

The overall objective of the study is to promote increased utilization of beneficial use materials in cement kilns. These include alternative fuels (e.g., scrap paper/wood, petroleum refinery spent catalyst and CSOS) and alternative raw materials (e.g., spent foundry sand, steel slag) used in cement clinker production. These materials are generally termed "alternative fuels and raw materials" (AFR).[b] The benefits of using alternative fuels in the cement industry include:

- Reduces the use of non-renewable fossil fuels such as coal as well as the environmental impacts associated with coal mining;
- Contributes towards a lowering of emissions such as greenhouse gases by replacing the use of fossil fuels with materials that would otherwise have to be incinerated with corresponding emissions and final residues;
- Maximizes the recovery of energy from the alternative fuel material. All the energy is used directly in the kiln for clinker production. It also maximizes the recovery of the non-combustible part of the alternative fuel material and eliminates the need for disposal of slag or ash, as the inorganic part substitutes raw material in the cement.[6]

The benefits of using alternative raw materials in the cement industry include the elimination of the need to dispose of the materials in landfills and avoidance of air emissions and other environmental impacts of production and transport of virgin (mined) raw materials.

Industrialized countries have utilized AFR successfully for more than 20 years. However, the cement industry in the U.S. lags behind several countries in the percentage of thermal energy substituted by AFR, as shown in Table 1.

Table 1: Share of AFR in Total Fuel Demand in the Cement Industry of Selected Countries

Country	**Percentage of thermal energy substituted by AFR**	**Year**
France	32%	2003
Germany	42%	2004
Norway	45%	2003
Switzerland	47%	2002
United States	25%	2003

Source: CEMBRUREAU, SINTEF, as presented in The GTZ-Holcim Private Partnership, *Guidelines on Co-Processing Waste Materials in Cement Production*, p4, 2006.

[b] The term "co-processing" is also use when discussing alternative fuels. Co-processing means the substitution of primary fuel and raw material by alternative fuels and raw materials in industrial processes.

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The study was conducted to refine our understanding of the challenges and opportunities for use of these materials by conducting material-specific analyses.[c] The study focused on the following:

- Technical Issues
- Cost Issues
- Regulatory Issues
- Supply/Logistics Issues
- Trends Analysis
- Emerging Issues/Materials

This report is the more detailed follow-up to the SSP report, *Beneficial Reuse of Industrial Byproducts in the Gulf Coast Region*, February 2008; see p. 15. Section 3.1 of that report discussed coal combustion byproducts, iron and steel manufacturing byproducts, and use of alternative fuels from other industries within cement production. The report noted a 10 year trend in increased AFR use, and found that development of innovative and proprietary technologies "can lower barriers to beneficial reuse for technology owners, but may create barriers to beneficial reuse by other facilities" in the Gulf Coast Region (p. 26). This finding is specific to the Gulf Coast Region and may be less of an issue in other regions of the U.S.

The scope of the study was limited because of budget constraints. Therefore a limited number of materials (initially four) were selected for analysis in the study and a limited number of contacts were made with cement plant contacts, regulatory agency contacts, and beneficial use material suppliers. These initial contacts identified substantive issues related to other materials and identified a number of emerging issues, so the scope of the study expanded from the initial four prioritized materials to a larger number of materials.

An initial objective of the study was to conduct comparative cost analyses of the use of beneficial use materials. However, research conducted for this study did not produce sufficient economic data set to conduct detailed economic analysis for any of the materials. Cement plant contacts and beneficial use material suppliers were reluctant to provide detailed cost and economic data, even with assurance of Confidential Business Information (CBI) protection.

The case study summaries provide a general overview of the issues surrounding each beneficial use material without identifying specific cement plants. Appendix A contains a more detailed discussion of the case studies.

Recommendations for further actions are based on conclusions and observations concerning beneficial use materials supply and demand and cost, technical, and regulatory issues. Potential health effects of beneficial use of materials is outside of the scope of this report; however, the use of AFR at cement kilns would be subject to the full suite of safety, health, environmental, and transportation regulations applicable to any commercial fuels

[c] This report also serves as a continuation of the EPA, SSP report, *Beneficial Reuse of Industrial Byproducts in the Gulf Coast Region*, February 2008. Section 3.1 of that report discusses trends, drivers, and barriers to beneficial reuse in the Cement Manufacturing sector.

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and raw materials used at those locations. The potential for health effects will need to be considered in evaluating and implementing recommendations for further actions. Potential public perception and associated public communications issues related to beneficial use of materials are also outside of the scope of this report.

The major sections of this report are organized as follows:

- Section 2 provides the background for the study;
- Section 3 outlines the beneficial use materials prioritization methodology, criteria, and results, and study methodology;
- Section 4 provides case study summations;
- Section 5 provides conclusions;
- Section 6 provides recommendations and potentials for further actions by cement plants, suppliers, and federal and state regulatory agencies;
- Appendix A includes the detailed case studies for the beneficial use materials; and
- Appendix B provides information for the cement plant contacts, regulatory agency contacts, and other contacts for the study.
- Appendix C provides a description of cement kiln types.

2. Background

This section provides the background for the study and an overview of cement kiln technology and beneficial use materials. Kilns produce cement clinker, which is used to produce Portland cement, a binding agent that when mixed with water, sand, and gravel or crushed stone forms the rock-like mass known as concrete. Concrete, in turn, serves highway, commercial, and residential construction projects. Limestone and other ingredients, including material that is aluminous, ferrous, and siliceous, are placed into a kiln where a thermochemical process occurs to make cement clinker. The cement clinker is mixed with additives (e.g., gypsum) to make Portland cement.

The U.S. Cement Manufacturing sector is concentrated among a relatively small number of companies; many U.S. cement plants are owned by, or are subsidiaries of, foreign companies. Together, 10 companies accounted for about 80 percent of total U.S. cement production in 2005.[7] California, Texas, Pennsylvania, Florida, and Alabama are the five leading cement-producing states and accounted for about 48 percent of recent U.S. production.[8] In 2007, about 91 million tons of Portland cement and about 4 million tons of masonry cement were produced at 113 plants in 37 States; total cement production capacity was about 127 million tons. Cement also was produced at two plants in Puerto Rico.[9]

2.1 Study Overview

The scope of this study is to identify potential barriers to increased use of AFR in cement kilns and to develop recommendations/further actions to address such barriers. Note that the scope of this study is limited to assessing the cost, regulatory, technical, and logistics and supply issues associated with use of AFR in cement kilns.

Cement kilns use AFR to reduce operating costs and to reduce emissions of criteria air pollutants and greenhouse gases. The use of alternative raw materials by cement kilns

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further avoids the need to mine and extract such materials and associated environmental and economic costs of mining and extraction. Alternative raw materials used as cement manufacturing ingredients (e.g., petroleum refinery spent catalyst, steel slag, spent foundry sand) supplies specific necessary elements (e.g., iron, silica) to the raw mix, replacing the need for virgin fuels or mined materials. The need for alternative raw materials depends upon the composition of the primary raw materials (e.g., limestone chemistry) available to the cement kiln. In some cases, if the readily available raw materials are deficient in one or more elements, an alternative raw material may be needed to achieve the needed composition of the cement manufacture raw ingredient mix.

Landfill issues are also important with respect to beneficial use of raw materials, for example, spent foundry sand and steel slag, in cement kilns. These alternative materials are used to replace mined (virgin) materials. Disposal of alternative raw materials in landfills does not represent effective management of the potential raw material value of the materials, does not reduce the consumption of mined materials, and results in the unnecessary utilization of landfill capacity.

An important component of the beneficial use of AFR as alternative fuels in cement kilns is the management of the energy content of the materials. Some of the materials addressed in this study, for example, scrap tires and biosolids, have substantial energy content and can be processed for energy recovery in cement kilns, but these materials can also be disposed of in landfills. These alternative fuels are used by cement kilns to replace conventional fossil fuels (e.g., coal, petroleum coke). Disposal of materials having calorific value in landfills does not represent effective management of the energy content of the materials, and reflects a lack of recognition that these materials have calorific value (BTU per pound). Conversely, use of alternative fuels in cement kilns avoids utilization of landfill capacity, and also represents effective management of the energy content of the materials and reduces the consumption of conventional fossil fuels. Use of alternative fuel materials also reduces emissions of greenhouse gases (carbon dioxide,) particularly where the alternative fuel material is a “carbon neutral” material such as biosolids. Also, utilization of alternative fuels in cement production results in the destruction of the materials in the manufacture of the clinker. Disposal of materials in landfills does not result in the destruction of the material, and therefore landfilling of materials may pose future liabilities that would not exist if the materials were destroyed in a cement kiln.

2.2 Cement Kiln Technology

Rotary kilns are designed to produce clinker through the intense heating of raw materials, as described above. There are four basic types of cement kilns: (1) long wet kiln process, (2) long dry kiln process, (3) preheater kilns, and (4) preheater/precalciner kilns.

The two primary kiln designs are the wet and dry processes. The number of wet process and dry process kilns operating in the U.S. is shown in Table 1. The primary difference between the various processes involves the state of the materials when entering the kiln. For instance, a kiln in a wet process plant must provide enough energy to evaporate the extra water used in the process. Additional discussion of cement kiln design and cement production technology is included in Appendix C.

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Table 2. Wet and Dry Kilns in the U.S.			
Year	Wet Kilns	Dry Kilns	Both
1998	34	74	2
1999	34	75	2
2000	32	77	2
2001	28	77	6
2002	27	80	3
2003	26	80	4
2004	24	80	5
2005	23	81	4
Note: Wet Kiln and Dry Kiln counts do not include kilns that are identified as "both" wet and dry in the USGS Mineral Yearbook. Source: USGS Mineral Yearbook – Cement, 1998-2006			

In long wet process kilns, raw materials are conveyed into the kiln in the form of a slurry with water. The water is evaporated in the kiln using heat from combustion of fuels. Heat to promote the chemical reaction of the raw materials to produce cement clinker is also provided by fuel combustion. Because evaporating the water in the raw material slurry requires energy, wet process kilns use more energy per ton of cement clinker produced than other kiln designs, and wet process kilns are typically longer than dry process kilns.

In long dry process kilns, raw materials are introduced into the kiln with less water than wet kilns, but the device continues to rely upon convection heating in a horizontal cylinder which is less energy efficient than heating in a tower. A preheater kiln introduces raw materials with much less water than wet kilns and uses a vertical tower to transfer heat to raw materials taking advantage of heats tendency to rise to more effectively transfer energy. A precalciner kiln introduces raw material with much less water than wet kilns, uses a vertical tower to transfer heat to raw material, and uses a direct fuel to raw material heat transfer in the vertical tower to further improve heat transfer.

All of these systems may use variations on the placement of burners and the recycle of waste heat to improve energy transfer to the raw materials. A typical preheater/precalciner type dry process kiln uses approximately one-third as much thermal energy as a typical wet process kiln (approximately 3.0 MMBTU per ton of clinker produced). Cement companies have been replacing their wet process kilns with dry process kilns. As of 2008, approximately 80 percent of all cement kilns operating in the U.S. were dry process kilns (of all types).

Raw materials that are conveyed into kilns to produce clinker include:

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- Clay
- Granulated (and other) blast furnace slags
- Ferrous materials
- Fly ash (and other ash)
- Lime
- Limestone
- Natural rock (and other) pozzolans
- Sand
- Sandstone
- Shale
- Steel (and other) slags

2.2.1 Cement Production

While various processes exist, the kilns are generally horizontal, inclined rotating cylinders that are internally fired. The cylinder's diameter can be up to 25 feet, is installed at a 3 to 4 degree angle, and rotates 1 to 3 times per minute. Rotary kilns run 24 hours a day, and are typically stopped only for a few weeks per year for essential maintenance.

The raw material always enters into the upper end of the kiln, moves down the cylinder against a flow of hot gases and toward the lower end of the cylinder containing a flame. The dry, calcined material then enters a sintering zone where combustion gas reaches a temperature of 1800° to 1980° Celsius (C), and becomes clinker.[10]

A kiln serves several purposes, acting as a chamber for fuel combustion, a flue for gases, a conveyor for solids, a calciner (driving off carbon dioxide from the calcium carbonate), a mixer for the raw feed, and a host for chemically transforming feed into clinker.

Cement clinker is the primary ingredient in cement. Cement clinker production data for 1990 through 2006 is shown in Table 2.[11] As shown, U.S. cement clinker production has increased 37 percent from 1990 through 2006.

Table 3 U.S. Clinker Production

Year	**Clinker Production** (1,000 metric tons)
1990	64,355
1995	71,257
2000	79,656
2001	79,979
2002	82,959
2003	83,315
2004	88,190
2005	88,783
2006	88,453

Source: USGS Mineral Yearbook – Cement, 1992-2006

2.3 Alternative Fuels and Raw Materials (AFR)

Cement manufacturers using AFR in kilns can achieve reduced energy costs and reduce criteria pollutant and greenhouse gas emissions. Considering the increasing cost of coal,

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petroleum coke, and other conventional fuels used in cement production, there is an increasing incentive for cement companies to identify new sources of alternative fuels. Data for the utilization of conventional and alternative fuels in cement production are shown in Table 3 in mass units and heat (BTU) units. Table 4 provides data for the calorific value of conventional and alternative fuels.[d]

There are important differences between cement manufacturing processes with respect to the beneficial use of AFR that are related to materials handling. For wet process kilns, and long dry kiln systems, for example, the primary means of introducing fuels into the process is directly into the front or lower end of the horizontal rotary kiln, at approximately the same location as the primary fuels (e.g., coal, petroleum coke). Some AFR may be introduced by penetrating the rotary kiln shell with introduction systems, but these locations can only supply a portion of the systems inputs. For example, alternative fuels introduced into the cement kiln at replacement rates greater than 50 percent would need to be conveyed into the kiln in the same general manner as the primary fuels are conveyed into the kiln, and would need to be in a physical form compatible with the kiln fuel handling system. An example of a system that penetrates the rotary kiln shell is a scrap tire burner or solid waste container burner. Whole scrap tires or containerized or bundled energy bearing waste can be dropped into a horizontal rotary kiln through a chute and gate mechanism installed in the midpoint of the kiln (mid-kiln entry).

For a preheater/precalciner-type dry process kiln, however, alternative fuel can be introduced either into the front end (lower end), and back end (upper feed shelve end) of the horizontal rotary kiln or into the systems vertical tower. This enables a broader range of alternative fuel characteristics to be introduced into the process.

Care must be taken to introduce AFR at a locations in the system where complete combustion will occur or where appropriate chemical reactions will occur. The introduction location's temperature, turbulence, oxygen, and time at conditions must be adequate to completely combust organic compounds, whether in the fuel, or contained in the raw materials (e.g., spent foundry sand). For raw materials the introduction location must allow adequate time for the materials chemical species to react in the manufacture process. For example a particular introduction point in a kiln system may allow too short a residence time to facilitate a fuel or raw material reaction. As such some dry kilns may require the use of tire chips, rather than whole tires because the chip has more surface area per mass and can react more quickly.

Table 4: Energy Derived from Fuels Used in Cement Production

Fuel Type	Quantity Used in Cement Production	Btus (billions) Used in Cement Production	
Coal	9,997,231 tons	226,539.64	64.05%
Petroleum Coke	2,560,737 tons	74,900.71	21.18%
Natural Gas	12,723 million cu. ft.	12,939.29	3.66%
Middle Distillates	20,766,405 gallons	2,875.66	0.81%
Residual Oil	3,534,995 gallons	523.99	0.15%

[d] Note: The terminology used in this section and in Table 3 reflects the terminology used in the Portland Cement Association U.S. and Canadian Labor-Energy Input Survey (2006).

Gasoline	1,485,385 gallons	185.61	0.05%
LPG	950,379 gallons	81.81	0.02%
Waste Oil	--	1,008.72	0.29%
Waste Solvents	--	14,026.48	3.97%
Tire Derived Fuel	--	12,622.12	3.57%
Other Solids	--	2,686.92	0.76%
Waste - Miscellaneous		5,311.63	1.50%
Source: PCA, U.S. and Canadian Labor-Energy Input Survey 2006[e]			

Table 5: Lower Heating Value (LHV) of Conventional and Alternative Fuels

Fuel Type	Btu per Pound	Notes
Coal	11,300	
Petroleum Coke	14,600	
Paint Residues	7,000	
Plastics	18,700	Polyethylene
	12,000	Mixed non-chlorinated
Refuse-derived Fuel	6,500-7,000	Post-processing
Scrap Carpet	7,300 – 12,000	Nylon; Polypropylene
	12,000 – 15,000	Post-processing
Scrap Tires	14,000	Tire-derived fuel
Automobile Shredder Residue	7,000	Pre-processing
	10,000	Post-processing
CSOS	8,000 - 9,000	Centrifuged
Biosolids	7,000-8,000	Class A Dry
Paper/Cardboard	8,500	Dry
Sawdust	7,000	Dry
Wood	6,500 – 7,500	Dry
Engineered Fuel	10,000	[Wet Kiln Fuel]
	6,500-8,000	[Dry Kiln Fuel]
Sources: Cement Industry Contacts; Murray, A.E., and Price, L., 2008.[12]		

2.4 On the usage of the Term "Waste"

Beneficial use of industrial materials (referred to in the cement sector as coprocessing) involves transferring industrial byproducts from one industrial sector to another. Such transfers can reveal differences in perspectives between industry sectors concerning the definition of the industrial byproducts involved. Industrial byproducts have historically been referred to as "wastes," even in cases where such products are recovered, rather than disposed of, and used as alternative fuels or alternative raw materials. "Waste oil," which may be burned for energy recovery, is one example of such terminology. Both the cement industry and other industry sectors have adopted the terminology "alternative fuels and raw materials" (AFRs) to refer to industrial byproducts used as alternative fuels and as

[e] This table contains the terminology of fuels used in the PCA U.S. and Canadian Labor-Energy Input Survey, 2006.

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alternative raw materials, however these materials are still referred to as "wastes" in cement sector and other industry sector documents. For example, the Portland Cement Association (PCA) Annual Labor and Energy Report [13] refers to "waste, oil," "waste, solvents," and "waste, other solids" as fuel type categories, and the U.S. Geological Survey Minerals Yearbook for Cement refers to "liquid waste" as a fuel type category. [14] Other key documents that use the term "waste" in this context include EU Directive 94/67/EC, and WBCSD Cement Sustainability Initiative (CSI) "Guidelines for the Selection and Use of Fuels and Raw Materials in the Cement Manufacturing Process Cement Sustainability Initiative" (December 2005).

The generators of industrial byproducts (e.g., petroleum refineries) may be more inclined to refer to these industrial byproducts as "raw materials," "feedstocks," or "products" than are the users of the industrial byproducts (e.g., cement kilns). This is in part because the cement sector and other industry sectors have historically been paid fees to accept such "wastes" from generators, while the petroleum refineries and other industrial byproduct generators have been paid a fee to deliver their facilities "products" to customers. More recently, suppliers of alternative fuel to cement kilns, including cement company wholly-owned subsidiaries and private companies, have adopted terms such as "engineered fuel" when referring to fuels derived from many different industrial byproduct streams. The preparation process used to produce this fuel adjusts for the technical and administrative specifications of cement, and guarantees that environmental standards are met independent of the specific industrial byproduct streams used in its production.[15]

Also note that the terminology of "waste" and specific regulatory definitions of "waste" (e.g., "hazardous waste;" "solid waste;" "municipal solid waste") date back several decades. The term "waste" has therefore come into general usage as applied to industrial byproducts even in cases where the material is not defined by regulation as a waste.

EPA generally has regulated units that process materials (waste or otherwise) for energy recovery under CAA 112 MACT standards, such as the Portland Cement Kiln MACT, Industrial Boiler MACT, and the Pulp and Paper MACT. However, the DC Circuit recently vacated and remanded two EPA rules promulgated under the CAA – the Commercial and Industrial Solid Waste Incineration (CISWI) definitions rule, issued under section 129 of the Act, and the Boiler MACT, issued under section 112 of the Act. The court concluded that EPA erred by excluding units that combust solid waste for purposes of energy recovery from the CISWI rule and including such units in the Boiler rule.

In response to the court's decision, EPA is currently examining the use of various materials by industries, including the cement industry, and is in the process of conducting a rulemaking to determine which materials are solid wastes under RCRA, subtitle D. EPA also is establishing new standards under both 112 and 129 for the various units subject to each section, as the community of units regulated under each section will change as a result of the ruling. A separate MACT Standard for hazardous waste combustors (HWCs) applies to cement kilns that burn hazardous waste. In general, cement kilns operate under Title V Operating Permits issued by state regulatory agencies implementing Clean Air Act programs.

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Specific types of "waste" are defined in the Resource Conservation and Recovery Act (RCRA) and other statues and regulations. For example, RCRA Hazardous Waste Code K170 waste is defined as: Clarified Slurry Oil (CSO) storage tank sediment and/or in-line filter/separation solids from petroleum refining operations.[16] This material is referred to in this document as Clarified Slurry Oil Sediments (CSOS). This material is categorized as a "RCRA hazardous waste."

Lastly, EPA's Office of Solid Waste and Emergency Response (OSWER) is currently considering organizational changes that, among other things, reflect the growing trend to view waste management as resource recovery and reuse opportunities, as appropriate. The cement and other industries are finding new ways to use materials that have historically been discarded or treated as wastes. Industrial facilities are reusing byproducts or waste materials in their own operations or sending them elsewhere for reuse as a substitute fuel or raw material. EPA values such beneficial reuse, and recognizes the many opportunities associated with converting waste products into valuable commodities.

The term "waste" in this document is not intended to connote any regulatory classification except when the term "waste" is used in phrases such as "RCRA hazardous waste;" "solid waste;" and "municipal solid waste," which are terms defined in EPA regulations. Other uses of the term "waste" (e.g., "waste oil") in this document are derived directly from the terminology used in the source documents (e.g., the PCA *Labor and Energy Report*; the USGS Cement Minerals Yearbook) and do not and are not intended to connote any regulatory classification of the material.

3. Beneficial Use Materials Prioritization

This section describes the beneficial use material prioritization, selection criteria, and results, and provides the methodology and rationale for selecting beneficial use materials for further material-specific analysis.

3.1 Development of Materials Prioritization List and Criteria

The study that gave rise to this initiative was the *Beneficial Use of Industrial By-Products in Cement Kilns: Analysis of Utilization Trends and Regulatory Requirements*, April 2005. This study was prepared to support the *EPA/PCA Beneficial Use of Alternative Fuels and Materials Workshop* organized by SSP and PCA and conducted in July 2005. The objective of the EPA/PCA Workshop was to initiate a discussion of regulatory and economic drivers and barriers among cement kiln operators, beneficial use material generators, and regulators. Ten beneficial use materials were evaluated in the ICF International April 2005 *Draft Beneficial Use Report* and discussed at the July 2005 EPA/PCA Workshop.[17] These include:

- Steel Slag;
- Spent Foundry Sand;
- Coal Combustion Products (fly ash);
- Scrap Tires;
- Scrap Paper/Wood;
- Construction and demolition (C&D) Debris;

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- Waste/Off-Specification Paint and used non-hazardous used oil;
- Refinery Spent Catalyst and Clarified Slurry Oil Sediment;
- Spent Aluminum Potliners; and
- Animal Meal (rendering plant by-products)

The ten materials evaluated in the *Draft Beneficial Use Report* were prioritized based on the following criteria:

- Amount of the Beneficial Use Material Generated in the U.S.;
- Amount of the Material Beneficially Used in Cement Kilns in the U.S.;
- Anticipated Availability of Economic Data;
- Alternative Beneficial Uses and Likelihood of Disposal; and
- Regulatory Framework and Disposal Methods

In addition, further discussion of the prioritization criteria with the PCA focused on the identification of a subset of materials for further analysis. Specifically, it was agreed that the four materials selected for further analysis should include three that are "commonly used" (i.e., non-hazardous waste) materials and one "challenge material," potentially a listed RCRA hazardous waste material. Also of value in considering materials for study in this report was the SSP report, *Beneficial Reuse of Industrial Byproducts in the Gulf Coast Region*, February 2008.[18]

3.1.2 Study Methodology

Cement plants were selected for this study to provide a range of beneficial use materials being used, a range of kiln types, and a range of geographic location. The types of beneficial use materials that each cement plant uses and the type of cement kiln was identified from the Portland Cement Association U.S. and Canadian Labor and Energy Report (2006).

Data for each cement plant included in the 2006 PCA *Labor and Energy Report* were organized in a spreadsheet by kiln type (wet kiln, dry kiln, preheater, precalciner); and by primary fuels and alternate fuels (coal, petroleum coke, fuel oil, natural gas, and "waste" fuels including "Waste, Oil;" "Waste, Solvents;" "Waste, Other Solids;" and "Waste, Miscellaneous" as separate general categories of "waste); and primary raw materials used (including spent foundry sand, steel slag, and "refinery catalyst," which could include spent FCC catalyst waste, among the raw material subcategories). When citing data from the PCA *Labor and Energy Report*, this study uses the terminology used in the underlying Report. Several of the cement plants that were identified as using "waste" as primary fuel were selected for the study, and several of the cement plants that reported using spent foundry sand, steel slag, or refinery spent catalyst were also selected for the study. No specific data concerning scrap paper/wood was included in the reference (this would be listed under "other" in the data) so preliminary research using public data sources was conducted to investigate utilization of C&D debris by cement kilns. Several of the cement kilns that reported using "other" fuel were selected for the study.

In August 2007, topics for discussion were developed for the initial prioritized beneficial use materials of spent foundry sand; steel slag; scrap paper/wood; C&D debris; and refinery spent catalyst and CSOS. The materials were developed as "interview guides" for

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conducting telephone interviews with the cement plant and regulatory agency contacts. Specific areas of discussion with the cement plant contacts included the types of beneficial use materials utilized; the sources of the materials; past and anticipated future trends in the available supply of the material and in the cement plant's utilization of the material, and technical and regulatory issues associated with utilization of the material. The technical and regulatory issues addressed included the quality of the available material; materials handling and materials processing requirements; potential effects of utilization of the material on cement clinker quality or on kiln environmental performance; and requirements for environmental permitting and performance testing prior to using the material.

Cement plant contracts were identified in coordination with the principal PCA contact and members of the PCA Energy and Environment (E&E) Committee in September 2007, and the topics for discussion were sent to cement plant contacts. Telephone interviews were conducted with the cement plant contacts using the topics for discussion as interview guides between November 2007 and March 2008. The initial list of cement plants to be contacted for the study expanded as the study was being conducted. In some cases the contact for one cement plant provided contact information for another of that company's cement plants, in order to provide additional information for a specific beneficial use material.

PCA and EPA also coordinated a meeting with API representatives in November 2007 at API Headquarters to discuss technical and regulatory issues related to clarified slurry oil solids issues. Several petroleum refiners represented at the meeting are generating CSOS for beneficial use in cement kilns or other onsite or offsite management. Telephone interviews were conducted with these petroleum refinery contacts in December 2007 and January 2008.

State and local regulatory agency contacts were identified through the telephone interviews with cement plant contacts and petroleum refinery contacts. Telephone interviews with agency contacts were conducted between November 2007 and March 2008. Agency contacts were identified specifically to obtain information concerning the site-specific state and local regulatory issues, permitting and performance testing issues, public perception issues, and related issues surrounding each beneficial use material. Agency contacts were also interviewed to research various state-level and local-level economic programs that have been established to promote the beneficial use of materials.

In addition to the four initially prioritized materials, alternative fuel beneficial use materials were identified for material-specific analysis and development of "emerging issue" case studies based on interviews with cement plant contacts and state and local regulatory agency contacts. These include:

- Wastewater Treatment Sludge (biosolids)
- Plastics
- Scrap Tires
- Automobile Shredder Residue (ASR)

The rationale for including these additional materials is described below.

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The interviews conducted identified economic, technical, and regulatory barriers to increased use; this information used to develop material-specific case studies. These case studies are included in Appendix A. The case studies identify specific recommendations and further actions to address identified barriers. The further actions/recommendations are integrated with the further actions and recommendations for the cement sector identified in the SSP *Beneficial Reuse of Industrial Byproducts in the Gulf Coast Region,* February 2008.[19]

3.1.3 Alternative Fuels Methodology

SSP contacted cement plant contacts, regulatory agency contacts, and suppliers concerning use of alternative fuels in cement kilns. EPA initiated research by contacting the cement plant contacts identified through discussions with the PCA. The discussions initially focused on prioritized materials, but led to the identification of "emerging material" alternative fuels, either in use or being investigated by the cement plants. The topics of discussion expanded as the telephone interviews progressed, including areas such as cement companies' business approach towards alternative fuels (e.g., some cement companies have a general policy that their cement plants do not accept hazardous waste) and corporate-wide as well as plant-specific issues and policies. In some cases follow-up calls were made to specific cement plant contacts to obtain additional information concerning issues that arose in other interviews or to obtain additional cement plant contacts to discuss the use of, or investigation of, emerging materials.

Cement plant contacts also identified state or local regulatory agency contacts responsible for permitting for their plants and other regulatory agency contacts (e.g., regulatory agencies responsible for management of state scrap tire management programs or programs to support beneficial use of materials). Cement plant contacts and regulatory agency contacts identified suppliers of alternative fuels, including contacts at the cement companies' wholly-owned subsidiaries responsible for materials sourcing and also independent alternative fuel suppliers.

SSP also conducted research into specific regulatory issues concerning alternative fuels (e.g., the regulatory status of CSOS and ASR) and conducted meetings with SSP counterparts for other Industry Sectors to obtain additional perspective on sector-specific issues.

3.1.4 Alternative Raw Materials Methodology

The methodology for alternative raw materials was similar to that for alternative fuels except that specific third-party materials suppliers were not identified by the cement plant contacts. Therefore, no third-party suppliers were interviewed. The wholly-owned subsidiaries responsible for alternative fuels material sourcing for cement plants also perform sourcing for alternative raw materials.

3.2 Criteria Application and Prioritization Results

The *Preliminary Prioritization of Beneficial Use Materials for Market Analysis* prepared in January 2006 provided an initial prioritization of the beneficial use materials for further analysis. *Portland Cement Association Briefing Materials* were prepared in January 2007,

DRAFT
US EPA ARCHIVE DOCUMENT

and the materials prioritization process and preliminary selection of four materials was discussed with the principal PCA contact at a meeting in February 2007. The selection of four materials for development of case studies were reviewed and confirmed by PCA's E&E Committee through an informal working group formed in June 2007 of PCA E&E Committee members identified by the principal PCA Contact. The preliminary prioritization analysis was prepared and discussed with the members of the PCA E&E Committee. From the preliminary analysis and subsequent discussions, spent foundry sand, steel slag, scrap paper/wood, C&D debris, and refinery spent catalyst and CSOS were selected for further analysis in this report. Application of the prioritization criteria and selection of materials is described further in this section.

3.2.1 Spent Foundry Sand

Spent foundry sand was selected as a material for further analysis based on the relatively large amount of this material generated and the relatively low amount used as raw material in cement clinker production. The industry consortium, Foundry Industry Recycling Starts Today (FIRST), notes that 6 to 10 million tons of spent foundry sand are discarded annually and are available to be recycled.[20] As shown in Table 5, the American Foundry Society reported in their 2007 survey that almost 50 percent of the spent foundry sand generated is used as construction fill; use in cement production (a subset of the "other" category in the survey data) is relatively low, and use as landfill cover (a category not separately reported by the AFS) is relatively high. An objective of this study is to provide insight into utilization trends for spent foundry sand.

Table 6: Beneficial Reuses of Spent Foundry Sands According to American Foundry Society Bench Marking Survey[21]

Beneficial Use Application	Quantity Beneficially Used (Tons) / Percent	
Construction fill[b]	1,140,914	43.13%
Concrete	303,531	11.47%
Not specified/Other	292,928	11.07%
Road construction	144,288	5.45%
Top soil mix/horticulture	220,949	8.35%
Reuse at another foundry[c]	48,426	1.83%
Asphalt	494,390	18.69%
Total:	**2,645,427**[d]	100.00%

a. Based on 244 total respondents, or a 24 percent completion rate. Survey respondents had the option of selecting more than one beneficial use application. Beneficial use quantities have been extrapolated to reflect beneficial use in the entire metal casting industry.
b. Construction fill includes both structural fill and flowable fill.
c. Spent foundry sand is transferred from one foundry to another for use in on-site construction projects or other application.
d. AFS excludes landfill cover as a beneficial use application from the total beneficial use quantity (2,645,427 tons).

3.2.2 Steel Slag

Steel slag was selected as a material for further analysis based on the relatively large amount of this material generated and recent trends concerning use as a raw material in cement clinker production. In 2006, iron and steel slag sales in the U.S. totaled 20.3

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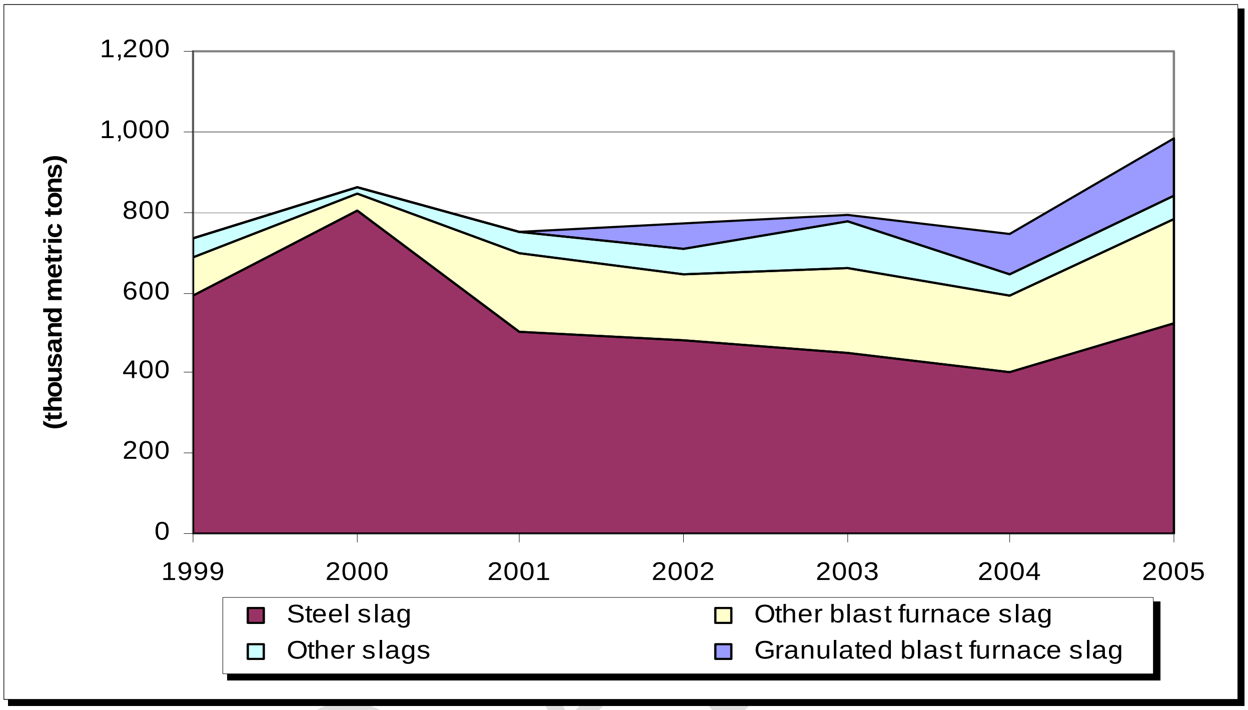
million metric tons.[22] As shown in Figure 1[23], use of steel slag in cement clinker production peaked in 2000 and then declined, showing a slight increase from 2004 to 2005. An objective of this study is to provide insight into utilization trends for steel slag.

Figure 1. Utilization of Iron and Steel Sector Slag in Cement Clinker Production in the U.S. (1999-2005)



3.2.3 Scrap paper/wood and C&D debris

Scrap paper and wood and C&D debris were selected as general material categories for further analysis specifically to provide a focus on C&D debris. An objective of this report is to provide insight into the potential for use of C&D debris and also scrap paper/wood in cement clinker production. The February 2008 *Gulf Coast Region Beneficial Reuse Report* specifically focused on the potential for beneficial reuse of C&D debris generated when tropical storms strike the Gulf Coast Region. In 2002, 35.7 MMT of C&D debris wood was generated, with 29.2 MMT potentially available for recovery; but, possibly only 2.7 MMT was being actually recovered in new construction.[24] Significantly larger amounts of C&D debris wood are generated during tropical storm events. C&D debris (i.e., C&D debris containing wood) could be used as an alternative fuel in cement production. While some utilization of scrap paper/wood has been reported, cement plants have not historically used significant quantities of alternative fuels derived from C&D debris in cement clinker production.

One cement plant contact[25] reported that the plant was offered C&D debris generated from Hurricanes Katrina and Rita. However, the C&D debris (containing wood) was so commingled with other types of C&D debris that the cement plant decided that the material could not be feasibly processed into alternative fuel. Therefore they declined to accept the material. Another cement plant contact[26] reported that the plant uses wood, including some segregated wood material from C&D debris yards. This wood material is preprocessed by the C&D debris yard prior to being sent to the cement plant. The cement

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plant itself does not have equipment to process C&D debris. No other cement plant contacts indicated that the cement plants were using wood or other alternative fuels generated from C&D debris.

3.2.4 Refinery spent catalyst and clarified slurry oil sediments

Refinery spent catalyst and clarified slurry oil sediment (CSOS) were developed and selected as materials for further analysis specifically to provide a focus on CSOS, a RCRA listed hazardous waste generated by petroleum refineries. Clarified slurry oil (CSO) is generated from fluidized catalytic crackers (FCCs) at petroleum refineries. Some of the FCC catalyst is entrained in the CSO. These fines settle out of the CSO as solids, and these solids periodically need to be removed from the CSO storage tanks. These solids, referred to as CSOS, are listed as RCRA hazardous waste (waste code K170). A single petroleum refinery may generate on the order of one million pounds (500 short tons) of CSOS per year from CSO tank cleanouts (but the yearly generation rates can be highly variable and may be significantly higher than that quantity in any given year, depending on tank cleanout schedules); a substantial portion of this CSOS is generated in Texas and elsewhere in the Gulf Coast Region, because of the high concentration of petroleum refineries in the region.[27] The calorific value of CSOS varies depending upon how it is generated and processed. Refineries can process the CSOS to remove more, or less, of the oil contained in it. One refinery contact [28] reported that after processing the CSOS by centrifuge to remove oil, the calorific value of the CSOS is on the order of 8,000 to 9,000 BTU per pound; though, as noted above, it can vary above or below that depending on how it is generated or processed prior to shipment.

Research conducted for this report identified several cement kilns that are using CSOS as an alternative fuel, however use of this material is limited to the relatively small number of cement kilns (18) that have RCRA hazardous waste combustor permits, and therefore this material was categorized as a “challenge material” for this report. An objective of this report is to assess regulatory, technical, and cost barriers associated with generation of CSOS and use as an alternative fuel in cement clinker production.

As shown in Tables 6 and 7, generation and management of K170 waste varies by year and the amount of K170 waste managed by offsite energy recovery decreased from 2001 to 2005 (the most recent data available through the EPA hazardous waste reporting system). In 2005 only 24 tons of K170 waste was reported as being managed through offsite energy recovery at a cement kiln, while approximately 16,000 tons of K170 waste was managed through other methods. Five cement plants accepted K170 waste for energy recovery in 2001, and only one in 2003 and in 2005.

Note that the amount of CSOS that is generated and managed on site at refineries is not reported into the EPA hazardous waste reporting system. Refinery contacts [29] indicated that refineries frequently manage their CSOS on site under an available regulatory exclusion, despite the fact that on site management may be more expensive, in part to enable the refineries to avoid having to classify the materials as hazardous waste when shipped offsite. Therefore, the data in Tables 7 and 8 do not reflect the amount of CSOS that is actually available for beneficial use in any given year. Table 9[30] contains API data with a summary of K170 waste generation that includes only hazardous waste streams with

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the primary waste code of K170.[f] Some hazardous wastes can be assigned more than one RCRA hazardous waste code.

Table 7: Annual Generation and Management Methods of K170 Hazardous Waste (Clarified Slurry Oil Sediments)

Reporting Year	Number Generators K170 Waste	Tons of K170 Waste Managed through Energy Recovery	Tons of K170 Waste Managed through Other Methods	Total Tons of K170 Waste Managed
2001	43	5,374	25,535	30,909
2003	37	2,080	30,327	32,408
2005	46	24	16,352	16,376

Source: EPA Hazardous Waste Reporting System, 2008

Table 8: Annual Disposition of K170 Waste (CSOS) Managed through Energy Recovery

EPA ID	Waste Management Facility Name	K170 Waste Quantity (in tons) Managed Through Energy Recovery		
		2001	2003	2005
ARD981057870	Rineco Chemical Industries	1.2		
IND005081542	**ESSROC Cement Corp**	48.5		
KSD980633259	**Systech Environmental**	2,445.3		
MOD054018288	**Continental Cement Co LLC**	1,130.8		24.31
MOD981127319	**Lone Star Industries Inc**	131.0		
SCD003351699	**Giant Cement Company**		698.1	
TXD007349327	**TXI Operations LP**	1,194.0		
TXD981053770	Duratherm Inc		1,382.1	
FCCANADA3	Not Available	423.3		
	Total	**5,374**	**2,080**	**24**

Source: EPA Hazardous Waste Reporting System, 2008

Table 9: NAICS 32411 GM Forms, Management Code H050 and H061, Outlier and Mixed Waste Excluded

Reporting Year	Number of Generators of K170 Waste	Tons of K170 Waste Managed through Energy Recovery	Tons of K170 Waste Managed through Other Methods	Total Tons of K170 Waste Managed or Shipped
2001	**37**	**9,734**	**14,330**	**24,064**
2003	**26**	**878**	**3,248**	**4,126**
2005	**35**	**3,284**	**5,954**	**9,238**

Source: API (2008)[31]

3.2.5 Other Prioritization List Materials

The other five materials on the prioritization list were eliminated from initial material prioritization based on various criteria. No cement kilns were identified as using either animal meal or spent aluminum potliners; these materials were eliminated from further

[f] This table excludes a single waste stream of 175,013 tons reported in 2005 because it is an outlier related to soil remediation activities. The waste stream was described as "haz waste soils and sludges generated during RFI remedy" which was disposed in a landfill. According to the facility, this was a one-time event.

consideration based on the anticipated lack of data concerning beneficial use. Similarly, the market for waste/off-specification paint is not well-developed; research conducted for this report identified one cement plant using latex paint solids as a raw material for clinker production. The cement plant mixes cement kiln dust with the latex paint solids to facilitate the introduction of CKD into the kiln; the CKD/latex paint solids mixture is fed into kiln. This material is discussed as an "emerging material."

Non-hazardous used oil, coal combustion products, and scrap tires were not initially selected for further analysis because the infrastructure for collection and utilization of these materials is already well-developed, and because utilization of these materials in cement clinker production is already relatively high. Scrap tires were added back to the report scope for further analysis because many cement sector contacts identified emerging issues related to scrap tire management.[32]

Non-Hazardous Used Oils

In 2006, according to the PCA U.S. and Canadian Labor-Energy Input Survey, 65 of 97 cement plants included in the survey reported using alternative waste fuels (with some plants reporting use of more than one type of alternative waste fuel). These included 48 plants using scrap tires and 16 plants using non-hazardous waste oil.[33] Non-hazardous waste oil includes used motor oil collected from commercial automobile service establishments, and used oils generated by industrial manufacturing facilities and other types of facilities.

Several cement plant contacts reported utilization of used (non-hazardous) oil as an alternative fuel. No trends data are available for used oil; however the overall amount of used oil and other liquid streams being used as alternative fuel in cement kilns, as reported by the USGS is trending up.[g] Liquid alternative fuel utilization in cement production was approximately 745 million liters in 1993, approximately 999 million liters in 2004, and approximately 1,470 million liters in 2005, the latest year for which the USGS has reported data.[34] Note that the category of "liquid waste" as reported by the USGS includes used oils, off-spec oils, liquid hazardous waste, and other liquid alternative fuels. USGS reported that approximately 1 billion liters (approximately 900,000 metric tons) of used oil and other liquids were used as alternative fuels in cement kilns in 2004, while approximately 1.5 billion liters of used oil and other liquids were used in cement kilns in 2005.

Coal Combustion Products

Figure 2[35] illustrates the amounts of coal combustion products used in clinker production and cement production. National data from PCA for 2006 indicated that, of the 115 operating Portland cement plants reporting in the PCA report, more than 50 plants used fly ash or bottom ash generated from electric power plants.[36] This includes use of coal combustion products as a raw material in clinker production and use of coal combustion products as additives in cement production. The scope of this report includes coal

[g] Note: The terminology used in this section reflects the terminology used in the U.S. Geological Survey Minerals Commodity Yearbook, Cement (2006).

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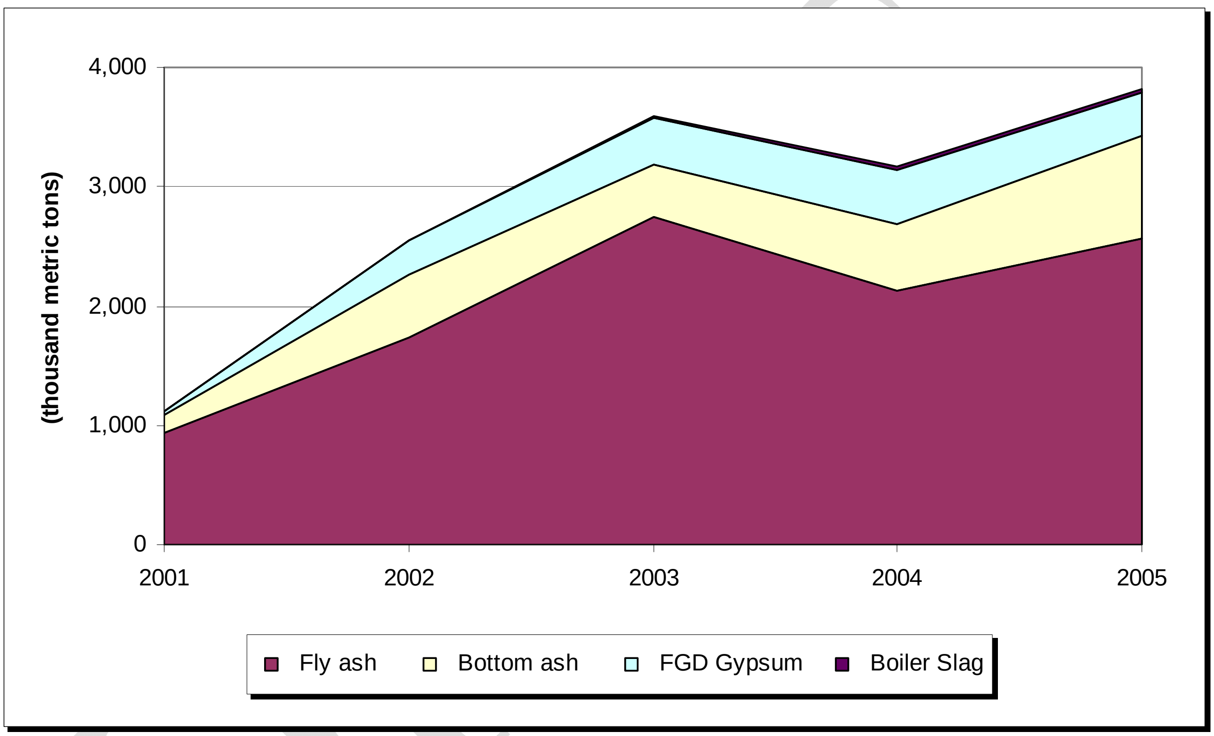
combustion products used as a raw material in the cement kiln, but not coal combustion products used as additives in cement production.

In 2006, 124.8 million metric tons of coal combustion products were produced.[37] The amount of bottom ash and fly ash being beneficially reused in cement production has actually been increasing faster than the amount of cement clinker produced. In 2005, according to USGS data, cement plants used 4.2 million metric tons of coal combustion products as raw materials in producing clinker, including fly ash, other ash, and other coal combustion slags. [38]

Figure 2. Coal Combustion Products Used in Producing Clinker and Portland Cement



Note: Includes both raw materials fed into kilns and additives used in producing cement

Scrap Tires

RMA estimates that about 299 million scrap tires were generated in 2005, representing an 8-fold increase in the percentage of scrap tires going into markets annually since 1990,[39] Approximately 400,000 metric tons of scrap tires were used as alternative fuel in cement kilns in 2005, according to USGS data. Table 8 illustrates the amount of scrap tires used as alternative fuel in cement production.[40]

Table 10: Scrap Tires Used as Alternative Fuels in Cement Production			
	Metric Tons of Scrap Tires Used		
Year	**Total**	**Dry Kiln Plants Utilizing Scrap Tires (Out of total Dry Kiln Plants)**	**Wet Kiln Plants Utilizing Scrap Tires (Out of Total Wet Kiln Plants)**
2002	304,000	210,000 (80)	94,000 (27)

2003	387,000	291,000 (80)	97,000 (26)
2004	377,000	312,000 (80)	66,000 (24)
2005	405,000	315,000 (80)	90,000 (23)

The use of scrap tires by cement plants has increased dramatically over recent decades: in 1991 nine plants in the U.S. were using scrap tires and by 2001, 39 plants were using scrap tires for fuel.[41] By 2005, 58 million scrap tires were used in 47 plants in the U.S. [42] In addition to calorific value, scrap tires also provide raw material content to the cement kiln. Iron is a necessary ingredient for clinker manufacturing. When scrap tires are used as an alternative fuel, approximately 250 kg Fe per ton of scrap tires is recovered, reducing the quantity of iron required from mined mineral sources. [43]

Figure 3 illustrates the overall trend in use of scrap tires as tire-derived fuel for energy recovery, including use in cement kilns. [44] Figure 4 illustrates that in 2005 approximately 52 percent of scrap tires generated nationwide were used in energy recovery (including in cement kilns and in other energy recovery processes), and approximately 14 percent were disposed of in landfills.[45] Cement kilns made up 38 percent of the tire-derived fuel market in 2005, according to data published by RMA.[46]

Figure 3. Scrap Tires as Tire-Derived Fuel

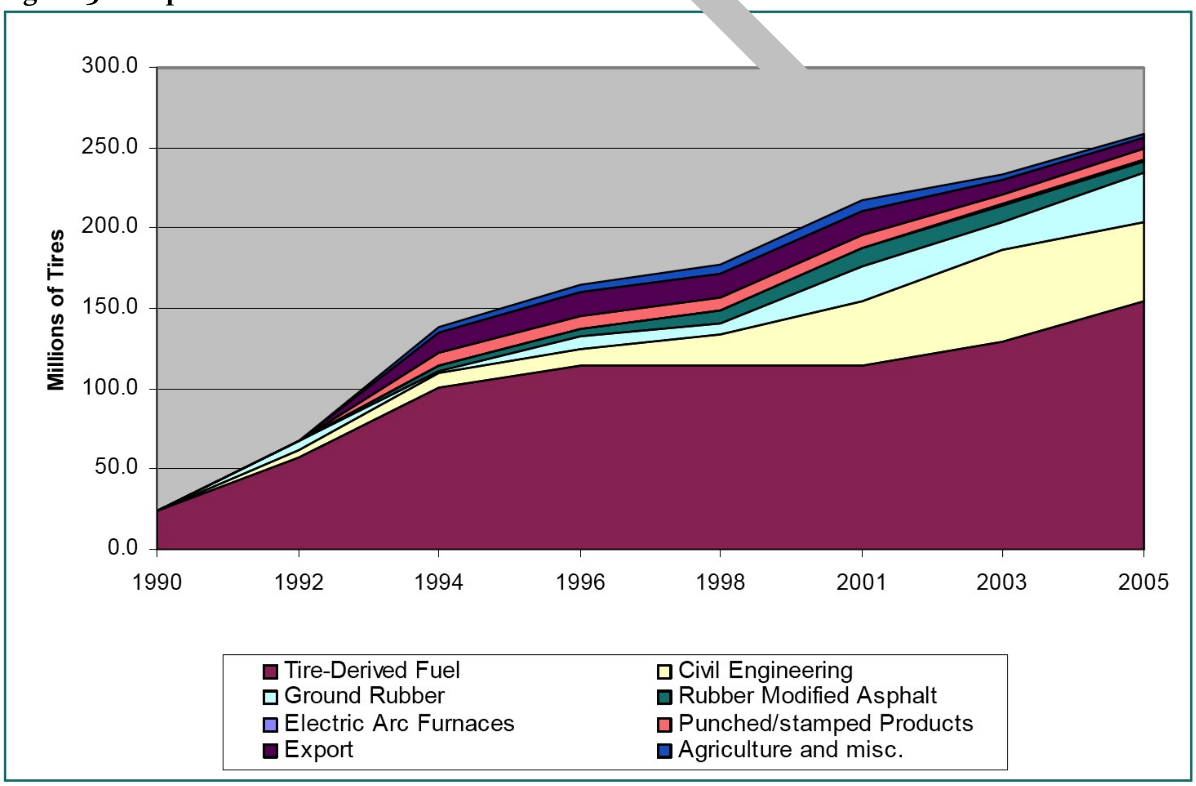


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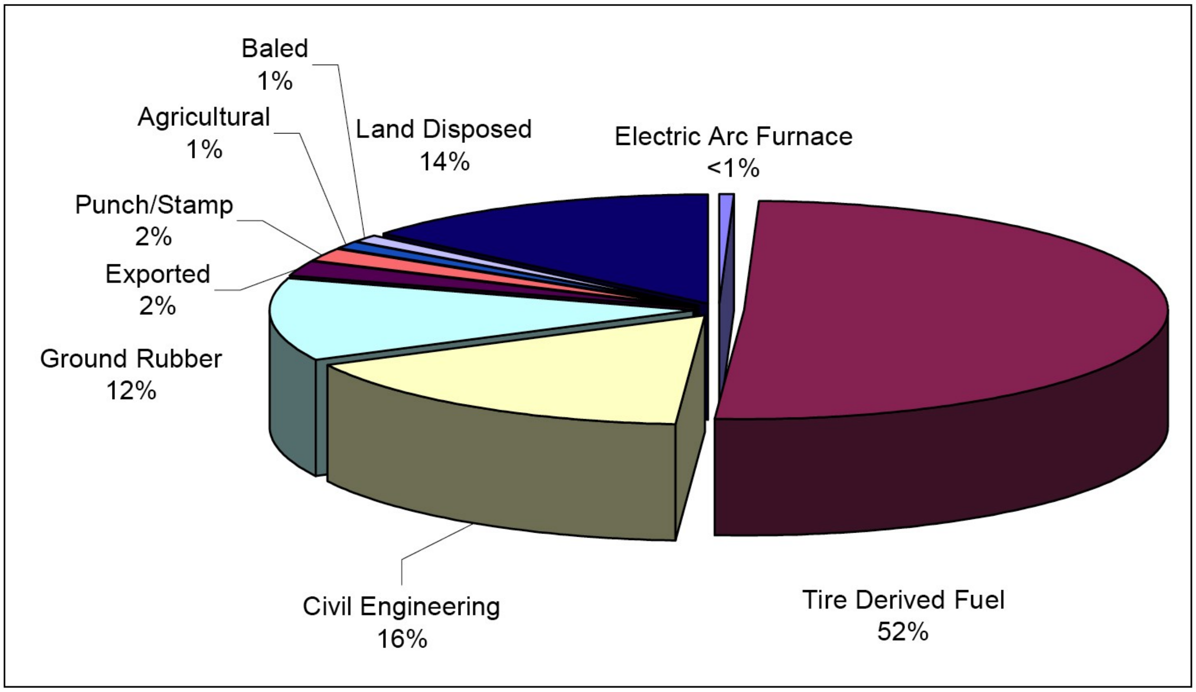
Figure 4. Use of Scrap Tires in 2005



3.3 Emerging Materials

Interviews with cement sector contacts and state and local regulatory agency contacts identified additional study materials for development of "emerging material" case studies. Issues identified for these emerging materials include limitations on supply, technical and logistics limitations, effects on plant air emissions, cost and regulatory issues related to landfill disposal, and other items identified by contacts.

3.3.1 Wastewater treatment sludge (biosolids)

Biosolids are generated primarily from municipal wastewater treatment plants (WWTP). In 40 CFR Part 503, EPA categorized biosolids as Class A or B, depending on the level of pathogenic organisms in the material. The classification of biosolids affects the feasibility of a cement plant to use the biosolids. Cement kilns may be limited to using only Class A biosolids both because of regulatory issues and materials handling issues. 40 CFR Part 503 requires specific treatment processes and treatment conditions that must be met for both A or B classifications. Class A biosolids contain minute levels of pathogens. To achieve Class A certification, biosolids must undergo heating, composting, digestion, or increased pH that reduces pathogens to below detectable levels. "Class B" biosolids "may have low levels of pathogens which rapidly die-off when applied to soils, essentially becoming pathogen-free within a short period following application." [47] Class B biosolids have less stringent standards for treatment. After treatment to reduce moisture content, the calorific value of biosolids may range from 7,000-8,000 BTUs per pound.

The North East Biosolids and Residuals Association (NEBRA) estimates that 16,583 wastewater treatment facilities in the U.S. generate 7,180,000 dry short tons of biosolids that can be beneficially reused or disposed.[48] NEBRA conducted a survey of water treatment facilities and consulted existing data from sources such as EPA. The resulting

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report estimates that about 3,300 of the largest facilities generate 92 percent of the total quantity of biosolids produced in the U.S.

Several contacts reported that their companies have recognized that there is a large and continuously-generated supply of this material and that in many jurisdictions the material is accumulating on the POTW sites rather than being used. These contacts also indicated that their company's investigation of biosolids as an alternative fuel is a proprietary issue for the company. Details of their investigations were therefore not disclosed.

Most biosolids generated nationwide are applied to land, and are not incinerated or burned for energy recovery in cement kilns. Some municipal wastewater treatment system operators have developed biosolids management programs that focus on land application rather than energy recovery. For example, The Sanitation Districts of Los Angeles County (CSDLAC) system, which operates the Joint Water Pollution Control Plant (JWPCP,) includes seven POTWs linked by a common sewer system serving 5 million people in Los Angeles County and treating 500 million gallons per day of wastewater. Because of the tremendous volume served by JWPCP, the County developed various ways to manage biosolids in the last several years. The four biosolids management practices include: land application, which accounts for 76 percent of the system's biosolids; injection into a cement kiln, which accounts for another 12 percent of the biosolids and helps reduce the levels of nitrogen oxide (NO_x) air emissions from the cement making process; composting, which has been moved off site to two privately operated facilities; and landfilling, which accounts for approximately 12 percent of the system's biosolids.[49]

3.3.2 Plastics

Several cement plant contacts reported recently establishing use of plastics as an alternative fuel[50] and others reported that they are investigating the feasibility of using plastics.[51] In 2006, 29.5 million tons of plastics were generated from MSW and other sources.[52] These materials included either plastic scrap from manufacturing processes or post-consumer plastics generated from MSW recycling programs. Cement plant contacts and regulatory agency contacts indicated that the principal issues associated with the use of plastics include identifying (generating) an adequate long-term supply of the material and ensuring that the material is "clean" and not commingled with the general MSW stream or with other non-plastic materials. The material must be adequately segregated from the general solid waste stream to facilitate material handling and adequately segregated from chlorinated plastics to ensure that chlorinated plastics are not included in the feed stream. Cement kilns need to limit the amount of chlorine feed to the kiln to maintain clinker quality. [53] Cement sector contacts reported that plastics, as generated by suppliers, have a calorific value similar to that of coal (approximately 12,000 BTU per pound).

3.3.3 Automobile shredder residue (ASR)

Automobile shredder residue was identified as an emerging material by the PCA E&E Committee Alternative Fuels and Raw Materials (AFR) subcommittee. Automobile shredder residue (ASR) contains the plastic and other non-metallic materials left after scrap automobiles are shredded, and can have a calorific value on the order of 10,000 BTU per pound after processing to remove residual metals and other non-combustible

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DRAFT

materials. According to the Argonne National Laboratory, as of 2003, U.S. auto shredders generated about 5 million tons of ASR annually.[54] Because of the lack of a cost-effective technology to recycle ASR, it is mostly landfilled; smaller amounts are incinerated. Scrap Magazine has estimated ASR generation at about 5.4 million tons per year.[55] This is consistent with Steel Recycling Institute automotive recycling rates data. These data show that automotive recycling rates have been relatively consistent from 2003 through 2006.[56]

The PCA E&E subcommittee is investigating the potential use of this material as an alternate fuel in cement kilns. The PCA E&E subcommittee contact indicated that the calorific value of ASR after it is processed is similar to the calorific value of coal, but that because of Toxic Substances Control Act (TSCA) regulations that specifically categorize ASR as a "PCB Waste" most of the ASR generated is landfilled rather than burned for energy recovery.[57] A recent study by the California Department of Toxic Substances Control (DTSC) included test data for ASR generated in California. The test results showed that the PCB content of disposed ASR generated by several California facilities averaged total PCB levels ranging from 16 to 82 ppm.[58] The California DTSC report indicated that modification of the TSCA classification definitions applicable to ASR may be needed to facilitate use of ASR as an alternative fuel in cement kilns. ASR can also contain copper and mercury (from mercury switches contained in scrap automobiles) and therefore ASR has the potential to affect air emissions from the cement kiln. Mercury can be emitted through the cement kiln stack, and copper, in combination with chlorine contained in cement kiln raw materials and fuels, can contribute to the formation of PCDD/PCDF emissions from the cement kiln stack.

Argonne National Laboratory recently developed a "froth flotation" technology to separate ASR into higher value high-purity plastics. The technology is being evaluated by a consortium of automobile manufacturers.[59] A full-scale demonstration project was conducted in Europe.[60, 61] Such treatment technologies may be a potential competitor to use of ASR as an alternative fuel in cement kilns. Boughton (2006) reported that automobile recyclers are also working on developing and applying technologies to improve the separation of materials in ASR and to improve its combustion characteristics with respect to cement kiln operation and environmental impacts. These include application of existing ASR density separation technologies to separate fine material (<1.2 cm) from the ASR. This can reduce effects of the use of ASR on CKD characteristics and on air emissions. Boughton (2006) also reported that ASR has raw material value in addition to its fuel value, and noted that ASR contains silicates, calcium, aluminum, and iron.[62]

3.3.4 Carpet Scrap

One cement plant contact reported using scrap carpet generated from residential and commercial building carpet installers[63] The Carpet America Recovery Effort (CARE) is an organization formed to promote diversion of carpet scrap from landfills to beneficial uses. The CARE 2007 Annual Report provides an overview of the collection and disposition of carpet scrap.[64] In 2007, approximately 2.4 million pounds (1,200 short tons) of carpet scrap were reported utilized as alternative fuel in cement kilns, representing approximately one percent of the total amount of material collected and diverted from landfill disposal. The total amount of material diverted from landfill disposal in 2007

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(approximately 296 million pounds) represented approximately 5.3 percent of the approximately 5,590 million pounds of material generated.[65]

Recycling of scrap carpet is technically challenging and energy intensive, because carpet is by design made to be highly durable.[66] One cement sector contact reported using scrap carpet as an alternative fuel, and reported that the material is difficult to process.[67] Scrap carpet may also be difficult to collect because the material may be generated by a large number of relatively small and geographically dispersed carpet installers. Therefore this material is not widely used in cement production. Realff (2005) estimated that approximately 2 million metric tons of scrap carpet are disposed of in landfills, and that the rate of disposal is expected to increase at 3 percent per annum over the next decade.

Scrap carpet provides both energy and raw material value to cement kilns. The lower heating value (LHV) of scrap carpet residues depends on the carpet material: nylon and polypropylene carpet residues have LHVs of approximately 17 and 28 GJ per metric ton, respectively (7,300 – 12,000 BTU per pound). In addition to the calorific value, scrap carpet also has a high fraction of calcium carbonate which would substitute for mined calcium carbonate and be incorporated directly into the clinker.[68]

3.3.5 Other Materials

Cement plant contacts reported several other types of AFR as being used in cement kilns. These include latex paint solids,[69] sandblast grit, storm drain solids (generated from municipal storm drain cleanouts)[70], and agricultural byproducts (e.g., almond shells, rice hulls).[71] Sufficient information is not available for these materials to develop case studies.

4. Case Study Summations

This section provides a summary of the case studies and overarching issues related to the beneficial use of AFR.

4.1 Alternative Fuels

4.1.1 Cost Issues

Cost is an overarching issue in selection of alternative fuels in cement production. One cement plant contact summed up the cost analysis methodology for alternative fuels in a simple manner: "Is it cheaper than coal?" As shown in Table 9, the price of coal varies depending upon the region of the country, in part because of transportation costs. For example, as of 2006, coal prices were on the order of $32 per short ton in Texas and $85 per short ton in Florida. Coal costs have been changing relatively rapidly through 2008 due to increasing transportation fuel costs and other factors, as well as exhibiting significant volatility.

Another cement plant contact indicated that the company has an overall corporate policy to move away from using fossil fuels to the extent possible because fossil fuels are increasingly costly.[72] Cement plant contacts that operate wet kilns or long dry kiln reported that their plants pursue alternative fuels more aggressively than do more modern dry process preheater/precalciner. The wet kiln and long dry kiln technologies are not as energy efficient as more modern dry process preheater/precalciner kilns, and therefore the

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older technology kilns have more of a need to offset fuel costs to remain competitive with newer plants.[73] Alternative fuels suppliers [74] concurred that the operating costs for wet process and long dry kilns make use of alternative fuels more of a necessity.

Table 11. Cost of Coal in Select States (per short ton)	
State	**Price**
Alabama	$68.27
California	$57.63
Florida	$84.16
Illinois	$36.95
Kansas	$48.04
Missouri	$45.72
New York	$74.79
Texas	$32.65
Source: DOE, Energy Information Administration Note: The price of coal changes continually; these prices represent the cost of coal in 2006	

There are various aspects to the overall cost of alternative fuels, including the capital costs and operating costs of:

- Kiln and equipment upgrades;
- Performance testing;
- Alternative Fuel conditioning (preprocessing);
- Engineered fuel production;
- Material transportation;
- Continuous Emissions Monitoring Systems (CEMS);
  Sampling and testing materials; and
- Material acquisition.

Kiln and Equipment Upgrades

Cement plant contacts indicated different approaches to management of cost for use of alternative fuels. Some companies [75] have company-wide initiatives to invest in upgrades to kilns or to materials handling equipment to initiate use of alternative fuels, and the company also promotes pilot projects in which different company cement plants conduct studies of different alternative fuels (e.g., biosolids would be tested at one company plant, plastics would be tested at another company plant, and the test results would inform ongoing corporate initiatives). In other cement companies [76] each company cement plant operates in a more autonomous manner, with each company cement plant conducting its own initiatives and managing its own costs. In some cases these companies are less inclined to invest in kiln or equipment upgrades and are more inclined to only test different alternative fuels that can be handled using existing materials handling equipment and existing kiln configurations. Several cement plant contacts [77] reported that their plants recently spent several million dollars in cement kiln or equipment upgrades in order to accept alternative fuel. One cement plant [78] spent several million dollars to configure the kiln to accept whole tires after the cement plant's supply of chipped tires was interrupted; another plant [79] spent a similar amount to install material

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handling and air emission (dust) control equipment to enable use of wood (sawdust) as an alternative fuel.

Performance Testing

In addition to the cost of making modifications to the kiln or materials handling system, the cost of performance testing is another cost that must be incurred to establish use of alternative fuels in cement production. Performance testing is generally required by state air quality regulations, and performance tests are designed to determine that the cement kiln operation is in compliance with its air emissions permit conditions. One alternative fuels supplier[80] reported that conducting performance testing for a non-hazardous alternative fuel (e.g., biosolids) could cost on the order of $50,000 per kiln, and that for multi-kiln cement plants each kiln using the alternative fuel must be tested individually. Performance testing costs for an alternative fuel that is regulated as a hazardous waste (e.g., CSOS) could be on the order of $250,000 to $500,000 [81] depending upon the regulatory requirements in the jurisdiction where the cement plant is located.

Cement sector contacts and alternative fuels suppliers have identified performance testing and associated permitting costs as a cost barrier to increased use of alternative fuels. In general, according to state regulatory agency contacts, each alternative fuel introduced into the plant is subject to individual performance test and permitting requirements. However, if various alternative fuel materials are preprocessed into an "engineered fuel" that meets defined specifications for calorific value and other fuel quality parameters, the cement kiln (at least theoretically) should be subject to only one performance test for the engineered fuel, because the quality of the engineered fuel would not vary regardless of the alternative fuel materials it is made from. One alternative fuel supplier [82] reported that they had some difficulty convincing a state regulatory agency that the quality of the engineered fuel was a constant, even though the alternative fuel materials it is made from could vary. Both cement companies and alternative fuel suppliers are advocating a permitting system in which the specific air emissions from the cement kiln are permitted, but the permit does not explicitly identify specific alternative fuels that can and cannot be used. Therefore, a cement plant could use different alternative fuels based on available supply and other factors, without having to modify the permit each time a change is made, provided that the air emissions limits in the permit are not exceeded. This is referred to as a "flexible fuel concept" of permitting.

Continuous Emissions Monitoring Systems (CEMS)

Continuous Emissions Monitoring Systems (CEMS) continuously measures air emissions from the cement kiln stack. A CEMS may be required by state air emissions regulations or by air emissions permit conditions for the cement kiln, however, not all cement plants are required by regulation or by permit conditions to install and operate CEMS. A cement plant that does not have a CEMS and that is applying for the first time to use alternative fuels may be required to install a CEMS as a condition of the revised air emissions permit for the cement plant. This represents an added capital and operating cost for use of alternative fuels at cement plants that do not already have a CEMS installed.

AFR Conditioning (preprocessing) and Engineered Fuel Production

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Certain AFRs (e.g., scrap carpet) may be required to be preprocessed for the purposes of size reduction, removal of undesirable constituents (e.g., for scrap carpet, nails and other metal components need to be removed). Preprocessing of alternative fuel materials prior to use in cement production represents an added cost over that for use of conventional fuels. Preparation of "engineered fuel" (i.e., preprocessed alternative fuel materials of a consistent quality from a variety of alternative fuel materials) also represents an added cost; however, preparation of engineered fuel has an advantage in promoting stability of kiln operation.

Material Transportation Cost

Material transportation cost is also an important factor in utilization of alternative fuels. The cost of transporting the material itself can render the alternative fuel to be not cost effective. One alternative fuels supplier [83] reported that their processing plant could supply cement plants located up to several hundred miles from their plant, but that supplying cement plants located 400 miles from their plant was not cost effective. The effect of materials transportation costs depends in part on the value of the material being transported, and also in part on local landfill disposal costs. One cement plant contact [84] reported that the alternative fuels sourcing initiative is targeting alternative fuel material generators within a 50 mile radius of the cement plant site. Note that regulated hazardous wastes (including waste solvents) may be transported hundreds or thousands of miles from the location of the generator to a cement kiln or other facility. One refinery operator, for example, reported that their U.S. refineries have exported CSOS to Canada for treatment and disposal.

Material Acquisition Cost

Another important issue is material acquisition cost; is the material a "waste" that the cement kilns charge the supplier a fee to accept, or is the material a "raw material" or "fuel" that the cement kiln pays the supplier to provide. CSOS, specifically, is currently regulated as a hazardous waste and the cement plants have generally charged the petroleum refineries a fee to accept CSOS for "hazardous waste treatment and disposal," and petroleum refiners have historically paid cement plants to accept the material for disposal. According to refinery contacts, CSOS was initially proposed for consideration as a hazardous waste because the material was being landfilled. Petroleum refiners are now promoting CSOS as an alternative fuel and raw material with a calorific value and also high silica and alumina (i.e., cement kiln raw material) content that cement plants should purchase from the petroleum refineries in the same manner as cement plants purchase other fuels and raw materials of similar value; however, the material remains regulated as a hazardous waste under existing regulations. Disposition of this issue may depend in part on the specific language of any decision to change the regulatory characterization of CSOS to remove the designation of the material as a hazardous waste.

4.1.2 Technical Issues

There are various technical issues related to use of alternative fuels, including materials processing and handling and control of air emissions. Differences in kiln technology and configuration and materials handling systems mean that not every cement kiln can use

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every type of alternative fuel. Materials handling systems designed for one alternative fuel may not be easily convertible to another type of alternative fuel. Examples of technical issues identified in the study include the following:

Scrap Tires and Kiln Design

Some cement kiln designs are not conducive to using whole scrap tires, and may be limited to use of chipped tires. This is specific to the individual cement kiln design. One cement plant contact, using a preheater/precalciner-type kiln, reported that the plant [85] conducted performance testing to introduce whole tires into the kiln. The testing showed that introduction of whole tires into the kiln riser resulted in the tire belts not moving into the kiln; and that introduction of whole tires lower down in the kiln resulted in insufficient oxygen for tire combustion. Despite spending several hundred thousand dollars in conducting the performance tests, the plant was unable to solve the technical issues. Chipping tires prior to introduction was not deemed to be a cost effective solution. The plant is now investigating sources of industrial rubber scrap, but is not planning on retesting whole scrap tires.

Introduction of scrap tires into cement kilns can reduce cement kiln NO_x emissions. One cement plant contact [86] reported that use of scrap tires in the cement kiln is actually incorporated as permit condition of the facility air permit for this reason. However, state regulatory agencies could not mandate the use of scrap tires in all cement kilns as air emissions control strategy, because some kilns cannot accept scrap tires.

Materials Handling Systems

Several cement plant contacts indicated that one technical issue with respect to materials handling is that their plant's materials handling system cannot handle two types of materials simultaneously (this is an issue both for alternative fuels and alternative raw materials). Therefore for these plants a decision to apply the materials handling system to a specific alternative fuel (e.g., wood) is effectively a decision to forego use of a different alternative fuel (e.g., plastics). Materials handling systems can be designed to accommodate multiple types of materials, however there is an increased capital cost involved in such flexible design. Also, different materials can be preprocessed to similar characteristics (e.g., size reduced) such that a single materials handling system can handle the different materials, however preprocessing the materials also involves a higher operating cost than using the materials as generated.

Also, C&D debris must be pre-sorted, processed, and pre-sized to be used in cement kilns. One cement plant contact with experience with wood generated from C&D debris [87] reported that one issue encountered was the difficulty in separating the gypsum wallboard and other non-combustible materials in the C&D debris from the wood. Only one cement plant contacted [88] reported that the plant is currently using wood generated from a C&D debris yard.

Preprocessing of Refinery Spent Catalyst and Other Materials

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Refineries generate a variety of materials (spent sandblasting media, granular catalyst beads, support balls, catalyst fines filter cake) that can be commingled to achieve a mixture that can be easily managed by conveyor belt systems. In addition, commingling enables blending of the chemical properties so that the material becomes more uniform chemically and physically. Stockpiling materials over several months promotes uniformity and large enough quantity to facilitate the variety of catalysts and other materials generated by the refinery.

4.1.3 Regulatory Issues

Cement plant contacts, regulatory agency contacts, and materials supplier contacts identified specific regulatory issues related to alternative fuels included in this study.

In general, cement kilns operate under a set of permit conditions established by the plant's Clean Air Act Title V Operating Permit. The permit conditions limit the emissions of criteria air pollutants (e.g., nitrogen oxides (NO_x), carbon monoxide (CO), sulfur dioxide (SO_2), and particulate matter (PM)) and hazardous air pollutants. Cement plants that do not burn hazardous waste are subject to MACT Standard 40 CFR 63 Subpart LLL, which regulates emissions of chlorinated dioxins/furans, particulate matter, mercury, and total hydrocarbons. A separate MACT Standard for hazardous waste combustors (HWCs) applies to cement kilns that burn hazardous waste. In general, cement kilns operate under Title V Operating Permits issued by state regulatory agencies implementing Clean Air Act programs.

Cement plants using alternative fuels may also need to obtain other state permits, including solid waste facility permits, depending upon the specific state regulations and the type of alternative fuel being used. Cement kilns using biosolids or scrap tires, for example, may be subject to state regulatory requirements to obtain a "solid waste facility" operating permit. Other states, e.g., South Carolina, exempt "recycling" facilities (including facilities burning alternative fuels for energy recovery) from state solid waste facility permit requirements.

Cement plant contacts and regulatory agency contacts provided information concerning how the environmental permitting process is implemented for cement plants testing the use of new alternative fuels. In general, cement plants are required to obtain construction permits to establish the use of a new alternative fuel, in part because modifications to the materials handling system involving capital expenditure need to be permitted.[89] Short-term testing of new alternative fuels for which no capital expenditure is required may be conducted under the MACT Standard without a permit modification. In this case there would be a limit on the duration of the test and the amount of alternative fuel material that could be tested. Cement kilns are generally required to conduct air emissions performance testing to demonstrate that use of the alternative fuel would not result in an increase in the air emissions from the cement plant. Cement kilns that have CEMS can use these systems to monitor emissions during performance tests; cement kilns that do not have CEMS would need to conduct physical testing of their emissions. If an increase in air emissions would result then other regulatory standards would be triggered. It is not necessarily the case, however, that every new use of alternative fuel or every modification needs to be permitted. State agencies [90] have developed guidance documents that outline what proposed activities would require permits.

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Cement kilns conducting tests of new alternative fuels are generally granted a short-term permit by the regulatory agency to conduct performance testing both to test the technical performance and feasibility of using the alternative fuel. Several regulatory agencies [91] reported that cement plants applied for and were granted permits to test alternative fuels [and also raw materials] that ended up not being used because of technical difficulties (as opposed to issues concerning the cement plant air emissions).

Scrap tires, CSOS, ASR, and biosolids each have unique regulatory issues with respect to permitting, performance testing, and public perception when used as alternative fuels. Scrap paper/wood and plastics are generally regulated as non-hazardous (municipal solid) wastes and have fewer specific regulatory issues; however, permit modifications and performance testing are generally required for cement plants to initiate use of these materials as alternate fuels. In general, construction or modification of materials handling systems or air emission control systems or kiln modifications made to accommodate non-hazardous waste alternative fuels would necessitate permit revisions.

Performance testing and permitting requirements for hazardous waste alternative fuels (e.g., CSOS) would be significantly more expensive and time-consuming than for non-hazardous waste alternative fuels, because hazardous waste combustion is subject to the Hazardous Waste Combustor MACT Standards and other standards that specify the permit and performance testing requirements. These requirements would generally include preparation of a risk assessment in addition to performance testing.

CSOS

CSOS is a listed hazardous waste (RCRA Waste Code K170) and therefore only cement kilns that are permitted to accept hazardous waste can accept this material for use as an alternative fuel (only 18 cement plants have hazardous waste combustor permits). Therefore the utilization of this material is constrained first by the logistics and geographic relationship of the CSOS generators (petroleum refineries) and the permitted cement kilns, and second by the need to handle the material as a hazardous waste, including transportation of the material by licensed waste transporters. As a result, most petroleum refiners[92] contacted for this study reported that they are inclined to manage the CSOS that they generate onsite rather than send the material off site (either to a cement kiln or other offsite treatment or energy recovery) as a hazardous waste. In other cases [93] there are no cement kilns in the vicinity of the petroleum refinery that are permitted to accept the CSOS, therefore the material is sent to other offsite facilities for treatment and disposal.

The TXI cement kiln in Midlothian TX, the Ash Grove cement kilns in Foreman AR and Chanute KS, the Lafarge (Systech) cement kiln in Fredonia KS, the Continental Cement kiln in Hannibal MO, and Giant Resource Recovery in Harleyville SC are all permitted to accept K170 hazardous waste. However, according to EPA hazardous waste reporting system data, these facilities' acceptance of CSOS from refineries has been intermittent.

Petroleum refiners have been pursuing an initiative through their trade association (the American Petroleum Institute) to change the regulatory characterization of CSOS so that the material is not regulated as a hazardous waste (or as a solid waste) but rather as a fuel material (i.e., as a refinery product) when legitimately used as a fuel, such as in a cement kiln. The refineries suggested that the most direct approach to defining CSOS as a non-hazardous waste is through the EPA "definition of solid waste" (DSW) regulatory process. If CSOS is deemed by EPA not to be a "solid waste" when beneficially used, then the material inherently cannot be classified as a hazardous waste either. This change in the characterization of the material could facilitate utilization of the material in commerce. Currently much of the CSOS generated is managed on site at the refineries. According to refinery contacts [94] if the CSOS were to be reclassified as a non-hazardous waste, or reclassified as a non-solid waste, it could be sold as a refinery product into higher value offsite markets. Also, if the material were not regulated as a hazardous waste, theoretically any cement kiln could accept it. The combination of the increase in the amount of the material available in commerce and the number of cement kilns that could accept the material could result in increased utilization of the material in cement kilns as an alternative fuel. Reclassifying the material as a refinery product may enable petroleum refineries to sell the material to cement kilns (as a product) rather than having to pay the cement kilns to accept the material. So it is also possible that cement kilns would not accept CSOS if the cement companies had to pay for it. One refinery contact reported that the refinery has already established a contact with cement plants that are paying for the CSOS. The emergence of CSOS as an AFR that was not classified as waste or hazardous material would open a new market comprised of all the cement companies unable to use the material now. The utility of the material and its price would be negotiated, but could ultimately be more than it is now.

Petroleum refiners could also more easily consolidate batches of CSOS from their own refineries, or a consortium of refineries, into large shipments of material to a cement kiln if the material was to be regulated as a product rather than as a waste. As it is now, such consolidation would also have to be conducted at a facility permitted to accept hazardous waste.

TCEQ expressed interest in reclassifying CSOS, but a decision from the EPA Office of Solid Waste (OSW) is needed on this issue for TCEQ to make a decision.[95] Correspondence between the API and EPA OSW on this issue has been underway for several years without any decision being made by EPA OSW on the regulatory characterization of the material.

Scrap Tires

Regulations related to management of scrap tires vary by state and within states. The RMA has reported that several states have achieved a program in which most or all scrap tires generated in the state reach end use markets. [96] Other states have not achieved such performance.[97] For example, the State of South Carolina has ongoing issues with scrap tire piles, and although three cement kilns in South Carolina are permitted to use scrap tires, only two of the three are currently doing so.[98] [99] Several state regulatory agency contacts reported that regulations concerning whether scrap tires can be landfilled, and if so in what physical form, are established by the local government agencies operating MSW landfills. Certain states [100] categorize scrap tires as "solid waste" and regulate the combustion of scrap tires under the state solid waste management regulations.

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One regulatory agency contact [101] reported that an air emissions (concentration) limit for sulfur dioxide (SO_2) applies to the combustion of scrap tires and that some cement kilns in the state were not able to meet the limit, limiting their ability to use scrap tires.

Biosolids

Biosolids (municipal wastewater treatment sludge) from wastewater treatment facilities can be legally used or disposed in three ways: (1) application of treated and tested biosolids to soils; (2) landfilling; or (3) incineration or combustion for energy recovery. The Clean Water Act provides the legal basis for management of biosolids nationwide. EPA established minimum national standards protecting human health and the environment at 40 CFR Part 503. Beyond these national standards, state and local governments make the key decisions regarding biosolids management.

One regulatory issue related to utilization of biosolids in cement kilns is the regulatory classification of the material with respect to pathogen content. Biosolids, as generated at POTWs, contain pathogens, and biosolids applied to different alternative uses (e.g., energy recovery, land application) have different regulatory classifications.

An alternative fuels supplier [102] that conducted performance tests of a cement kiln [103] using biosolids in California reported that the test was required to be conducted using only "Class A" biosolids. [*This is not unreasonable considering that the cement kiln could otherwise potentially introduce pathogens into the cement plant materials handling system if "Class B" biosolids were used.*] However, Class A biosolids must be subjected to temperatures of 60° C, which requires energy, while Class B biosolids, which can be applied to soil, are not required to be subjected to heat. Therefore there is an "energy penalty" associated with preparation of biosolids for use as alternative fuel in cement kilns that would not be incurred if the material was land disposed.

Another regulatory issue concerning biosolids is recent state and local government legislation to reduce emissions of greenhouse gases, and particularly CO_2 emissions. Biosolids are biogenic materials that are "CO_2 neutral." Use of biosolids in cement production to replace fossil fuels can therefore reduce the total CO_2 emissions per ton of cement produced.

Automobile Shredder Residue

The PCA E&E subcommittee contact [104] indicated that TSCA regulations specifically categorize ASR as a "PCB Waste" unless proven otherwise, and that it is "difficult to prove otherwise." EPA regulation 40 CFR §761.62(b)(1) Disposal of PCB bulk product waste [105] [106] applies specifically to landfilling of ASR but also, according to cement sector contacts, is being applied by EPA Region VI to incineration of ASR. Section (b)(i) specifically applies to landfilling of ASR. As of 2005, EPA Region VI was strictly interpreting the phrase "from which PCB small capacitors have been removed" in the regulation as applying to ASR, and interpreting the phrase in ways that shredders could not certify compliance. A recent study by the California DTSC on beneficial use of ASR as alternative fuel in cement kilns concluded that the current regulatory framework for ASR with respect to PCBs actually promotes landfilling of the material as opposed to beneficial uses and that changes to the

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regulatory framework applicable to ASR may be needed to facilitate use of ASR as an alternative fuel in cement kilns. [107]

4.1.4 Supply/Logistics Issues

Obtaining a sufficient long-term supply of material of consistent quality is a principal issue concerning use of alternative fuels in cement kilns. A principal reason for this is that a cement plant may need to spend several million dollars to purchase or upgrade the kiln or materials handling equipment in order to establish use of an alternative fuel, and an assurance that a long-term supply of material will be available would be needed to justify such expenditure. Materials handling systems that are designed for a specific alternative fuel (e.g., biosolids, plastics, wood) may not be easily converted to handling a different alternative fuel if supply of the original alternative fuel is interrupted, and even if so, the cement plant would incur costs in converting the materials handling system for the new material. Another reason why cement plants need a sufficient long-term supply of material is to maintain stable kiln operation. Unanticipated changes in the characteristics of the raw materials and fuels to the cement kiln that need to be made due to interruption of supply can result in kiln upsets.

Several companies operate wholly-owned subsidiaries that are responsible for sourcing of AFR. The subsidiaries obtain materials from suppliers, process the materials, and transport the materials to the company's cement plants.[108] Other cement companies contract with third party contractors [109] that perform the same functions as the cement company subsidiaries do. [110] Third-party contractors may provide services to more than one cement company; the subsidiaries are captive to a particular cement company. Other cement plant contacts indicated that their plants are relatively autonomous with respect to sourcing of AFR.[111] Some cement companies are working with independent suppliers of "engineered fuel" that is manufactured to a specific quality specification for the cement kiln. The independent supplier is responsible for sourcing alternative fuel materials that are used as raw materials in making the engineered fuel, manufacturing the fuel to quality specifications, and delivering the fuel to the cement plant.

Subsidiaries and private sector companies have been effective in materials sourcing of alternative fuels for cement plants. For example, one cement plant [112] recently established use of plastics, cardboard, scrap paper, and rubber scrap an alternative fuels. The plant installed two on-site shredders and other materials handling equipment that cost on the order of $7 million. The cement plant subsidiary company responsible for material sourcing established individual contracts with between 10 and 20 suppliers of these materials to obtain a sufficient supply of alternative fuel material for the cement plant. These suppliers are industrial facilities, not recyclers of post-consumer MSW.

The availability of material for use as alternative fuel may also be related to the relative price to dispose of the material in a landfill and/or the relative cost of alternative beneficial uses. Cement plant contacts [113] and alternative fuels suppliers [114] reported that the available supply of plastics may be constrained because MSW recycling agencies may be more inclined to send post-consumer recycled plastic to plastics manufacturers to be used as raw materials, rather than to cement kilns or other facilities for energy recovery. "Unrecyclable" plastics may also be unavailable as a cement plant alternative fuel if the

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cost of landfilling the material is sufficiently low, unless cement companies are willing to pay fair market prices for those materials based on their inherent calorific value.

Finally, cement kiln use of alternative fuels and raw materials that would otherwise be disposed as waste plays a part in EPA's hierarchy of waste management. EPA emphasizes reducing waste generation whenever possible. If byproduct material is generated, EPA encourages minimizing the quantity released or disposed as waste by recycling or reusing it, using it to produce energy, or treating it.

4.1.5 Trends Analysis

The overall trend is towards increasing use of alternative fuels, with emerging materials representing a potentially increasing percentage of the total amount of alternative fuels used. Generally cement plant contacts reported that the utilization rate of the alternative fuels used has been relatively constant from year to year. According to data in the 2006 PCA *Labor and Energy Report*, overall use of alternative fuels in U.S. cement plants has been relatively constant at 9 percent of total energy input for the past several years. Cement plants contacted indicated the amount of energy derived from alternative fuels is as low as zero percent for some cement plants [115] and as high as 50 percent for others. [116] Specific trends for alternative fuels evaluated in this study are described below.[117]

<u>Scrap Paper/Wood and C&D Debris</u>

As discussed above, only one cement plant contact [118] reported that their plants are using alternative fuels (wood) derived from C&D debris. No other cement plant contacts reported that their plants either using or investigating use of wood derived from C&D debris. Several cement plant contacts [119] reported that their plants recently established use of scrap paper/wood (e.g., scrap paper and cardboard) and that utilization rates are relatively constant. However, several other contacts at cement plants that are using scrap paper/wood reported that they are considering phasing out the use of scrap paper/wood in favor of other alternative fuels (e.g., plastics).[120] More recently, several states have banned disposal of C&D debris in landfills or are contemplating doing so, including Massachusetts and New York, creating an additional supply of C&D debris that could potentially be processed into alternative fuel for cement kilns.

<u>CSOS</u>

Cement plant [121] and petroleum refinery contacts [122] did not provide detailed information concerning the amount of CSOS being used as an alternative fuel in cement kilns; data from the EPA hazardous waste reporting system on the disposition of K170 waste indicates that use in cement kilns has been intermittent. Petroleum refinery contacts reported that they are pursuing market initiatives and identifying cement kilns that are permitted to accept CSOS in an effort to increase the amount of CSOS used in cement kilns. The availability of CSOS for utilization as alternative fuel in cement kilns would likely increase if regulatory barriers restricting the use of this material to RCRA-permitted cement kilns are addressed, as more CSOS would be readily available and more cement kilns would be able to accept it. One can anticipate changes in the market valuation of the CSOS if the material were not classified as a hazardous waste, and this may affect the pattern of future utilization of this material in cement kilns and other facilities for energy recovery.

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Scrap Tires

Cement plant contacts at plants that are already using scrap tires generally reported that they are either using the maximum amount of scrap tires that the cement kiln is physically capable of processing (or that the cement kiln is permitted to process) or that they are conducting performance tests or initiating kiln modifications to increase the number of scrap tires that they can process. Several cement plant contacts reported that their plant is actually permitted to process more scrap tires than can physically be fed to the kiln.[123] One cement plant contact [124] reported that the supply of scrap tires available in the area of one of their plants exceeds the capacity of the cement kiln to use them; surplus scrap tire supply is chipped and transported to a second of the company's cement kilns for use as an alternative fuel.

Contacts at cement plants that are not currently using scrap tires generally did not report they are pursuing permits to use scrap tires at their plants. As discussed above, overall utilization of scrap tires as alterative fuels in cement kilns has been increasing. An issue that may tend to reduce the utilization of scrap tires in the future is the fact that certain types of cement kilns (e.g., short dry process kilns) cannot as easily process whole tires as other types (e.g., long wet process kilns).. Ongoing conversion of wet process plants to dry process plants may reduce the number of kilns for which accepting whole tires is feasible.

Biosolids

No specific trends data are available for biosolids, however, it appears from the number of cement plant and alternative fuels supplier contacts that provided detailed information concerning biosolids that utilization of this material in cement kilns is likely to increase substantially in the near future. Several cement plant contacts reported using biosolids as an alternative fuel and other cement plant contacts reported that they are investigating the use of this material either as a replacement for other alternative fuels (e.g., wood[125]) or as a new alternative fuel.[126] Other cement plants were identified that have recently conducted performance tests using biosolids.[127] Private sector companies that produce alternative fuels for cement kilns [128] are drying and processing biosolids materials specifically for cement plants.[129] One company is operating sludge dryers in New Jersey to supply a cement kiln in Indiana and in Baltimore City to supply a cement kiln in Maryland; a second company is producing alternative fuel to supply cement kilns in Western Pennsylvania; this company reported that the alternative fuel they produce has up to 40 percent biogenic content.

Plastics

Several cement plant contacts reported that they have recently conducted performance tests using plastics or have recently established the use of plastics[130] and that their plastics utilization rates are relatively constant. One cement plant recently established the use of plastics through materials sourcing conducted through a wholly-owned subsidiary.[131] Plastics are an emerging material; increased utilization of plastics will depend upon addressing supply/logistics barriers.

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Automobile Shredder Residue

Only one cement plant was identified that is currently evaluating ASR as an alternative fuel. ASR is an emerging material; establishing utilization of this material in cement kilns will depend on addressing regulatory barriers.

Hazardous Waste Fuels

One cement plant contact [132] that has several cement kilns permitted as hazardous waste combustors reported seeing a slow but steady decline in the available supply of hazardous waste for use as alternative fuel over the past several years. This is in part because there is competition from other energy recovery facilities for hazardous waste fuel and in part because industrial facilities are continuing their waste minimization/pollution prevention efforts and thereby they are generating less hazardous waste. Another reason is very likely that the kilns are charging the generators to accept it rather than paying for it based on its fuel value, which drives generators to look for other alternatives.

4.1.6 Emerging Materials

One cement plant contact [133] reported using scrap carpet generated from residential and commercial building carpet installers as an alternative fuel. Two cement plant contacts [134] reported using oil filter fluff as an alternative fuel. Oil filter fluff is generated from used vehicle motor oil filters after the free oil and the metal parts are removed. The remaining oil-soaked paper is used as an alternative fuel.

4.2 Summary – Alternative Fuels

4.2.1 Scrap Paper/Wood and C&D Debris

Construction and demolition debris was deleted from further consideration in this report because only one cement plant contacted was found to be directly using wood derived from C&D debris. No other cement plants were identified that were either using or investigating using alternative fuels derived from this material.

The principal issues associated with the utilization of alternative fuels derived from C&D debris in cement production are the feasibility of processing this material into a consistent physical condition such that the material can be conveyed into the kiln, and the availability of a consistent supply of this material for the cement kiln. As discussed above, C&D debris (including wood) generated from Hurricanes Katrina/Rita was offered to one cement plant [135] but found to be unsuitable for processing into alternative fuel because the wood was commingled with other C&D debris. Cement plant contacts reported utilization of scrap paper/wood, including recycled cardboard, landscaping wood, and sawdust from lumber mills, and provided information concerning the supply and quality issues associated with the use of scrap paper/wood.

A contrast can be drawn to the case study for a cement kiln using wood (sawdust) generated by a lumber mill.[136] The sawdust is generated in a dry condition and in a form that can be conveyed pneumatically into the cement kiln. The permitted feed rate is

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approximately 5 short tons per hour. The cement plant incurred a significant amount of capital expenditure to install conveying equipment and emission control designed to prevent the material from becoming wet and also to prevent fugitive dust emissions; if the material becomes wet it could create blockage in the conveying equipment. If the material becomes wet, the moisture content also reduces the calorific value of the material, making it less desirable as an alternative fuel. The cement plant also invested significant amount of capital for performance testing and obtaining permits to use the material.

A contrast can also be drawn to the case study for a cement kiln using wood generated by a regional landscaping company.[137] This material is primarily creosote-treated wood used in landscape architecture. The material is processed into shredded wood by a supplier. Based on an average calorific value of 6,500 BTU per pound for wood and 12,000 BTU per pound for coal, two tons of wood are needed to replace one tone of coal. The cement plant reported an annual utilization rate of approximately 10,000 short tons per year wood waste (an hourly feed rate of four tons per hour). The cement plant contact reported that the plant was considering phasing out the use of this material because of uncertainty of the long-term supply of the material. This plant also invested a substantial amount of capital in purchasing materials handling and conveying equipment and also on the performance testing process, which took approximately two years to complete. The plant is considering converting the materials handling system to handle plastics instead of wood.

C&D debris would necessarily be generated on an intermittent basis under normal circumstances. Even in the event that a large amount of C&D debris was generated (e.g., from a tropical storm event) the material would need to be organized (likely from multiple points of generation) and then processed into a consistent long-term supply of consistent quality to be used as alternative fuel in cement kilns. Cement kilns would need to already have materials handling equipment in place to handle the processed material. Processing generally non-homogenous, and also potentially wet, C&D debris into a conveyable physical condition compatible with the materials handling equipment would be more difficult and costly than processing a relatively homogenous material generated by a lumber mill or by a landscape supplier. The capital investment needed for the materials handling equipment and the performance testing required to obtain a permit to burn the material are significant, and therefore cement plants would want some assurance of a consistent and long-term supply of a material of known quality to recover this investment. Cement plants also may not be able to obtain a permit to burn a certain type of alternative fuel material from a certain source and then change to another type of alternative fuel material from another source.

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4.2.2 Refinery Spent Catalyst and Clarified Slurry Oil Sediments

The CSOS generated by petroleum refineries is managed in several ways. Petroleum refineries can return this material to the onsite refinery coking unit or other refinery processes, send the material to other petroleum refineries for processing, send the material to a RCRA hazardous waste-permitted cement kiln or other hazardous waste facility for use as an alternate fuel, or (in limited cases) send the material to Canada for treatment and disposal. [h]

As discussed in Section 4.1.3, petroleum refineries, through their trade association, the API, are pursuing a reclassification of CSOS so that the material would be regulated as a refinery product when beneficially used as a fuel or raw material in cement manufacturing, rather than as a hazardous waste or as a solid waste. A decision by EPA OSW would be needed to reclassify CSOS as a refinery product.

Gulf Coast petroleum refineries are already sending CSOS to hazardous waste-permitted cement kilns in the Gulf Coast Region. One refinery [138] reported that one of their refineries is sending some CSOS to a cement kiln[139] but that the company's other refineries are generally managing this material on site even though it may be less expensive to send the material offsite to a RCRA-permitted hazardous waste facility.

Petroleum refinery contacts reported that that one reason why CSOS is being managed onsite at potentially higher cost is to reduce the amount of hazardous waste generation reported by the refineries. The amount of hazardous waste generated by each refinery annually and sent offsite for disposal is publicly reported through the RCRA Biennial Hazardous Waste Report, and certain constituents may be reportable through the Toxic Release Inventory when shipped offsite as a waste. Refinery contacts indicated that the public perception associated with the required classification of this material as hazardous waste when shipped offsite, even for beneficial use as a fuel or raw material to cement, is an important factor in their decision to manage CSOS on site (at greater expense).

Refinery contacts indicated that they are conducting research into changing the method by which they maintain their CSO tanks in order to generate a lower quantity of CSOS. The CSO product is generally generated with roughly 1 percent or less solids; the remainder of the solid in the CSO tanks settles and is eventually removed as CSOS (a mixture of CSO and catalyst fines/solids). The refineries are researching methods of shipping the CSO with higher solids content to cement kilns. One refinery contact [140] reported that they had shipped CSO with a solids content of up to 20 percent in specialized transport trucks. Solids are generally classified as CSOS after they settle out of the CSO in the CSO storage tanks (although interpretation of this definition is one of the issues under discussion between the API and EPA OSW). Any solids that remain contained in the CSO product prior to settling are not classified as CSOS.

Refinery contacts also indicated that they are conducting research into consolidating the CSOS generated from several refineries (either their own company's refineries or others) and blending the material into a consistent supply for cement kilns. Consolidation is useful for refineries and cement kilns because individual refineries generate CSOS only on a batch basis (but potentially in million pound quantities) when maintaining their CSO storage tanks. CSO tank maintenance schedules among refineries in the same region

[h] Treatment and disposal of CSOS in Canada would not be feasible for a Gulf Coast petroleum refinery, and anticipated changes to Canadian waste management regulations in the future may preclude this option for managing CSOS.

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could potentially be coordinated to levelize the amount of material generated if there was a reliable market outlet driver to do so.

Presently, however, the RCRA hazardous waste designation of this material represents a significant cost barrier to improved management of the CSOS. Petroleum refinery contacts indicated that it is difficult to ship CSOS to cement kilns in hazardous waste transport trucks on a daily basis, both because of the cost and because of the logistics of scheduling hazards waste shipments.[141] Both the cost and the logistics barriers would be addressed if the CSOS were reclassified as a refinery product; transport could be conducted in conventional trucks complying with standard DOT requirements for similar hazardous materials rather than by licensed hazardous waste transporters, and at lower cost. At the same time, reclassification of the CSOS would increase the number of cement kilns that could potentially accept this material as an alternative fuel. The issue of whether cement kilns would continue to charge refineries for the material or whether refineries would be able to sell the material to cement kilns (as a refinery product) would need to be addressed. Cement kilns would be able to evaluate the utilization of CSOS based on cost and technical issues rather than based on whether or not the cement kiln is permitted to accept hazardous waste. This could greatly expand the utilization of CSOS as an alternative fuel in cement kilns, particularly in regions where there are refineries but not a large concentration of cement kilns that are permitted to accept hazardous waste.[142]

4.2.3 Scrap Tires

Cement plants made up 38 percent of the market for tire-derived fuels in 2005.[143] Contacts at several cement plants using scrap tires reported that the plants are using as many tires as the kilns are physically capable of accepting based on the equipment configuration, and others reported that their plants are either retrofitting additional existing kilns to accept scrap tires[144] or making modifications to their kilns to enable an increased throughput of scrap tires.[145] Some cement plant contacts[146] reported that their plants are actually permitted to burn more tires than the kiln is actually physically capable of burning, on account of process limitations. Cement plant contacts reported various rates of scrap tire utilization, from 5 percent of the heat input (equivalent to one scrap tire per minute)[147] to 12 percent of raw mix as tire-derived fuel, corresponding to approximately 1,000 short tons per year of whole tires.[148]

Contacts for several cement plants using scrap tires reported that there is increasing competition for scrap tires from other beneficial uses (e.g., crumb rubber) and also from continued disposal of scrap tires in landfills. These conditions may be characteristic of the specific local markets and do not necessarily reflect the overall national upward trends of scrap tire utilization for both energy recovery and for crumb rubber applications.

Scrap tire management programs vary by state, and in some cases vary by local jurisdiction. Certain states subsidize beneficial use of scrap tires by charging a fee to consumers for each scrap tire collected. The fees are applied, for example, to grants for projects utilizing scrap tires. Other states are either prohibited by law from collecting such consumer fees, or are prohibited by law from spending such fees as grants to use of scrap tires as alternative fuel.[149] Also, State Departments of Transportation may actively support production of crumb rubber for use in production of rubberized asphalt. California, Arizona, and Florida are the largest users of crumb rubber for production of

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rubberized asphalt. This application consumed approximately 12 million tires in 2006. Other states using increasing amounts of asphalt rubber include Texas and South Carolina. [150]

Despite various state-level programs to promote beneficial uses of scrap tires, a significant number of tires are disposed of in landfills. The RMA reported that in 2005 14 percent of scrap tires generated were land disposed.[151] [152] In some states, local governments operating MSW landfills implement local regulations concerning landfilling of scrap tires and other non-hazardous solid waste. In one state,[153] for example, revised regulations were recently implemented that allowed landfilling of cut up tires. Under the previous regulations, whole tires or cut up tires could not be landfilled, and therefore local suppliers chipped the scrap tires to supply alternative fuel to cement kilns and other applications. Upon implementation of the revised regulations, these suppliers no longer had any regulatory incentive to chip scrap tires, as scrap tires could be cut up and landfilled at much lower cost (chipping tires is an energy-intensive process.) As a result, one cement plant contact reported that the plant could no longer obtain a supply of chipped tires. The company had to spend several million dollars to outfit the cement kiln to accept whole tires instead of chipped tires in order to reestablish the use of scrap tires as an alternative fuel.

Public perception of utilization of scrap tires in cement kilns was also found to vary widely. One cement plant contact reported that the plant initiated a pilot project to burn scrap tires and obtained broad acceptance of the program from both the regulatory agency and the local community. Unfortunately, the pilot program was not successful; the kiln dimensions were not amenable to mid-kiln introduction of the scrap tires, and the raw material feed was also not of sufficient dimension to feed whole tires. Chipping the tires was deemed to be cost-ineffective.[154]

Several cement plant contacts reported that the utilization of scrap tires as an alternative fuel in the kiln is actually categorized by state regulators as a nitrogen oxide (NO_x) air emission control strategy, and the utilization of scrap tires is actually incorporated into the air emissions permit for the cement kiln.[155] Use of scrap tires has been shown to reduce NO_x emissions from cement kilns. Other states [156] have a state-wide ban on the use of scrap tires in cement production.

4.2.4 Wastewater Treatment Sludge (Biosolids)

As discussed in Section 3.3.2, biosolids are generated by municipal wastewater treatment plants throughout the U.S., and large amount of this material is potentially available for use as an alternative fuel in cement kilns. Several cement plant contacts[157] reported that the plant is using biosolids and others reported that they are investigating the use of biosolids [158] or have conducted performance testing for biosolids.[159]

Cement plant contacts and regulatory contacts indicated that the public and regulatory perception of use of biosolids in cement kilns is lower than that for wood, and permitting can therefore be more difficult. Wood has in some cases been viewed as a cleaner fuel than coal, while the perception not necessarily the case for biosolids. This could affect the type performance testing and public involvement for proposed use of biosolids. As discussed in Section 4.1.3, there are regulations that require the biosolids to be processed prior to use in cement kilns, and the material has to be “dry” in order to be desirable as an

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alternate fuel. Therefore there is an energy cost to processing the material. Further, as discussed above, in some jurisdictions biosolids can be land disposed with less intensive treatment than would be required for use in a cement kiln. Therefore both land disposal costs and treatment costs are a potential barrier to increased use of biosolids in cement kilns.

Cement kilns using biosolids have been required to conduct performance testing to demonstrate that air emissions (e.g., NO_x emissions) would not increase.[160] Cement sector contacts reported that such performance testing was successful.[161]

4.2.5 Plastics

Several cement plant contacts reported using plastics, either generated by MSW recycling programs or generated by industrial plants that manufacture plastic products; other contacts indicated that their plants are investigating using plastics either by identifying private sector suppliers or by investigating how to partner with municipal government MSW recycling programs. Two important issues related to utilization of plastics as an alternative fuel in cement kilns are obtaining an adequate supply of the material and managing the quality of the material.

Cement plant contacts and regulatory agency contacts reported that in some jurisdictions plastics generated from MSW recycling programs are not segregated adequately such that the plastics can be used as alternate fuel in cement kilns.[162] Cement kilns do not want chlorinated plastics (e.g., polyvinyl chloride) in their feed stream because the chlorine in the plastic can generate air emissions (e.g., chlorinated dioxins and furans) in excess of permit limits. Cement kilns also closely control the chlorine content of the raw mix because chlorine can affect the quality of the clinker produced. However, cement plants in different regions with different characteristics of available raw materials may have different tolerances for the amount of chlorine, depending on the alkali content of the raw materials and other parameters.

Cement plant contacts and regulatory agency contacts also reported that the recycling rate for plastics in many jurisdictions is not as high as it could be, reducing the amount of plastics collected for potential utilization in cement kilns.[163] Municipal governments responsible for operating MSW recycling programs in some cases would need to invest in equipment (e.g., sorters, shredders) and establish additional procedures to adequately segregate plastics and supply the plastics for use in cement kilns. The benefits of such investment would be a steady supply of high calorific value fuel (on the order of 14,000 BTU per pound) for the cement kilns and reduction of the potential for generation of landfill gas from disposal of plastics in landfills. However, cement plant contacts reported that it is not necessarily clear to the municipal governments managing the MSW programs that such capital or labor cost expenditures would pay for themselves in the increased value of the plastics that could be supplied to cement kilns. This is particularly the case in regions where the cost of landfill disposal is low. Low landfill disposal costs may drive local government decision making concerning recycling programs. Cement plants can either purchase shredded plastic from a supplier or install a shredder onsite. Installation of a shredder on site would be a significant capital expenditure. Some plants using plastics have chosen to install shredders on site, while others have chosen to purchase shredded plastic from a supplier.

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US EPA ARCHIVE DOCUMENT

DRAFT

One cement plant contact [164] reported that they are investigating how to form partnerships with municipal government recycling agencies to promote increased and improved segregation of plastics. In the company's estimate the additional sorting of materials would ultimately "pay for itself." Another cement plant contact [165] reported that their materials sourcing subsidiary recently conducted a market study to identify sources of plastics for the cement kiln. The subsidiary did not identify post-consumer plastics from MSW recycling agencies, but rather plastics generated by local industries. This is an indication that the MSW recycling agencies either are not generating plastics in sufficient quantities to supply the cement kiln or that the plastics being generated are not being adequately segregated.

4.2.6 Automobile Shredder Residue

Automobile shredder residue (ASR) is an emerging material. As discussed in Section 4.1.3, a principal barrier to use of this material in cement kilns is its regulatory classification. A recent study by the California DTSC assessed the regulatory and technical barriers to use of ASR as an alternative fuel in cement kilns. [166] In addition to the regulatory issues related to PCB capacitors, other potential regulatory issues include the occurrence of mercury switches and lead (e.g., wheel weights) in the scrap automobiles from which ASR is generated. The EPA recently established a voluntary program for management of mercury switches and a regulatory program for management of mercury switches and lead waste in processing of scrap automobiles and other ferrous metal scrap. [167, 168] The California DTSC Report also identified issues concerning the quality of the material, specifically related to the content of metals (e.g., copper wire scrap,) non-combustible material, water, and other undesirable materials (e.g., PVC plastic). The California DTSC Report identified specific technologies needed to upgrade the quality of ASR for use in cement kilns and evaluated their feasibility.

4.2.7 Emerging Materials

Other emerging materials identified by cement plant contacts and regulatory agency contacts include MSW, agricultural byproducts, scrap carpet; tire fluff, and oil filter fluff.

<u>Municipal Solid Waste</u>

Regulatory agency contacts[169] identified MSW as an emerging material and indicated that cement plants have expressed interest in burning this material. MSW includes durable goods, non-durable goods, containers and packaging, food wastes and yard trimmings, and miscellaneous inorganic wastes. According to New Source Performance Standards (NSPS) for MSW combustors, an existing cement plant would be permitted to burn up to 30 percent of MSW as a percentage of total feed rate. A higher throughput would trigger the NSPS for MSW incinerators; office paper is technically MSW, according to the regulatory definition.

<u>Agricultural Byproducts</u>

Several cement plant contacts reported that they formerly used agricultural byproducts but no longer do so because of supply issues.[170] One alternative fuel supplier [171] reported that cement plants in the Midwest had been burning off-spec seeds for energy recovery, but that this material was only available in [on the order of] 10,000 pound batches and not available in a continuous supply. Therefore when the batches of material were used up, the cement kilns needed to return to using conventional fossil fuels.

Oil Filter Fluff

Two cement plant contacts [172] reported using oil filter fluff as an alternative fuel. The cement plant contacts reported that the supply of oil filter fluff is relatively stable and that the material has a relatively high calorific value.

Scrap Carpet

One cement plant contact [173] reported using scrap carpet as an alternative fuel, consuming approximately 2,000 metric tons per year of scrap carpet and other textile materials. This material includes old carpet pads, cutting scraps, carpet rolls, and other materials from residential and commercial carpet replacement, and is generated by a regional carpet supplier. The principal issues with using this material are organizing the carpet installation personnel to segregate the scrap carpet from other debris (e.g., nails, metal strips) and segregate the material for transport to the cement plant rather than to the local landfill where other debris would be transported. The cement plant contact reported that small carpet installation companies cannot manage this effectively because they have less control over their carpet installation personnel than a larger company does. For example, the regional carpet supplier deploys their carpet installation personnel from central company locations on a daily basis. The cement company is working with CARE to organize other carpet suppliers to provide scrap carpet for use as an alternative fuels. However, cost of supplying this material is a substantive issue in increasing utilization.

Transportation cost for the scrap carpet is an issue; for example the hauling capacity of a truck may be only three to five tons of carpet, vs. a hauling capacity of 20- 25 tons of tire chips in the same size truck. As for other non-hazardous solid materials the cost of landfill disposal is an important competing factor. Landfill disposal fees in the Western U.S. (not including transportation cost) may be as low as $10 per short ton. The cost for transporting the scrap carpet and the labor and equipment costs of processing the material for utilization in a cement kiln may be higher than the landfill disposal fee. However, scrap carpet is not a very dense material and therefore takes up more space in landfills than an equal weight of other solid materials, potentially affecting the cost of landfill disposal. As for other non-hazardous solid materials, scrap carpet generator companies conducting cost-benefit analysis of landfill disposal vs. beneficial use of scrap carpet would need to consider the sustainability advantages of the beneficial use as well as the incurred costs of beneficial use vs. landfill disposal.

Realff, 2005, also reported that use of scrap carpet as an AFR has the potential to affect cement kiln air emissions, because of the nitrogen content of the scrap carpet. Nylon carpet residue contains approximately 4.5 percent nitrogen by mass, while polypropylene carpet residue contains less than 0.05 percent nitrogen. Therefore, use of scrap nylon carpet has the potential to result in increased NO_x emissions as compared to use of scrap polypropylene carpet. [174]

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4.3 Alternative Raw Materials

4.3.1 Cost Issues

Spent Foundry Sand

Several cement plant contacts reported that the cost-benefit analysis for spent foundry sand vs. mined sand is not favorable after material acquisition costs, transportation costs, screening and grinding costs are considered. Several cement plant contacts reported that their plants have phased out or are phasing out use of spent foundry sand because of cost-quality issues.

Cost issues associated with the use of spent foundry sand are directly related to the geographic location of material generators and cement kilns, and the specific type and quality of the spent foundry sand being generated. One cement plant contact reported that use of spent foundry sand is "cost neutral" after the transportation cost is considered [175] while another cement plant contact [176] reported that considering the quality of the available material and transportation costs, use of spent foundry sand was not cost effective for the plant. A third cement plant contact [177] reported that they had identified several nearby sources of high-quality spent foundry sand, including a conventional metal casting foundry and a fused silica foundry, and that the cement plant was using whatever amount of spent foundry sand that these facilities could provide to them. Other cement plant contacts reported that they did not have a strong incentive to seek out spent foundry sand because mined sand was relatively inexpensive and widely available in their region, or that they generated a sufficient amount and quality of sand from company-owned quarries such that they did not need to obtain an additional supply of sand from spent foundry sand.[178]

Another cement plant contact [179] reported that the cement plant's use of spent foundry sand is "minimal" because of a combination of quality and cost issues. This contact reported that a supply of spent foundry sand is not available at a reasonable rate, and that is difficult to go through the screening process to screen out debris (tramp metal, etc). After considering transportation costs and other costs, spent foundry sand is "not a good value" compared to the cost of virgin materials.

Steel Slag

No specific cost issues were identified by cement plant contacts related to the use of steel slag.

4.3.2 Technical Issues

Spent Foundry Sand

Not every cement kiln can use spent foundry sand or needs to use spent foundry sand; the ability of a cement kiln to use spent foundry sand depends on the kiln type and the type of spent foundry sand available. Spent foundry sand supplies silica; cement plants that have

DRAFT

a supply of virgin and other alternative raw materials that have a sufficient quantity of silica would not need to use spent foundry sand to supplement the silica content of the raw mix. One cement company [180] reported that the company as a whole is phasing out the use of spent foundry sand because of air emissions issues concerning carbon monoxide (CO) emissions. Some spent foundry sand available to them contains volatile organic compounds including the binder materials (oils, phenolic resins) used to make molds. Older technology long dry kilns were able to use spent foundry sand without incurring increases in CO emissions. As the company converted their cement kilns to one-stage preheater designs, the volatile organic compounds in the spent foundry sand started to burn off in the cement kiln preheater, rather than in the kiln itself, generating excess CO emissions. The CO emissions were such that the cement plant was approaching its overall permitted CO emission limit, so the company began to phase out the use of spent foundry sand for their new one-stage preheater design kilns. The company's older long dry kilns are capable of using spent foundry sand. Other cement plant contacts [181] reported that they have not experienced any issues with use of spent foundry sand resulting in excess CO emissions or other air emissions.

Several cement plant contacts [182] noted the necessity of processing of spent foundry sand to remove "tramp metal" (metal chips) that can damage cement plant grinding equipment. The material can be screened either at the supplier or at the cement plant. Other spent foundry sand applications (e.g., construction fill) are less sensitive to the quality of the material.

One cement company [183] reported a change in kiln design resulted in them phasing out the use of spent foundry sand. Older technology long dry kilns were able to use spent foundry sand without incurring increases in CO emissions resulting from the combustion of volatile organic compounds in the spent foundry sand. However, in the company's new one-stage preheaters design kilns, the volatile organic compounds in the spent foundry sand started to burn off in the cement kiln preheater, rather than in the kiln itself, generating excess CO emissions. The company's older long dry kilns are capable of using spent foundry sand without creating excess CO emissions. Other cement plant contacts [184] reported that they have not experienced any issues with use of spent foundry sand resulting in excess CO emissions or other air emissions.

<u>Steel Slag</u>

No specific technical issues were identified by cement plant contacts related to the use of steel slag.

4.3.3 Regulatory Issues

Cement plant contacts and regulatory agency contacts reported fewer regulatory issues for utilization of non-hazardous solid materials as raw materials in cement production. Alternative raw materials (e.g., spent foundry sand, steel slag) have generally fewer regulatory issues than do alternative fuels with respect to permitting, performance testing, and public perception. For example, air emissions performance testing and modifications to the facility air emissions operating permit are generally required for cement plants to initiate use of alternative fuel, while cement plant contacts reported that for use of alternative raw materials (e.g., spent foundry sand, steel slag) permit modifications and

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performance testing are not necessarily required for cement plants to initiate use of the materials. Several cement plant contacts [185] and regulatory agency contacts [186] reported that no modifications to plant operating permits were required for the plant to initiate use of spent foundry sand, steel slag, or other "non-fuel" alternative raw materials. Initiating the use of "non-fuel" alternative raw materials were considered to be an "operational change" to the plant and required only a letter to the regulatory agency, not a permit modification, provided that no changes to facility emissions or the ability to comply with existing permit conditions would result.[187]

Some cement plant contacts and state regulatory contacts [188] reported that in their states sand and other solid raw materials are relatively inexpensive and widely available, and that therefore there is little if any cost benefit for cement plants to seek out spent foundry sand.[189] Competing uses (construction fill, daily landfill daily cover) are less costly than transporting spent foundry sand to cement kilns, and there are lower potential environmental permitting issues in using the spent foundry sand for competing uses than for raw material to cement kilns.

Some states do not have an active regulatory agency program for managing spent foundry sand. Several cement plant contacts reported that in their states management and disposal of foundry sand is not highly regulated. Foundries can accumulate the spent foundry sand on their property or use the material as a "soil amendment." A soil amendment is any material added to a soil to improve its physical properties. Most foundries, depending on regional and contractual variables, do not have a strong incentive to move the spent foundry sand offsite. Cement plants incur transportation costs and processing costs to obtain and prepare spent foundry sand for introduction into the cement kiln. The lack of incentive for foundries to send the spent foundry sand to cement plants and cost barriers for cement plants to obtain and process the spent foundry sand decreases the desirability of the material as an alternative raw material.[190] Unlike scrap tires, however, landfilling of spent foundry sand probably cannot be precluded by state or local MSW landfill regulations, since landfill daily cover is one of the principal applications of spent foundry sand. Daily cover is material placed on the surface of the active face of a MSW landfill at the end of each operating day to control vectors, fires, odors, blowing litter, and scavenging

4.3.4 Supply/Logistics Issues

Spent Foundry Sand

The supply of spent foundry sand available to cement kilns depends upon the locations of and production capacity of foundries in the vicinity of the cement kiln. Some cement plant contacts [191] reported that they have contract relationships both with individual foundries and with third-party "consolidators" that consolidate spent foundry sand generated by multiple foundries into shipments to the cement kiln. Either the foundries or the third-party consolidators may process the spent foundry sand (e.g., to remove metal, for size reduction) prior to shipment to the cement kiln. Several cement plant contacts [192] reported that the supply of spent foundry sand is limited and that the cement plants could use more spent foundry sand than is available to them.

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DRAFT

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<u>Steel Slag</u>

Two cement plant contacts [193] reported using a specific type of steel slag from Japan as a clinker additive. Use of slag as clinker additive is outside the scope of this study. One cement plant contact [194] suggested that competition from concrete batch plants using steel slag as an additive may be affecting the market for steel slag use as a cement kiln raw material. Other than supply issues, cement plant contacts did not report any specific issues related to use of steel slag as a raw material in cement kilns.

4.3.5 Trends Analysis

It is unclear from information provided by the cement sector contacts for this study whether utilization of spent foundry sand in cement kilns will increase or decrease in the future. A number of cement plants (and some entire cement companies) reported that they are phasing out the use of spent foundry sand as being incompatible with their kiln design or because use of the material is not cost effective.[195] The number of older technology kilns that could easily use spent foundry sand (without preheaters and associated carbon monoxide emissions issues) is anticipated to decrease over time, and more immediate uses of spent foundry sand, such as construction fill and landfill daily cover, may be more cost effective with respect to both transportation costs and material processing costs than utilization as a raw material in cement production. However, other cement plant contacts reported that they are not able to obtain as much spent foundry sand supply as the plant is capable of using [196] or that spent foundry sand that could be used in cement production is being landfilled or stockpiled because the state does not have an effective regulatory program for managing spent foundry sand.[197] It therefore appears that there may be local or regional differences in trends for utilization of spent foundry sand.

Utilization of steel slag is anticipated to increase through application of CemStar[tm] and similar steel slag processing technologies. TXI transferred the patent for the CemStar[tm] process to an independent company specifically to promote the expanded use of the technology.

4.3.6 Other Emerging Materials

Cement plant contacts reported several other alternative raw materials as being used in cement kilns. These include latex paint solids,[198] sandblast grit, and storm drain solids (generated from municipal storm drain cleanouts).[199] Each of these materials was identified by single cement plant. Sufficient information is not available for these materials to develop case studies.

5. Conclusions

This section summarizes the conclusions of the material-specific analysis for each beneficial use material studied. These observations are based on the interviews conducted with cement plant contacts, regulatory agency contacts, and suppliers, and on additional research conducted for this study.

5.1 General Observations

A wide variety of AFR are being used in cement kilns, and the cement sector is being aggressive at identifying and testing various types of beneficial use materials. Most of the cement plant contacts indicated that their plants, or their companies, have been conducting performance testing of new AFR and/or investigating potential suppliers of these materials

Cement sector contacts, regulatory agency contacts, and suppliers all indicated that the principal focus of cement plants in beneficial use is alternative fuels; there is less of an ongoing focus in the cement industry on the beneficial use of raw materials (e.g., spent foundry sand, steel slag). This is principally related to cost. For example, several cement plant contacts indicated that the use of spent foundry sand was not cost effective for their plants because of transportation costs, processing costs, or both, while other contacts indicated that their plants are using spent foundry sand on an ongoing basis but could replace this material with mined sand or other silica raw materials if necessary.

Almost all of the cement plant contacts indicated that use of alternative fuels was important to the continued competitiveness of their plants. This is reflected in the ongoing programs at many cement plants to conduct performance testing of new materials and the appearance of third-party alternative fuel suppliers with business plans specifically targeted towards cement kilns (as well as the operations of the wholly-owned subsidiaries of some cement companies that are responsible for sourcing of AFR).

The technical issue of handling materials was a common issue. For instance, a contact for a cement plant using wood reported that they are investigating the use of biosolids, but that the plant could not use both wood and biosolids because the materials handling system cannot handle two different materials simultaneously.[200] So a decision to use biosolids is also a decision to no longer use wood. Biosolids, scrap paper/wood, and agricultural byproducts offer the potential of greenhouse gas emissions offsets for the cement plants, from replacement of fossil fuels with biogenic fuels.

State agency involvement in promoting beneficial use in cement kilns is currently at a relatively low level, and the level of state agency involvement varies by material. Regulatory agency involvement in managing scrap tires is somewhat higher than for other AFR. Many states have statewide programs for managing scrap tires [as reported in the RMA 2005 *Scrap Tire Markets Report*.] For other AFR, some states [201] operate state assistance programs and maintain databases of potential suppliers and potential users (including cement plants) of these materials, but other state regulatory agency contacts [202] indicated their view that it is more the responsibility of the suppliers and users (e.g., cement kilns) to organize themselves and that the responsibility of the agency is (in the words of one regulatory contact) to "give alternative materials a fair shake" in the permitting process. The overall sentiment was that the economic market is more efficient at matching alternative fuel and raw material suppliers and users than regulatory agencies would be. However, one key observation is that certain regulatory constraints, such as the strict hazardous waste combustor requirements applied to offsite management of CSOS when beneficially used as an alternative fuel and raw material, create "false economics" and do not allow the true economic opportunities in the cement scenario to be realized.

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Both EPA and state regulatory agencies have generally appeared reluctant to provide the appropriate regulatory adjustments to address those issues. Where some of those alternate fuel materials may currently be subject to RCRA hazardous waste requirements, regulatory agency involvement may be necessary to recognize this as a legitimate fuels supply business, rather than hazardous waste management, in order for the full beneficial use opportunities to be developed.

The cement industry has the capacity to collect information concerning potential AFR suppliers on their own either through corporate beneficial use departments, wholly-owned and dedicated subsidiaries, non-affiliated commercial suppliers, or individual plant purchasing departments, but clear regulatory agency support is sometimes necessary to allow the AFR use to proceed effectively.

There is a growing commercial market for "brokers" of industrial byproducts, and they are recognizing their potential value as fuel and feedstock to various industry sectors; these brokers may consolidate smaller quantities of materials into larger shipments to cement plants and may also process the material prior to shipment. For example, in some states[203] third-party brokers are consolidating shipments of spent foundry sand from multiple suppliers to supply a cement plant. In the Gulf Coast region there is the potential for third party brokers to organize shipments of CSOS from petroleum refineries into consolidated shipments to cement plants. The wholly-owned subsidiaries perform this function for their company's cement plants, for example, by organizing and entering into contracts with multiple local suppliers of plastics.[204] There are also independent alternative fuel suppliers that are sourcing various types of alternative fuel materials and using the materials to manufacture engineered fuel to specific quality specifications for use in cement kilns.

Significant differences were identified in corporate management of the beneficial use of materials among cement companies: some companies[205] set corporate benchmarks for the beneficial use of materials and transmit benchmarks to their cement plants; for example, in some companies [206] different plants are working on different pilot projects with different beneficial materials, with the results of the performance tests communicated to the company's various plants. In other companies,[207] each cement plant operates more autonomously, setting plant-specific objectives for use of AFR.

Significant differences were also identified in cement companies' interest in expending capital to establish or expand use of AFR. Some companies were relatively conservative in making capital expenditures to enable or expand the use of AFR; other companies [208] appeared to routinely make such investments in their plants, in some cases responding to specific issues related to material supply.

In general, both cement plant contacts and suppliers indicated that the cost and proximity of landfill disposal of beneficial use materials was a significant barrier to increased use of materials in cement kilns when landfills are closer and less expensive. This general conclusion applies to scrap tires, ASR, biosolids, plastics, spent foundry sand, and other non-hazardous materials that can be disposed of [by regulation] in non-hazardous solid waste landfills or otherwise used in cement production or other beneficial uses. In general, the lower landfill costs (including transportation and tipping fee) are in a

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particular region, the more difficult it is for cement plants or AFR suppliers to divert this material from landfill disposal.

Other factors in local and state government decision making concerning promotion of AFRs vs. landfill disposal include the local and state governments' approach to the "waste management hierarchy." In general, if a waste management hierarchy is implemented as government policy at the local or state government level, landfill disposal of materials is a less desired option than reuse, recycling, or beneficial use. Therefore government policies that actively take into account a waste management hierarchy would discourage landfill disposal of materials that could be used as AFRs. Also, local and state governments that are implementing regulations to reduce greenhouse gas emissions may also be establishing specific "waste diversion goals" to promote beneficial use of materials in industrial processes, including cement production, to reduce greenhouse gas (CO_2) emissions.

Table 10 presents tipping fees for landfills in 2004. Note that total landfill cost includes the tipping fee and transportation cost. Landfill costs tend to be lower in the Western U.S. (except for California) and higher in the more densely populated Eastern U.S. Several cement plant contacts reported that landfill tipping fees in Texas and Oklahoma (not including the waste transportation costs) can be as low as $10 per ton.

Table 12. Landfill Tipping Fees , 2004

Region	**Dollars per short ton**
Northeast	$70.53
Mid-Atlantic	$46.29
South	$30.97
Midwest	$34.96
South Central	$24.06
West Central	$24.13
West	$37.74
National Avg.	$34.29
Source: National Solid Wastes Management Association 2005 Tip Fee Survey (2006)	

Much of the AFR being used in cement kilns provide natural synergies [direct correlation] between the cement sector and other sectors. These include:

- Automobile Manufacturing: Automobile Shredder Residue
- Automobile Parts Manufacturing: Plastics
- Oil and Gas: Refinery Spent Catalyst and CSOS
- Metal Casting: Spent Foundry Sand

This correlation among sectors provides opportunities for joint projects, based on geographic proximity, among the sectors matching up material generators and potential users (cement kilns).

Material-specific conclusions are as follows:

DRAFT
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- Scrap Paper/Wood and C&D Debris

As discussed above, only one cement plant was identified that is using alternative fuels derived from C&D debris; no other cement plants were identified that are investigating the use of alternative fuels derived from C&D debris. The principal issue with this material is the difficulty in identifying a long-term supply of C&D debris and the difficulty in processing the material into a consistent quality of alternative fuel for use in cement kilns. The principal issue identified with use of scrap paper/wood is also the difficulty in securing a long-term supply of the material. In order to secure long term supply, one cement plant identified a wood products manufacturing plant as a source of wood, and another cement plant, through a wholly-owned subsidiary, organized a number of local suppliers to supply scrap paper and cardboard. Some cement plant contacts indicated that they were investigating discontinuing the use of scrap paper/wood and initiating use of plastics in part because of the uncertainty in the long-term supply of the scrap paper/wood.

- CSOS

The regulatory classification of CSOS as a hazardous waste (RCRA Waste Code K170) is a significant barrier to increased beneficial use of this material in cement kilns and other applications as an alternative fuel and raw materials. Under the current regulatory classification, only facilities that are permitted as RCRA hazardous waste facilities can accept this material. Petroleum refinery contacts reported that they are often managing this material onsite using thermal treatment (coking) processes, rather than sending the material to cement kilns for use as alternative fuel, even though in some cases processing the material onsite is more costly than sending the material off site to a cement kiln. Petroleum refineries are managing the material onsite in part to avoid classification of the material as hazardous waste when shipped offsite, and in part because managing shipments of the material as a hazardous waste is difficult from a logistics standpoint. Also, the classification of the CSOS as a hazardous waste means that only [the 18] cement kilns that have hazardous waste combustor permits can accept the material. Some CSOS is sent to cement kilns, but trends data indicate that shipments of CSOS to cement kilns are intermittent and have been decreasing (see Table 7). If CSOS was not hazardous waste, all cement kilns could use it and the amount available to the market would increase because refineries would no longer have the same incentives to manage the material on site.

There are two potentially competing factors related to potential reclassification of CSOS as a non-waste material when beneficially used. Reclassification would likely mean that petroleum refineries would limit, or cease entirely, managing the CSOS on site based on cost and environmental efficiency considerations. It could therefore be anticipated that the supply of CSOS available to the market would increase if the CSOS was reclassified as a non-waste material. However, reclassification would also likely mean that others could also accept the material for use as an alternative fuel. This would potentially increase the market competition for the material, although this effect could be lessened by the potential increase in the supply of the material. According to refinery contacts, CSOS was initially considered for listing as a hazardous waste because the material was being

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disposed of in landfills. Therefore, it is unlikely that any change in the classification of the material would permit disposal of the material in non-hazardous solid waste landfills, as opposed to using it for energy recovery.

- ASR

The classification of ASR as a "PCB-containing waste" under TSCA is a barrier to use of this material as an alternative fuel in cement kilns. Much of this material is being disposed of in landfills as a result. ASR is generated from automobile shredders that are located throughout the country, and (other than its regulatory classification) would represent a widely-available source of high-calorific value material for use as alternative fuel in cement kilns. The technologies needed to upgrade the quality of ASR for use in cement kilns also represents a potential cost barrier to use of the material in cement kilns. Modification of the waste classification definitions applicable to ASR may be needed to facilitate use of ASR as an alternative fuel in cement kilns.

- Scrap Tires

Barriers to increased use of scrap tires in cement kilns include negative regional public perception concerning such use and the perception that recycling of scrap tires into new products (e.g., playground, sidewalk, and other crumb rubber material) is a "higher use" for scrap tires. The waste management hierarchy applied to scrap tires to some extent depends on the perception and consideration of the calorific value of the scrap tires. The "higher use" perception can be reflected in state regulations concerning scrap tire management that promote crumb rubber uses while remaining neutral on beneficial use in cement kilns.

Another barrier to increased use of scrap tires in cement production are state and in some cases local regulations that allow scrap tires to be disposed of in non-hazardous solid waste landfills. This issue could potentially be addressed by coordination among EPA, state governments, and the cement sector to establish programs to divert scrap tires from landfill disposal, potentially by revising state regulations or establishing or revising state scrap tire management programs.

- Spent Foundry Sand

As discussed above, several cement sector contacts indicated that their plants (or companies) are not using spent foundry sand either because the use of the material is not cost effective or because the phenolic resin content of the material is not compatible with dry kilns with preheater/precalciner design. The cost issues are related to the quality of the material and the availability of inexpensive virgin material. The need to screen the lower quality spent foundry sand to remove metal and other extraneous materials increases the cost of using the material. Some cement plant contacts indicated that they are working with local spent foundry sand suppliers to solve the quality issues; other cement plant contacts did not express interest in continuing to use the material. Cement plant contacts for which their kiln designs are incompatible with the organic compound content of the spent foundry sand also did not express interest in continuing to use this material.

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Another barrier to increased use of spent foundry sand in cement kilns is competing uses. Uses of spent foundry sand such as for construction fill are less sensitive to the quality of the material, and the locations of these competing uses may be closer to the facilities that are generating the spent foundry sand than the cement kiln is. These conditions would provide a cost disadvantage to use of spent foundry sand in cement kilns. Also, some states do not have active regulatory management programs for spent foundry sand and permit the material to be land disposed, or stockpiled on the foundry site. This lowers the cost of disposal of the material and does not provide an incentive for foundries to generate high-quality spent foundry sand for cement kilns.

- Steel Slag

Cement plant contacts and regulatory agency contacts did not identify specific issues related to use of steel slag as an alternative raw material in cement kilns.

6. Recommendations/Further Actions

This section summarizes further possible actions that could be taken by cement plants, suppliers, and federal and state regulatory agencies to address identified barriers to increased beneficial uses of materials.

Regional differences were identified in the use of beneficial materials depending upon the availability, cost, quantity and quality of virgin materials and availability, cost, quantity and quality of beneficial use (AFR) materials, and also depending upon federal, state, or local regulatory frameworks. Such geographic differences suggest that the development of recommendations for possible further actions be tested regionally.

Also, these recommendations for possible further actions consider supply and demand issues and associated cost, technical, and regulatory issues; health effects issues associated with the beneficial use of materials are outside of the scope of this report, but health effects will need to be considered in implementing any recommendations for further actions.

SSP Sector Partnerships

- SSP could consider promoting the development of partnerships between the cement sector and other SSP sectors; there is a strong interest in examining these issues jointly among various sectors. Considering the wide variety of alternative fuels and raw materials identified as being used or potentially being used in cement kilns, SSP could also consider expanding the types of materials under the program's review.

- SSP could develop partnerships between SSP and state agencies with active beneficial use promotion programs and also work to promote the establishment or expansion of state beneficial use promotion programs.

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Regional Workshops and Pilot Projects

- SSP and the Portland Cement Association could coordinate setting up regional meetings and workshops with cement companies, state regulatory agency and EPA Regional offices, and beneficial use material suppliers to address barriers to increase use and to connect cement plants with potential AFR suppliers.

- SSP could work with OSW and PCA to promote "pilot projects" with specific cement plants and AFR suppliers as an outgrowth of the regional workshops.

- With respect ASR and CSOS specifically, SSP should consider initiating meetings with other relevant EPA offices to discuss where regulatory classification of these materials may impose barriers, prior to coordinating regional workshops or pilot projects.

Examples of potential actions that SSP and PCA could undertake include:

- Promoting a performance test project with a cement company, an ASR supplier, and state and EPA Regional offices to obtain data concerning the performance of the material as an alternative fuel. This pilot project could potentially be expanded to other regions that have refineries generating CSOS and cement kilns that could potentially use the material as an alternate fuel and raw material.

- Organizing a workshop to address performance testing issues related to expanding use of CSOS to cement plants in the Gulf Coast region.

- PCA and EPA could potentially jointly develop long-term goals for replacing conventional fuels and materials with alternatives (e.g. increasing national alternative fuel replacement to specify increasing a certain type of alternative fuel by a certain percentage by a certain year).

- PCA and EPA could consider initiating discussions with State government agencies concerning development of more a standardized permitting and performance testing approach for alternative fuels in general and "engineered fuel" specifically.

- PCA and EPA could potentially initiate discussions with State government agencies concerning development of a "stewardship strategy" for AFRs, including standardized receipt and characterization and testing standards.

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7. Appendix A: Case Studies

7.1 Beneficial Use Case Studies

Appendix A presents the results of the material-specific analysis for each beneficial use material analyzed for each cement kiln case study.

7.1.1 Spent Foundry Sand

California Portland Cement Company, Colton CA

The California Portland Cement, Colton CA plant uses approximately 10,000 to 25,000 tons[i] per year of spent foundry sand from multiple suppliers. A third party collects the material, screens the material for trash and debris, combines the material into truckloads, and delivers the material to the Colton cement kiln site. The use of the spent foundry sand has resulted in an overall decrease in raw material costs (after the cost of testing the material) of $0.70 per ton clinker.

Foundry sand is used at the Colton Plant for silica replacement. The Colton Plant quarry operation produces high purity limestone, but the limestone has no silica or alumina content. Thus, the Colton Plant has to import silica and alumina from spent foundry sand and other sources to make their raw material mix. The California Portland Cement plants in Rillito AZ and Mojave CA don't have this issue with the silica/alumina content of their limestone.

The Colton Plant does not have as much spent foundry sand as desired, and they also use mined silica and diatomaceous earth to supply silica to the raw material mix. The Colton Plant's spent foundry sand supply is limited because there are not enough aluminum and steel foundry sand suppliers in proximity. Competition from alternative uses of spent foundry makes the material more expensive for the Colton Plant to obtain. There is more efficient recycling of foundry sand within the foundry (driven by internal cost), and there are alternative uses for spent foundry sand. The overall cost for the Colton Plant to acquire the spent foundry sand is $14 per ton.

The Colton Plant uses spent foundry sand from aluminum and steel foundries. The plant does not use spent foundry sand from brass foundries because brass foundry sand contains lead; using lead-containing waste would require the plant to obtain a RCRA permit. The Colton Plant has not experienced any regulatory issues with aluminum or steel foundry sand.

CEMEX, Knoxville, TN

CEMEX operates one preheater/precalciner kiln in Knoxville. The cement kiln uses two primary types of spent foundry sand: (1) spent foundry sand from a "typical casting facility

[i] All "ton" quantities in these case studies are "short tons" unless otherwise specified.

for casting metal parts" and (2) spent sand from a "fused silica" plant, which is used in manufacturing transistors. The material is more than 99 percent silica, consisting of high purity sand mixed with fused silica. CEMEX has not encountered any issues related to phenolic resin binders in the spent foundry sand or other effects on air emissions from the use of spent foundry sand from the casting facility.

A broker that works with the cement industry connected CEMEX with the foundry. The quantity of spent foundry sand used has been constant over time, and the CEMEX plant uses whatever the facilities produce. This source of silica is cheaper than mined material.

The plant operates under air permit conditions including a 12-month "rolling sum" of emissions. The emission factors are derived from previous stack tests, including tests for total metals. There are NO_x, SO_x, and CO emission limits in the permit; the 12-month rolling sum emissions limits in the permit are for lead, mercury, and beryllium. Mercury is part of the "raw material substitute" program for the plant. Raw materials, including the spent foundry sand, are analyzed quarterly, and an updated alternative materials report is completed every month. The plant has not encountered any environmental permit issues associated with the use of these materials. Alternative raw materials are subject to emission limits; however, as long as the materials are not hazardous wastes, they are permitted for use. The regulatory agencies involved in permitting for the Knoxville plant include the Tennessee Solid Waste Department and the Knoxville Air District.

TXI, Midlothian, TX

The TXI Midlothian TX cement plant used spent foundry sand previously, but does not do so now because of processing costs, transportation costs, and availability of the material. TXI indicated that management of spent foundry sand in Texas is not subject to any active state regulatory program. Without an active state regulatory program, foundries have little incentive to send this material off site either for beneficial use or disposal. Many foundries are piling their spent foundry sand up on their sites, avoiding transportation costs.

One facility in Fort Worth TX processes spent foundry sand for subsequent beneficial use. The processing includes screening the spent foundry sand to remove oversized materials so that the material can be beneficially used.

The plant noted several issues regarding the quality of spent foundry sand depending on the type of foundry producing the material. Spent foundry sand from aluminum foundries has organic compound content, while spent foundry sand from steel and magnesium foundries generally does not. The organic compound content of spent foundry sand, specifically phenolic resin binders, has been identified as an important issue for preheater/precalciner cement kilns because it can generate excess carbon monoxide emissions and potentially affect compliance with air emissions permit limits. Phenolic compounds can also react to form hazardous air pollutant emissions if the compounds oxidize in mid-kiln without reaching the combustion zone of the kiln. This can also potentially affect compliance with air emissions permit limits. Spent foundry sand may also contain chromium, which natural sand does not contain. Therefore use of spent foundry sand in cement kilns would cause the state regulatory agency to look at the

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operation and the potential disposition of the chromium with respect to the potential for hazardous air pollutant emissions.

The capacity of cement kilns to use spent foundry sand in Texas exceeds the amount of available spent foundry sand in Texas; most cement plants charge a recycling fee of $5 per ton for spent foundry sand. The transportation cost for the material is also a barrier to increased use of spent foundry sand in Texas.

The increase in fuel prices and the associated increase in transportation costs have led to more spent foundry sand being used as a "soil amendment." Texas policy on spent foundry sand does not discourage such use of the material, leading to less material available in commerce for potential use in cement production.

Lafarge, Seattle, WA

The Lafarge Seattle cement kiln uses a small amount of spent foundry sand. This material is mixed with petroleum-contaminated soils that are used as an AFR. These materials are used to replace silica. There are no restrictions on permit flexibility related to the use of these materials. The spent foundry sand shipments are set up on a just-in-time delivery. The material is not stored on site, and the plant has experienced no difficulty in transportation or availability of the material. Approximately 40 tons of the material are stored on site at any one time.

The Lafarge Seattle cement kiln is a wet process kiln and has experienced no issues with phenolic resin content in the material, excess CO emissions, or clinker quality as a result of using the spent foundry sand. To obtain the material, the Lafarge Seattle plant works through Systech Environmental Corporation, a wholly-owned subsidiary of Lafarge. The Systech sales representatives located at the plant help find alternative materials, investigate prospective materials, and produce chemical and physical profiles of the materials.

Lafarge, Sugar Creek, MO/Tulsa, OK

The Lafarge Tulsa Oklahoma plant formerly used spent foundry sand from a local foundry; however, the plant experienced material quality issues with the spent foundry sand and discontinued its use by 2004. The Tulsa plant found tramp metal, pig iron and other solid materials in the spent foundry sand that got caught in the raw material mill and damaged the equipment. There was also a neutral cost to get the spent foundry sand material to the plant as compared to mined materials. The Tulsa plant has since installed a screening process that can be used to screen out tramp metal. The screening equipment was purchased for another application, but could be applied to spent foundry sand. The plant is considering using material from the same supplier, and would screen the material first to remove tramp metal. The spent foundry sand feed rate would amount to 1 to 2 percent of the raw mix, about 60,000 tons per year.

The Lafarge Sugar Creek Missouri plant uses approximately 3,000 tons or more of spent foundry sand annually, depending on the available supply. The plant did not report any quality issues or other issues related to use of spent foundry sand.

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DRAFT

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Lehigh Cement, Mitchell, IN/ Fleetwood, PA

Historically Lehigh Cement used a lot of spent foundry sand to supply silica to the kilns. Lehigh Cement is phasing out the use of spent foundry sand because of issues with excess CO air emissions. Spent foundry sand contains volatile organic compounds in the binder materials (oils, phenolic resins) used to make foundry molds. As Lehigh Cement converted their long dry kilns to one-stage preheaters, spent foundry sand was introduced into the preheaters, and the material started to burn off the volatile organic compounds in the preheater. Some Lehigh Cement plants adopted voluntary CO emissions limits in their permits to avoid Prevention of Significant Deterioration (PSD) air emissions review. The spent foundry sand caused CO emissions to increase, approaching the CO l air emissions limits. The Lehigh Cement Mitchell Indiana plant is a long dry kiln; this kiln technology can still take spent foundry sand; preheater kilns are newer technology; these cannot generally take spent foundry sand because of the preheater issues.

7.1.2 Steel Slag

TXI, Midlothian, TX

TXI developed the proprietary CemStar tm process that processes steel slag into a raw material for cement production. TXI recently sold the patent rights to a separate company. TXI researched where the steel plants are in relation to the cement kilns to market CemStar tm to cement kilns. TXI conducted representative raw mix calculations for cement kilns throughout the U.S. and found that there is a constant need for steel slag at cement kilns in most regions of the U.S. except for the Northeast where the limestone quality is "perfect" for clinker, negating the need to supplement raw mix with steel slag.

TXI reported that most steel slag generated in Texas is being used as a raw material in cement kilns. Chaparral Steel (formerly a unit of TXI, and now a separate company) sends their steel slag to TXI. The SMI steel mill in Seguin, TX sends steel slag to Hunter Cement. Some steel slag from Chaparral Steel is also going to Ash Grove Cement, located in Midlothian.

The rate of steel slag feed to the TXI Midlothian cement plant is relatively constant, about 6 percent of clinker production. The maximum feed rate is controlled by product quality. TXI Midlothian cement kiln clinker production rate is increased because of the steel slag. Previously the production rate was 35 tons per hour of clinker for the wet kiln. TXI added 2 tons per hour of slag and is now getting 37 tons per hour of clinker. Steel slag also improves fuel efficiency and reduces cement kiln NO_x emissions.

According to TXI, with the CemStar tm process there is no technical reason for steel mills not to send their steel slag to cement kilns. The material can be easily processed for use in cement kilns using the process. When analyzing the use of steel slag in cement kilns, one must compare the transportation and processing costs with the value of the extra clinker that would be produced and the extra tons of cement that would be produced. Most cement markets are "sold out" (although this is changing somewhat), so cement plants using the steel slag with the CemStar tm process would increase clinker production and cement production by the amount of steel slag used.

CEMEX, Knoxville, TN

The CEMEX Knoxville plant uses mill scale, mixed mill scale, and iron slag as alternative raw materials. Use of these alternative raw materials is not cost issue but a product quality issue. The chemistry of limestone dictates how much sand the kiln needs and how much iron the kiln needs. The chemistry of raw materials mix enables CEMEX to meet standards for customers, product strength profile, etc.

Mill scale used as alternative raw material in the CEMEX Knoxville plant comes from ponds, affecting the quality of the material. Initially, the mill scale material removed from the ponds contained some metallic debris. The plant noted that the metal debris got into the grinding mill and conveyor belts, damaging the equipment.

The material used to be landfilled. The material vendor put in screens to screen out debris, enabling better handling of product and enabling use in the cement kiln. Still, the materials are subject to waste acceptance testing criteria including TCLP {toxicity screening) and heavy metals analysis.

CEMEX identifies sources of alternative raw material through contractors. For the mill scale a contractor was working for the supplier and started looking for potential outlets of the material. The contractor submitted sample of the material to CEMEX for analysis, then CEMEX evaluated the material against their permit conditions and then accepted the supply and established a contract.

CEMEX also works with vendors concerning material supply issues. For example, in the winter months the vendor may have an extra amount of material. CEMEX stores the material and, in return, gets a better price for material. There is less supply of the material in the summer, so CEMEX handles the surge of material. The storage pile of material is turned over within a 12-month period, and material supply changes from week to week or month to month.

7.1.3 Scrap Paper/Wood

Lehigh Cement, Redding CA

The Lehigh Cement Redding, California plant has a long history of burning wood and other biogenic materials. The Redding Plant was first permitted in the 1970s to burn agricultural byproducts; however, the market for this material in cement kilns collapsed in the 1980s because facilities in California started to install wood-fired boilers. The Redding Plant then switched to burning rice hulls. Then, rice hull burning power plants were built in California, and the supply of rice hulls disappeared. It took the Redding Plant four years to get wood back on line, which was a corporate initiative. The Redding Plant is a “small” capacity cement plant (800,000 tons per year of cement) and the plant therefore needs to use alternative materials to remain competitive with larger cement plants.

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In order to reestablish the use of wood, the Redding Plant needed to build a new storage silo and materials handling equipment. The Redding Plant conducted a market evaluation; the plant purchasing department sought suppliers. The only material the plant identified in the vicinity to replace the rice hulls was sawdust from window frame production plants. Sawdust production is tied to the building industry. The sawdust goes into the front of the kiln, displacing coal. The wood at the Redding Plant can represent between 4 to 15 percent of the plant's total fuel consumption, depending upon the availability of supply.

The Redding Plant needed to be repermitted to burn wood, in part because the plant needed to apply capital expenditure to construct the new storage silo, materials handling equipment, and associated air emissions control equipment. The amount of wood that can be burned is based on the results of the performance tests conducted. Because of the repermitting, the plant cannot burn more than 7 tons per hour of wood. Under California Law AB2588, toxic emissions law, the Redding Plant could not get a permit to process more than 15 percent more wood than the amount of wood tested in the trial burn test; the test run was conducted at 5 tons per hour wood. The Redding Plant could permit the plant at a wood feed rate of 8 tons per hour if they conducted a new trial burn test, but there is currently a lower market supply of wood because of the housing market slump. The Redding Plant has a direct contract with the window frame company and is hopeful that the supply of wood will continue from the window frame company.

The moisture content is important to the materials handling characteristics of the wood The Redding Plant had to get new permits to upgrade materials handling equipment to keep material dry. This included installation of new baghouse, extended materials handling system covers, and upgraded hoppers to keep out rainwater. The sawdust tends to seize up in the materials handling equipment when gets wet.

Sawdust, when dry, tends to bridge in pipes, and the dust is explosive, like coal dust. Therefore sawdust is difficult to use. Although not a federal regulation, the equipment modification required state BACT review, including installation of state of the art dust collectors. This made using the material more challenging. Application of the California Environmental Quality Act (CEQA) was not required for the wood because sawdust is cleaner than coal. The Redding Plant has evaluated switching to plastics (the plant could not use plastics and wood simultaneously because of limitations of the materials handling system). If the plant switched to plastics, or MSW, CEQA would need to be implemented because the perception is that these alternative fuels may not be cleaner than coal. The CEQA Environmental Impact Report (EIR) and subsequent permitting could take several years to complete, and even after the process is complete the Shasta County Supervisors would have to vote on the issue, lending uncertainty to the process.

Lehigh Cement, Fleetwood, PA

The Lehigh Cement Fleetwood plant used approximately 9,000 tons of wood in 2007, predominately ground scrap creosote-treated wood. The plant initiated use of wood five years ago. The supplier is a local company that started as a landscaper and became a wood processor; the company approached the Fleetwood plant and asked whether the plant could burn wood. The Fleetwood plant then ran a trial to establish the maximum

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burning rate in the kilns, showing that two tons of wood were needed to offset one ton of coal (wood provides 6,500 BTU per pound, and coal provides 12,000 BTU per pound).

The Fleetwood plant obtained plan approval and established a contract agreement with the wood processor. The supplier sources the wood, processes the wood, loads the processed wood onto trailers, and delivers the wood to the plant on as as-needed basis.

A large capital expenditure was needed to install an "alternate fuel dosing system" for the wood. This system consists of trailers that are run hydraulically through the plant process control system. The wood is unloaded to a bin and conveyor. The bin has a load cell on it, and the conveyor feeds a "Pfister Feeder" that takes the ground wood into rotary feeder and blower. The wood blows into the front end of the kiln right above the coal pipe/burner. The maximum wood feed rate is two tons per hour for each kiln, four tons per hour total. The feed rate can be adjusted by adjusting how fast or slow the dosing equipment runs. There is a separate set of feed equipment for each kiln. The plant noted technical issues with handling wood, particularly with respect to moisture. If the wood gets wet it reduces the calorific value of the material.

The permitting process took several years to complete. In order to obtain plan approval, the plant submitted a "coproduct determination" application through PADEP to get approval to use the wood as a "coproduct." The PADEP Air Board required that the material have a minimum of 5,000 BTU per pound of heat input available to prevent "sham recyclers."

As a permit condition, the plant needs to analyze the wood for metals content. This includes weekly sampling. The operating permit requires sampling of each load of wood. The samples are composited into weekly load samples for calorific value, proximate and ultimate analysis, metals, and other constituents. There are no specific permit limits for these parameters but the plant is required to report the analysis results to PADEP. PADEP could use sampling and analysis reports to provide limits, but the agency hasn't done so, because cement plants doesn't create ash. If the wood was burned in a wood-fired boiler the permit conditions would be different.

The supply of wood is now fairly constant, but the plant anticipates that the supply may disappear sometime in the future. Issues associated with purchasing wood include the difficulty of maintaining wood supply from an economic standpoint. Many companies are looking for wood supply. Wood generators used to pay the cement plant to accept the material; now the cement plant pays the supplier for the material, and the long-term supply of the material is questionable.

The alternate fuel dosing system equipment could be expanded to other alternative fuels. The Fleetwood plant is obtaining leads from the corporate level concerning utilization of plastic; Lehigh Cement plants elsewhere in the US or in Europe also put out ideas that other plants can use with respect to alternative fuel uses.

Lafarge, Sugar Creek, MO

US EPA ARCHIVE DOCUMENT

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The Lafarge Sugar Creek Missouri plant initiated use of plastics, cardboard, rubber scrap, paper, and related materials in March 2008. These materials are being obtained from generators in the greater Kansas City metropolitan area. The plastics, rubber, cardboard, paper, and related materials are all being obtained through direct contracts through different suppliers.

The Lafarge subsidiary Systech conducted a market study to identify suppliers, working with a non-profit "byproducts synergy group" to identify markets for alternative fuel materials. Systech supplies hazardous waste and non-hazardous alternative fuels to the Lafarge plant. The Lafarge plant has also established contracts to use landfill gas from local landfills as an alternative fuel.

The target for the alternative fuel use is 40 to 50 percent of total BTU input to the kiln; this will involve ramp up over two to three years; the interim target for the end of 2008 is 20 percent replacement of total BTU input including landfill gas (10 percent) and solid fuels (10 percent).

A permit modification of the plant air permit was needed to clarify what alternative fuels the plant could use, including plastics, paper, cardboard, and related materials. A permit was also obtained from the local government; this is a "special use permit" which allows the city to tax the use of alternative fuels as a "solid waste facility" operation. Public notification was required, but no public hearing was requested. No changes in air emissions permit limits were needed to introduce plastics, only changes to the list of materials identified in the operating permit that could be burned. The permitting process for the plastics was initiated earlier than the Prevention of Significant Deterioration (PSD) permit process for the entire plant; otherwise the State permitting agency might have been able to ask for lower emission limits in the PSD permit. However, other plants performance tests showed no increase in emissions or reduction in emissions from plastics use.

California Portland Cement, Rillito, AZ / Mojave, CA

California Portland Cement reported that their Rillito AZ and Mojave CA cement plants are permitted to use wood, and have used wood in the past, but that there is little supply of this material in the areas of the two plants and neither plant is using wood at present. The two plants are also permitted to use on-spec surplus oil and surplus jet fuel.

7.1.4 Refinery Spent Catalyst and CSOS

Gulf Coast Petroleum Refineries (Generators)

Clarified Slurry Oil (CSO) is produced at refineries in the Fluidized Catalytic Cracker (FCC) process. The catalyst used results in an alumina/silica-based fines material with no heavy metals content that is suspended in the CSO. When the CSO material is removed from the FCC unit into refinery tankage (slurry oil tanks), some catalyst fines are entrained in the product stream, which later settle in the slurry oil tanks.

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As noted above, the CSO is produced with inherent solids content; the solids that are settled out of the CSO are classified as Clarified Slurry Oil Solids (CSOS). CSO is sold directly to various energy markets as a fuel material (i.e., as a refinery product) with various ash specifications (generally representing the solids content). As the fines (i.e. ash) content increases in the CSO above certain ash specifications, market outlets become limited and refineries cannot sell the material directly into conventional markets such marine fuel (i.e., bunker fuel) or carbon black feedstock. Therefore there is an economic incentive for the refineries to separate the CSO from the CSOS. Refineries let the CSO material settle in the slurry oil tanks, the oil is then pumped out and is sent to traditional energy markets as a refinery product. The value of the CSO as a refinery product is based on the solids content, the higher the solids content, the lower the value of the material. Once the solids content of the CSO reaches about 0.7 percent the value of the material to potential customers decreases substantially.

The settled material remaining at the bottom of the slurry oil tanks is considered CSOS – CSOS is a listed hazardous waste (K170), Historically this material was landfilled; however, now refineries avoid utilization of landfills as a matter of corporate environmental policy. Centrifuged CSOS "cake" can fail EPA land disposal restrictions test for semivolatiles, and the material cannot in any case be sent to a landfill. The material is generally managed onsite at the refinery, such as by reprocessing the material back into the cokers (thermal treatment). One incentive of refineries reinjecting the CSOS into the cokers is that the refineries then do not have to classify the material as a waste. Since material processed onsite at the refinery is not classified as a "waste," it is not reportable wither in the RCRA Biennial Hazardous Waste report or the annual TRI reports.

Some refineries have sent their CSOS (as a hazardous waste) to cement kilns for energy recovery. Systech (Lafarge) cement kilns in Fredonia KS and the TXI cement kilns in Midlothian TX, among other cement kilns, are permitted to accept K170 hazardous waste. The CSOS provides the cement kiln with both energy content and raw material content (alumina, silica). Typically cement kilns first analyze an initial sample of the material to ensure that they are permitted to accept the material, and then may analyze additional samples in the event that the characteristics of the material change (e.g., there is a change in the solids content of the material as generated by the refinery). Data concerning the amount of CSOS (K170 waste) transferred to cement kilns for energy recovery is included in the main section of this report.

The CSOS is not generated on a continuous basis; tank cleanouts are conducted as a batch process. Typically, refineries remove CSOS from their each of the slurry oil tanks every ten years or so. These settling tanks are on the order of one million gallons each; a typical large refinery can generate over one million pounds of K170 waste per year depending upon the schedule of tank cleanout. The CSOS material is typically slurried out of the settling tank and the solids are sent to 20 cubic yard roll-off boxes. The liquid becomes (low solids content) CSO product, and the solids removed become CSOS.

According to refinery contacts there is an outstanding and fundamental question regarding the point at which the CSOS becomes "hazardous waste" in the CSO settling and CSOS removal process. CSO is not hazardous waste, it is a refinery product, however, CSOS is classified as a hazardous waste. "Wet" FCC catalyst that is removed directly from

US EPA ARCHIVE DOCUMENT

DRAFT

the fluidized catalytic crackers during catalyst replacement isn't classified as hazardous waste either, and cement kilns use this material as a non-hazardous alternative raw material. Spent FCC catalyst is classified in Texas as "Class II non-hazardous waste" and is being recycled into materials used for road bed construction in Texas. This material is a major alternative raw material from petroleum refining to cement manufacturing.

A fundamental regulatory question is where (at what physical location within the CSO settling tank) is the catalyst material first classified as hazardous waste? According to the refineries, EPA OSW has not directly answered this question. The refineries suggested that the most direct approach to defining CSOS as a non-hazardous waste is through the EPA "definition of solid waste" (DSW) regulatory process. If CSOS is deemed by EPA not to be a "solid waste" when beneficially used, the material inherently cannot be classified as a hazardous waste either. The refineries pointed out that CSOS was originally listed by EPA as a hazardous waste because of its chromium content and poly-aromatic hydrocarbon (PAH) content, and that the material was originally considered for listing as a hazardous waste because the material was historically being landfilled. However, the PAH content in this material (just as the PAH content in any other commercial fuel) is not a technical issue for processing of CSOS in cement kilns for energy recovery. Therefore, according to refinery contacts, there is a basis for reclassifying CSOS used as an alternative fuel or raw material as a refinery product rather than as a solid waste.

Reinjection of CSOS into the cokers is recognized by refineries as a less optimum use than cement kilns would be, but refineries do this to avoid having to classify and report the material as a hazardous waste. Refineries have to use energy to prepare the CSOS material to go back to the cokers or incur the cost of centrifuging the material. They would generally prefer being able to sell the material to cement kilns without further processing. The refineries have identified transport trucks that can transport unprocessed CSOS as a "free-flowing" material. Such cost savings are of no value, though, as long as CSOS is classified as a hazardous waste. Refineries have estimated that if the CSOS were not classified as a hazardous waste the refineries could save more than $1 million per tank cleanout from the increased value of the CSOS and avoidance of the onsite management costs (i.e., the processing cost of slurrying the material out of the tank and centrifuging the material for reinjection into cokers). The cost of sending the CSOS to a hazardous waste landfill is about $150 per ton. Therefore, refineries are incurring higher cost to avoid having to dispose of the CSOS as hazardous waste in landfills.

Refineries have been discussing CSOS supply with cement companies. The acidity of the CSOS has so far not been an issue for the cement kilns; however, cement kilns as customers want to know the sulfur content, mercury content, and calorific value of the CSOS, and whatever other characteristics of the material that the cement companies could impact air emission control system. The cement kilns want material that is in the range of 9,000-10,000 BTU per pound, and can accept material with up to 20 percent solids content. However, centrifuged CSOS (which is about 70 percent solids) can range from 8,000-9,000 BTU per pound, because the centrifuging process removes some of the oil content (the slurried material prior to centrifuging is about 20 percent solids). The centrifuged CSOS can be transported to cement kilns on trucks in roll-off boxes. The centrifuged material is tipped into a screw conveyor and mixed with other liquids at the cement kiln to make a slurry to inject into the cement kiln.

US EPA ARCHIVE DOCUMENT
DRAFT

The refineries noted that because of the batch nature of the slurry tank management process that generates CSOS, a single refinery would not generate sufficient material to supply a cement kiln on a continuous basis. However, the refineries also noted that if several refineries coordinated their tank cleanout schedules and perhaps also worked through a third party consolidator, the refineries collectively could generate sufficient material to continuously supply a cement kiln. Refineries are also developing methods of modifying their settling tank operating procedures; rather than operate the settling tank to build up solids (CSOS) and allow them to settle, the tank could be operated with CSO with higher solids content without letting sediment build up in the tank. The operating concept is to sell the CSO with the higher solids to markets (e.g., cement kilns); maybe then the refineries pump out solids once a year rather than once every ten years. Refineries may also contract out the management of the settling tanks to third parties. The third party would manage removal of the material from the tank and return the "empty tank" to the control of the refinery.

The refineries indicated that transportation costs preclude long-distance transport of CSOS, but that the material can be transported on a regional basis. The refineries supported the concept of a regional workshop with the cement companies to discuss generation and management of the CSOS.

Motiva, Norco LA (generator)

Motiva Norco typically sends 4,000 tons per year of FCC catalyst to the Holcim Theodore cement kiln rather than to a landfill. Since the material is a dusty powder, it is managed and transported in pneumatic trucks. This form is compatible with the pneumatic feed system at the kiln and maximizes the tonnage per truckload. Overall economics make this practice competitive with landfilling. The spent catalyst material is about 75% aluminum oxide and silicon dioxide.

The challenge in using the material was to set up a management system that could turn several smaller loads of granular or damp catalyst material into a larger load of uniform composition that could be easily transported and handled in silos, conveyor belts, and pulverizers of the cement kiln. The concept of stockpiling and mixing the materials together worked to achieve the uniformity and handling properties needed. In addition, reusing the larger load was cheaper or competitive with the cost of landfilling. Motiva conducted trials to demonstrate material compatibility over a period of many months. Motiva Norco initiated use of this material as a kiln feedstock when it barged 3,900 tons of a mixture of spent material to Holcim Theodore in August, 2006.[209]

Refineries generate a variety of materials (spent sandblasting media, granular catalyst beads, support balls, catalyst fines filter cake) that can be commingled to achieve a mixture that can be easily managed by conveyor belt systems. In addition, commingling enables blending of the chemical properties so that the material becomes more uniform chemically and physically. Stockpiling materials over several months promotes uniformity and large enough quantity to facilitate the variety of catalysts and other materials generated by the refinery.

DRAFT

US EPA ARCHIVE DOCUMENT

Marathon Oil, Houston TX (generator)

Marathon Oil has seven refinery locations: St. Paul Park, MN; Detroit MI; Canton OH; Robinson IL; Catlettsburg KY; Garyville LA; Texas City TX. The Marathon Oil refineries generate CSOS. The slurry oil tanks are "flow through units" in which the CSOS collects. The slurry oil tanks are typically cleaned out on 10-year cycle. CSOS can be a difficult material to handle since it may be thick and sticky or gummy. In some cases, the material needs to be "excavated" from the slurry oil tanks. Less labor is involved with continuous slurrying rather with periodic cleanout. Refinery service companies have proprietary technologies for slurry oil tank management, and some refineries are changing practices to continuously remove solids from the tanks rather than removing the solids periodically. This is referred to as "continuous slurrying." However, Marathon Oil is not yet convinced that these proprietary processes are proven technology and is still investigating them.

One Marathon refinery conducted slurry oil tank cleanout projects in 2001, 2002, and 2008. This refinery generated approximately 4 to 5 million pounds of CSOS per tank on cleanout; another refinery removed almost 7 million pounds of CSOS material in 2007. This refinery, in Illinois, shipped the CSOS to Canada. Canada permits landfilling of this material after stabilization. There is no land disposal ban in Canada at present, but the CSOS is still classified as a hazardous waste in Canada. Land disposal restrictions are coming into effect in Canada in 2009, and material would then need to be treated before disposal.

The Marathon Oil refineries in Detroit, MI, Catlettsburg, KY, and Robinson IL, are within reasonable transportation distance to the disposal facilities in Canada. Marathon Oil is continuing to work with disposal facilities in Canada to meet the land disposal ban requirements. The material first would be treated in the U.S. Alternatively, starting in 2009 the material generated by the Illinois refinery could be incinerated in US. However, hazardous waste incineration cost is 2 to 3 times more than landfill cost.

Marathon Oil has established a corporate goal for waste management to choose onsite management first; then fuel blending for energy recovery; then disposal in a landfill or an incinerator.

Marathon also operates two refineries in Gulf Coast, Garyville, LA and Texas City, TX. These refineries have not conducted tank cleanouts in the past seven or eight years. Previously the Gulf Coast refineries either disposed of the CSOS through incineration or by transport to Canada. The Texas City refinery has worked with the Clean Harbors hazardous waste incineration facility in Deer Park TX for incineration of CSOS. Clean Harbors or a subcontractor is also the transporter of the CSOS as a hazardous waste transport common carrier.

Marathon has investigated sending the CSOS to cement kilns for energy recovery. The CSOS material is a "solid" at certain conditions, but it can be liquefied depending upon how much oil is left in it. Marathon refineries could slurry the material and ship the material to a fuels blending facility in a tanker truck. The blending facility would need "stirred tank" to process the material into alternative fuel. Marathon has had discussions with vendors, but has not done any projects with them yet.

US EPA ARCHIVE DOCUMENT

DRAFT

Some of this CSOS waste from the St. Paul Park, MN refinery is generated on a continuous basis; the generation rate is approx. 1,000 pounds per month. They will generally try to recover oil from the CSOS and return that oil to the refinery for processing, using a sieve trap to filter the oil; the filter collects fines from oil, and the fines go into a drum. The CSOS generated from this refinery has more oil in it than CSOS generated at other Marathon Oil refineries because of the continuous slurry processing. CSOS has been sent from the St. Paul Park refinery through SYSTECH to the Lafarge Fredonia KS cement kiln.

The Garyville LA refinery is considering continuous slurrying technologies. A refinery service company (TRADEBE Company) has a proprietary technology for slurry oil tank management. Under this proposal the service company, as a third party, would manage the tank for the refinery. The Garyville, LA refinery has a secondary oil recovery unit that should be able to treat the CSOS from tank cleanouts on site. This is high temperature sludge treatment unit. Marathon is investigating installing a similar process at Catlettsburg KY refinery. The Garyville refinery process treats the API separator sludges and other refinery wastes. The CSOS would be a small part of the total feed to the sludge treatment unit.

Marathon Oil also generates non-hazardous spent FCC catalyst and is looking to send this material to cement kilns also. The Texas City refinery generates approximately 11,000 tons per year of spent FCC catalyst. This material is now being landfilled at a cost of $20 per ton.

Ash Grove Cement, Foreman AR; Chanute, KS

Ash Grove Cement operates hazardous waste-permitted cement kilns at Foreman AR and Chanute KS. These facilities are permitted to accept hazardous wastes, including CSOS, and occasionally accept CSOS for use as an alternative fuel. These facilities formerly accepted refinery waste "tank bottoms", which were delivered to the cement plants in roll off boxes. Ash Grove ceased accepting this material when the regulatory status of the material changed in 1995 and the material was deemed non-hazardous waste. Ash Grove could no longer charge a fee to accept the materials, and therefore the cost of continuing to use the material as an alternative fuel was cost-prohibitive.

Ash Grove has maintained permits for burning hazardous waste in the Chanute KS and Foreman AR plants since mid-1980s. The Chanute plant obtained the first "Boiler and Industrial Furnace Rule" (BIF) permit issued in the U.S., and the Foreman plant obtained a BIF permit shortly afterward. The BIF Standards were replaced by the Hazardous Waste Combustor (HWC) MACT standards, so all of the hazardous waste-burning cement kilns were required to obtain a new permit. Ash Grove rebuilt the Chanute plant after the HWC MACT standards were issued, and the Chanute plant had to comply with the new HWC MACT Standard at startup in 2001.

The number of cement kiln hazardous waste combustors has been decreasing nationwide because of public perception, and EPA enforcement and regulatory requirements. Public perception can affect the ability of cement kilns to use alternative fuels and particularly solid and hazardous wastes. For example, Montana has state regulatory requirements

US EPA ARCHIVE DOCUMENT
DRAFT

prohibiting use of alternative fuels that are solid wastes in cement kilns. Montana citizens in particular are very active, and oppose even using scrap tires in cement kilns. There are now 18 permitted hazardous waste combustor cement kilns in the U.S.

The cost for maintaining a hazardous waste combustor permit includes the cost of monitoring and testing. This includes performance testing (stack testing) under the hazardous waste combustion NESHAP. Routine testing is required every 2.5 years, full Comprehensive Performance Testing (CPT) is required every five years, and full risk assessment is routinely required every 10 years. This involves reevaluating the prior risk assessment for the facility, conducting a screening-test risk assessment, evaluating any changes in the emissions and how changes may affect risk assessment results. Either the facility passes the risk screen or has to revise the risk assessment. Such revisions are an expensive process.

The cost for obtaining a hazardous waste combustor permit for a newly-permitted cement kiln would be on the order of several million dollars including permitting, risk assessment, and performance testing. Cement plants that are not already permitted would not spend several million dollars to obtain a new hazardous waste combustor permit just to burn refinery CSOS. It is highly unlikely that any cement plant that had not been burning hazardous waste prior to the HWC MACT standards (i.e., the cement kiln was previously permitted under the BIF rules) would obtain a hazardous waste combustor permit; this would be difficult both from a public perception standpoint and from a cost standpoint. Therefore, the number of cement kilns permitted as hazardous waste combustors is not expected to increase.

Ash Grove uses a third-party supplier (Cadence Environmental Energy) to supply alternative fuels to their cement kilns and does their own fuel blending. Cadence has no physical facilities; they operate sales staff and call on large hazardous waste generators, facilities that are producing hazardous waste manifests. Cadence is an independent company, not a subsidiary like Lafarge/Systech and Holcim/Geocycle.

7.1.5 Wastewater Treatment Sludge (biosolids)

CEMEX, Victorville, CA; Vexor Fuels, Medina OH

Vexor Fuels, an engineered fuel supplier to cement kilns, conducted a performance testing using biosolids at the CEMEX Victorville, California cement plant. The performance test baseline was a kiln feed rate of 10 tons of coal per hour; using biosolids the coal feed rate dropped from 10 to 3 tons per hour, with good emissions results.

A driver for biosolids beneficial use in California is landfill costs. Generators cannot landfill biosolids in California. The material has to be first dried at temperatures of at least 60 ° C to generate "Class A biosolids." Energy is needed to dry the material. Some biosolids generators are using a combination of filter presses and driers to dry the material. The dried biosolids has good ash content for cement kilns, including silica. The dried biosolids has 7,000-8,000 BTU per pound. The transportation cost of the dried material is also lower; generators are not paying to transport the water.

US EPA ARCHIVE DOCUMENT

DRAFT

US EPA ARCHIVE DOCUMENT

Vexor Fuels also identified a number of other ongoing biosolids projects, including a New Jersey project to dry biosolids to the consistency of sand; this project may be supplying cement plants in Evansville IN and Union Bridge MD. Vexor Fuels also reported that the Union Bridge MD cement kiln is obtaining biosolids from Baltimore City. The Synagro Company is drying the material for the Union Bridge cement kiln.

Lehigh Cement, Fleetwood, PA

As discussed above, the Lehigh Cement Fleetwood PA cement kiln is investigating the use of biosolids potentially as an alternative to wood. The plant is currently conducting a trial to burn dry biosolids from municipal wastewater treatment plants. There is less moisture in biosolids (less than 10 percent) than there is in wood; the calorific value is about the same as wood, and the economics are about the same as wood.

The Synagro Company already has sludge dryers on line and is putting more dryers on line; the City of New York already has sludge dryers on line. The Union Bridge MD plant is already permitted to burn this material;

The Fleetwood plant considers biosolids to be a potential future material, and considers wood to be a past material to be phased out. Permitting of biosolids may not be any different than permitting wood; the plan approval for this material has been accepted by PADEP, and local municipalities are already on line to provide biosolids.

Lehigh Cement, Redding, CA

The Lehigh Cement Redding plant is evaluating use of biosolids, but has not conducted any performance testing. The plant material handling system, which is used now for wood (sawdust), could also be used for biosolids but the Redding plant considers sawdust to be a more secure market at the moment. The Redding plant expectation is that public involvement for biosolids would be more difficult than for sawdust. The plant can't burn sawdust and biosolids at the same time using the same materials handling system so the plant would have to give up burning sawdust to burn biosolids. Redding has a population of approximately 80,000 people; Shasta County has a population of approximately 150,000 people. Redding is two to three hours from Sacramento and Bay Area, which are the major sources of biosolids in the area. There would therefore be additional materials transportation costs to obtain a sufficient supply of biosolids for the plant. The sawdust generator is much closer to the Redding plant than are the biosolids generators.

7.1.6 Plastics

Lafarge, Sugar Creek, MO

The Lafarge Sugar Creek Missouri plant initiated use of alternative fuels including paper, cardboard, plastics, and related materials in March 2008. The plastics are not derived from C&D debris or post-consumer plastic (municipal solid waste) but from industrial plants. One issue that the cement plant encountered with the plastics was how to get plastics sorted adequately. The cement plant needed to develop an understanding of the

DRAFT

industry practices and design a sorting process so that PVC plastics are separated from the other plastics.

The Sugar Creek plant permit has a chlorine limit, one reason why PVC plastic is not desired. The plant runs tests on the plastics streams for a number of characteristics including chlorine content and hazardous constituents. The plant will reassess the materials acceptance procedures as plastics shipments start coming in from different suppliers, but the intent is not to sample each and every incoming load considering that there maybe ten or twenty different suppliers with separate contracts.

Plastics shipments are processed on site, with a "two path shredder" system to 2 inch minus size. The materials handling system includes a warehouse, and storage and conveyor systems to transport the material to the preheat tower. The plant spent on the order of $7 million for capital equipment. The original market studies were initiated in April 2006 and the plastics came on line in March 2008.

TXI New Braunfels, TX

TXI is working on a demonstration project at their New Braunfels, TX plant with company that procures plastics for cement kilns. TXI previously conducted a performance test in Midlothian using refuse-derived fuels. The refuse-derived fuel test was conducted with material from Minneapolis for a thesis test in 1993. The test demonstrated that the cement kiln could burn RDF within permit limits and without an increase in pollutant emissions. New Braunfels is scheduled to conduct a trial burn using RDF in mid-2008.

One barrier for cement kilns using RDF in Texas is that it is very inexpensive to landfill MSW plastic material. Landfill costs in Texas can be as low as $10 per ton. Therefore, it takes a lot of momentum and incentives to get a municipality to sort plastics to make RDF. Plastics must be sorted separately from general trash; chlorinated plastics and non-chlorinated plastics must be sorted separately to make RDF for cement kilns. Municipal governments would bear the capital and operating cost of sorting the plastics, TXI is investigating how to collaborate with municipalities and provide incentives to get municipalities to do this. The sorting would eventually pay for itself in fuel and potentially also carbon cost; use of RDF as an alternative to landfilling the MSW is a climate change issue for avoiding generation of landfill gas CO_2 and CH_4.

Lehigh Cement, York, PA

Vexor Fuels manufactured "plastic fuel" for Lehigh Cement for a performance test and the test was successful. However, Lehigh Cement initially could not obtain a sufficient amount of plastics from the market for full-scale introduction of plastics because the plastics generated in the local area are being recycled into new plastics. This is a waste management hierarchy issue, and is common to other alternative fuel materials that can be recycled into new products.

The Lehigh Cement plant in York Pennsylvania is a White Cement plant. The York plant is about 1/10 the size of a gray cement plant. The York plant uses plastics as an alternative fuel. This material is a high-calorific value material, but Lehigh needed to organize 10

US EPA ARCHIVE DOCUMENT

DRAFT

suppliers to get sufficient quantities of the material for the York plant. It would be more difficult to organize a sufficient number of suppliers to supply a gray cement plant with plastics than a white cement plant 1/10 the size. These plastics being used are not recyclable and otherwise would have been landfilled; i.e., these are materials that would not otherwise get into the recycling stream. The material is received at the plant already shredded.

Initially the plant had a supply problem with the plastics supply; has worked out this problem and is now working on technical issues. For example, the existing conveyor system is not adequate to convey material, delivery feed problems being addressed. White cement plants are even more difficult to feed alternative materials than gray cement plants, because white cement plants cannot feed anything that would affect the whiteness of the cement.

Pennsylvania Department of Environmental Protection

The Pennsylvania Department of Environmental Protection (PADEP) has a grant-making economic development agency that works with AFR generators but does not have a very active market program to identify suppliers and users of plastics. One view is that the private sector is better at matching suppliers and users than agencies are. The PADEP contact did acknowledge that MSW plastics recycling rates are not high in Pennsylvania and that too much of this material going to landfills. This material could otherwise be use as alternative fuel and reduce the demand for fossil fuels. State/local governments in Pennsylvania are currently recycling only plastics recycle grade 1 and plastics recycle grade 2. Existing recycling processes cannot segregate plastics recycle grade 5 and plastics recycle grade 6 from the plastics stream. This type of segregation is needed for segregation of chlorinated plastics from non-chlorinated plastics because chlorine affects the quality of the cement.

Permitting for alternative fuels for the Lehigh Cement plant did not encounter much opposition. The plant is subject to PCDD/PDCF limits; but these emissions are lower with alternative fuels than with coal. In addition, there are fewer "shooting events" (startups and shutdowns) with alternative fuels than with coal. If a cement kiln is contracted to make 100 tons of clinker, the kiln potentially needed to make 120 tons if startup and shutdown makes 20 tons of off spec product. The use of alternative fuels makes the quality of fuel more consistent, and therefore less off spec product is produced.

7.1.7 Scrap Tires

Holcim/Geocycle, Midlothian TX/Ada OK

Geocycle is a wholly owned subsidiary of Holcim and is responsible for sourcing and processing alternative fuel and raw material feedstocks and supplying the Holcim cement plants with alternative fuels and raw materials. Both the Midlothian Texas and Ada Oklahoma cement plants are completely non-hazardous with respect to the materials that the cement plants are permitted to accept.

DRAFT
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The Midlothian plant is primarily a coal-fired plant; the plant started using petroleum coke last year. The Midlothian plant includes two kilns, each a four-stage preheater precalciner kiln. The current plant fuel mix includes:

- 20 percent petroleum coke,
- 15 percent alternative fuels
- Remainder coal

The Ada plant is primarily a coal-fired plant. The plant includes two wet process kilns. The current plant fuel mix includes:

- Petroleum coke 25 percent
- Alternative fuels 20 percent (almost all tires)
- Remainder coal primarily

The Midlothian plant is currently coprocessing tire chips; wood, spent activated carbon, spent filter cake solids, and oil filter fluff (described below). The Midlothian plant is also permitted to coprocess used oil, glycols, and glycerin. In terms of calorific value, the alternative fuels used in the Midlothian plan are primarily TDF, oil filter fluff, and wood. TDF and oil filter fluff are higher percentage in terms of heat input because these materials have a higher calorific, wood is a lower percentage in terms of heat input because wood has a lower calorific value. The tire chips, wood, and oil filter fluff market supplies are relatively stable. The tire chips derive from the Holcim/Geocycle Ada Oklahoma plant where they have a tire chipping plant. Geocycle hauls 25 tons in a truck, one way transportation is about 180 miles. Geocycle backhauls another material to Ada from Midlothian to decrease cost of shipping the tire chips.

Scrap tires are chipped in Ada and transported to Midlothian because the scrap tire supply in Ada does not perfectly match whole tire consumption (demand) at Ada. The “safety valve” for surplus scrap tire supply in Ada is chipping the scrap tires and transporting the tire chips to Midlothian.

Tires are not available in the open market in Oklahoma. Oklahoma runs the tire program, under the Oklahoma DEQ. Post consumer tires pay $1 per tire; this funds the Oklahoma Tire Fund. The processors, end users, and transporters of tires are all covered by the program, but very confusing legislation and implementation. At the end of each month each tire transporter and tire processor/user sends a report to state and applies to state for funds for tires handled. The State pays out money every month. If the program is over funded or under funded in a particular month, the state balances this out in dispersing the funds. The transporters are paid first; then the processors and end users are paid. Therefore, the transporters try to control the supply because they are paid first.

There are two crumb rubber operations in Oklahoma, and several cement kilns in Oklahoma are using tires. One company is also using tires as erosion control on riverbanks. Tires are therefore a stable market but also a dynamic market.

Lafarge, Seattle WA

US EPA ARCHIVE DOCUMENT

DRAFT

The Lafarge Seattle WA wet process cement plant was using chipped scrap tires as an alternative fuel until 2006. Prior to 2006, whole scrap tires could not be disposed of in MSW landfills. Therefore, suppliers chipped the tires and provided the chipped tires to local customers including the Lafarge cement plant. A change in local regulations in 2006 allowed the disposal of "quartered" scrap tires in MSW landfills. Quartering and landfilling the scrap tires is relatively inexpensive compared to the cost of the energy-intensive process to chip the scrap tires. After the change in the local regulation, suppliers did not have an economic incentive to continue chipping tires, and chipped tires became unavailable. The Lafarge plant was informed that suppliers would send not be sending the plant any additional shipments of chipped tires by the truck driver who brought the final shipment of chipped tires to the plant. The Lafarge plant decided to modify the kiln by installing a kiln chute so that the kiln could accept whole tires instead of chipped tires. The capital cost of this modification was about $4 million, not including the cost of permitting and performance testing. Therefore, this local regulatory change cost the cement plant $4 million to maintain the use of scrap tires in the cement kiln.

The local regulatory agency, the Puget Sound Clean Air District, is responsible for air emissions permitting for the Lafarge Seattle plant. The objective of the kiln modification was to achieve 20 percent replacement of calorific value with whole scrap tires, on the order of 1.5 tons per hour of scrap tires. The draft permit (notice of construction) required a complete series of trial burn performance testing. The test program was based on a certain period of time with conducting 5 individual stack testing events including baseline and four other tests. Initially the permit modification had hard and fast dates in it for scheduling and conducting the performance tests. Lafarge worked with the local permitting agency to change these. The original dates would have made it too difficult for management to make decision concerning the capital expenditure. The change to a flexible date for the performance testing: "x days from complete installation of the equipment" saved the project, because management had time to make a good decision.

Washington Department of Ecology
Solid Waste and Financial Assistance Program

There is no statewide prohibition on landfilling of scrap tires in Washington. Municipal governments that operate MSW landfills control regulations on landfill disposal of scrap tires. Some municipal landfills accept scrap tires and quarter them for disposal. Washington DOE does not provide any support at the state level for scrap tire management. Washington cannot provide financial assistance for management of scrap tires and cannot collect "dollar per tire" consumer fees, because of a prohibition in Washington Constitution concerning the collection and distribution of such fees. The state can support pilot testing programs. For instance, there is some crumb rubber research and pilot testing work underway, and the Washington Department of Transportation has a "quiet road test" using rubber-modified asphalt, and the City of Bellevue is initiating a program to use "crumb rubber" rubberized sidewalks for tree plantings.

Puget Sound Clean Air Agency

DRAFT

US EPA ARCHIVE DOCUMENT

For the whole tire kiln modification project, Lafarge applied for a permit to burn whole tires. The local regulatory agency required performance testing because there were "unknowns" related to the potential effects on cement kiln emissions. For the performance test, there was limit on the duration of the test and the amount of scrap tires that could be used during the test. The performance test was conducted for demonstration of compliance with the cement plant MACT rule and chlorinated dioxin and furan emission limit. The amount of scrap tires the cement plant can burn per hour will be based the results of the performance test. The cement plant would be issued a construction approval for that amount of tires, included in the cement plant Title V operating permit. The cement plant needed to obtain a notice of construction because the cement plant needed a capital modification to convert the cement kiln to burn whole tires. If capital expenditure had not been required, the agency could have implemented the "15-day" rule under EPA MACT Rule for testing of new materials.

California Portland Cement, Colton, CA

The California Portland Cement Colton California plant is a long dry kiln that is permitted to use coal, petroleum coke, natural gas, fuel oil #6, fuel oil #2, and whole scrap tires. The scrap tire feed rate for Colton plant is at a "target" of 2 tires per revolution (i.e., two tires every 90 seconds) to replace approximately 50 percent of cement kiln fuel requirements. Petroleum coke is obtained from local refineries and also from offsite locations. The petroleum coke market in California is becoming more expensive, and most petroleum coke produced in California is therefore exported.

The ability of the Colton plant to obtain a scrap tire permit from the South Coast Air Quality Management District (SCAQMD), the regional agency responsible for permitting for the Colton plant, is specifically related to the economics of burning scrap tires and the technical aspects of tire burning. The Colton plant gets paid to use the scrap tires, and thus gets paid to use the BTUs. Also, the use of scrap tires reduces the NO_x emissions from the plant, and scrap tires are therefore categorized as a NO_x control strategy. This made the permitting of scrap tires much more palatable for the agency. Scrap tires are now mandated in the Colton Plant air permit as a NO_x control strategy for plant.

California Portland Cement spent maybe $500,000 in air toxics emissions testing for "before tires" and "after tires" in order to secure the scrap tire permit from the SCAQMD. SCAQMD would require similar "before" and "after" air toxics testing for any other type of alternative fuel, so the economics of alternative fuels do not work for the plant, except for scrap tires.

California Integrated Waste Management Board

The California Integrated Waste Management Board (CIWMB) is responsible for regulation of non-hazardous wastes in California. The CIWMB estimates that close to 40 million scrap tires per year are generated in California and approximately 10-11 million scrap tires are going to landfills annually in California. There are several beneficial use applications of scrap tires in California:

- Crumb rubber for sidewalks

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- Field turf applications, recreational surfaces, playgrounds
- Larger chips for lightweight fill for Caltrans transportation applications
- Smaller chips for vibration attenuation for rail applications
- Construction aggregate projects
- Landfill alternative daily cover
- TDF for cement kilns/power generation

The CIWMB conducts a study of scrap tire management and generates an annual report. The agency does market development and studies to divert tires from landfill disposal, and has an annual budget of $30 million for market development efforts. Historical stockpiles of scrap tires in California have been largely worked off – there were two large tire pile fires in California in the late 1990s and early 2000s. Larger tire piles (millions of tires) have now been cleaned up by state agencies or by landowners, smaller tire piles still exist to be worked off.

Many of the projects that the CIWMB issues grants for are transportation infrastructure projects conducted through local government agencies. The CIWMB issues grants to local agency for these types of projects. Construction aggregate projects are not developed enough for the CIWMB to give out grants yet; these are demonstration projects only at present. Tire-derived product projects are mixed local government and private entity projects. Grants are available for from the agency for these projects also.

Grants are no longer available from the agency for supporting the use of TDF in cement kilns or electric power generation. The California state legislature passed a statute that changed the law three or four years ago to prohibit agency grants to TDF projects. This was part of the public resource bill – the bill created refunding of the CIWMB tire program and raised the consumer scrap tire fee to $1.75 per tire. The reauthorization restricted grants to TDF projects. The premise of the restriction is that TDF projects don't need to be subsidized. TDF as an application for scrap tires would exist even without any CIWMB intervention. However, a subtext here is that some legislators opposed expanding the use of TDF in cement kilns/power generation applications.

In California, scrap tires must be shredded or baled in order to be landfilled, but otherwise municipalities operating landfills set prices/practices for scrap tires to be landfilled. Scrap tires can also be processed into "alternative daily cover" for landfills. From an engineering standpoint scrap tires cannot be landfilled whole because they don't stay in place if they are whole and affect the integrity of the landfill structure.

The consumer fee for scrap tires is $1.75 per tire. Of this fee, $0.75 goes to the California Air Resources Board (CARB) for their diesel fuel engine research program; the rest of the fee goes to the CIWMB.

Lehigh Cement, Redding, CA

The Lehigh Cement Redding California cement kiln is a dry process plant that formerly used chipped scrap tires; the plant then switched to whole scrap tires. The whole scrap tires are put into the riser duct of the four-stage preheater. In some cement plants this is

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equivalent to a precalciner. The scrap tires are used to replace coal at approximately 20 percent of fuel usage, approximately 1.75 to 2.5 tons per hour. The plant is feeding the maximum amount of scrap tires; increasing the feed rate would affect the pyroprocess and heat load and would affect product quality. There is no limit in plant operating permit on the scrap tire feed rate; but the plant is burning as many scrap tires as they can burn. The plant is permitted as a tire recycling facility. A third party on site supplies the scrap tires; these include truck tires and small tires as well as automobile tires.

The Redding plant was expanded in 1982; 800,000 tons per year of cement production capacity. Now Redding is a "small" cement plant; tires are important to keeping the plant running and keeping up with competitors.

Burning scrap tires lowers NO_X emissions, and scrap tires are a cleaner fuel than coal. The Redding Plant has periodic stack test data; the stack test data has been provided to the state regulatory agency in Sacramento. Nearly half of cement plants in California are permitted to burn scrap tires, however only two are doing so. The California climate change statute AB32 could not "mandate" that cement kilns use scrap tires because some plants cannot burn scrap tires for technical reasons.

The Redding Plant has experienced no community relations issues with respect to their use of scrap tires or with respect to other issues. The California Environmental Quality Act (CEQA) affects scrap tire and tire-derived fuel projects and other alternative fuel projects such as plastics. This is because plastics fuel and scrap tires are viewed by regulatory agencies as "not necessarily cleaner" than coal and therefore potential environmental impacts need to be demonstrated. For a new alternative fuel application, it could take several years for the CEQA-required Environmental Impact Report (EIR) to be approved. Preparation of the EIR and other state permit application documents for a new alternative fuel application could cost $250,000 - $500,000.

The California Integrated Waste Management Board regulates scrap tire usage and also regulates non-hazardous solid waste landfills. The CIWMB charges $4 per tire for tire management. The state legislature recently passed regulations so that cement plants cannot apply for grants for tire-derived fuel projects anymore. In 2005, the Redding Plant installed an automated system for tire feed based on 2004 grant, including installing a sorting hopper to replace a manual sort system. Grants are no longer available to cement kilns for these types of projects. Grants can still go to crumb rubber and other scrap tire uses. Most cement plants in California also operate aggregate plants. The aggregate is used in asphalt plants, and crumb rubber goes to asphalt plants among other applications. Chipped tires can also be used in playground construction and other applications. Scrap tires can also be landfilled in California.

California is a "free market" with respect to scrap tires. The Redding plant anticipates that despite the competition for scrap tires, scrap tires will continue to be available to the plant if a free market environment for scrap tires is maintained.

CEMEX, Knoxville, TN

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The State of Tennessee has an active scrap tire management program, and the State Agency approached the CEMEX plant about eight years ago concerning their ability to use scrap tires. The plant is using about the same amount of scrap tires now as it was then. Scrap tires are a significant source of heat input; somewhat less than 5 percent of heat input to the cement kiln is scrap tires. The plant is permitted to burn three tires a minute, but the plant can only burn one tire a minute because of process limitations. While studies have been done to increase the throughput of scrap tires, capital expenditure would be needed to improve the rate, and no decision has been made as to whether to make the capital expenditure.

The scrap tires are supplied by a third party supplier. The State scrap tire management program gets a fee for each scrap tire and the supplier gets a fee for each scrap tire. Tire customers (people purchasing new tires) pay a dollar per tire to dispose of scrap tires; the state gets half, the supplier a gets part, and the end user gets part.

Lafarge, Tulsa, OK

The Lafarge Tulsa Oklahoma plant is a dry process plant that uses whole scrap tires. Approximately 12 percent of entire raw feed is tire-derived fuel. In the first quarter of 2004 the plant used 216 tons of scrap tires. This is a relatively constant feed rate. The plant first started burning tires in 1994; the operating permit including scrap tires was issued in 1995. The permit revision incorporated scrap tires, landfill gas, and onsite generated oils and greases into permit [the permit conditions for landfill gas and onsite generated oils and greases were never used].

For scrap tires the permitting process was a prequalification program – i.e., the scrap tires are not hazardous waste and use of scrap tires would not increase emissions; the plant modeled ambient air concentration for SO_2 and estimated the fence line concentration beyond the baseline. The plant does not have a Continuous Emission Monitoring System, so the plant is using emission factors for emissions estimation. The plant CAAA Title V operating permit was issued in November 2007, no criteria pollutant stack testing was required before that time. The plant was required to conduct opacity determination by May 2008; NOx and PM determination by May 2008; and a one-time test for criteria pollutants and HCl emissions within five years of permit issuance. This test is to be conducted at one set of operating conditions. No parametric testing was required for scrap tires vs. no scrap tires. (This differs from other states, e.g., California, in which parametric testing was required for cement kilns using scrap tires).

7.1.8 Automobile Shredder Residue

TXI, Midlothian, TX

TXI has been investigating use of automobile shredder residue (ASR) at their Midlothian plant. The material is generated by Chaparral Steel. Chaparral Steel is a former subsidiary of TXI that is now a separate company, and is located in Midlothian. Chaparral Steel generates ASR from shredding automobiles for its steel mill operation. The ASR, also referred to as "fluff," includes non-metallic material from seats, dashboards, etc. ASR generated by automobile shredders has historically been landfilled.

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TXI has worked with Chaparral Steel on processing ASR at the Chaparral site. The steel mill first processes the automobile shredder residue to separate out non-ferrous metals. Nickel, aluminum, copper, and other non-ferrous metals sell at prices on the order or $1000 per ton, so the additional material processing of the ASR to remove the non-ferrous metal is cost effective. Shredders use eddy current or other processes to remove the non-ferrous metals to capture this value. As a final processing step, Chaparral puts the ASR through a "vertical mill" to get the material processed and sized to cement kiln standards. Chaparral processes the material down to – ¼ inch size and to low moisture content. After this final treatment step the ASR has a calorific value similar to coal.

The regulatory barrier to use of ASR in cement kilns is the Toxic Substances Control Act regulations. The TSCA regulations (referred "Superrules") for PCB wastes affect the status of automobile shredder waste. Shredder waste is categorized as a "PCB waste" until proven otherwise, and according to TXI it is very difficult to prove otherwise. Therefore, automobile shredders can landfill this material relatively easily, but cement kilns cannot burn the material without encountering major regulatory hurdles under the PCB regulations. TXI is continuing correspondence with EPA concerning the TSCA issue.

7.1.9 Miscellaneous Materials

VEXOR Fuels, Medina OH / CEMEX, Wampum PA /ESSROC, Bessemer PA

Engineered Fuel (Biosolids/Plastic/Paper)

Engineering Fuel Production and Specifications

Vexor Fuels operates a facility in Medina OH that manufacturers "engineered fuel" for cement kilns and cogeneration plants. The engineered fuel consists of various types of non-hazardous materials, including used oil, wood and other biosolids, paper, and plastic. Vexor engineered fuel can have as much as 40 percent biomass in it, depending upon the alternative fuel material feedstocks used.

Vexor Fuels started processing non-hazardous materials in 2000 and by 2003 was blending non-hazardous fuel for cogeneration units, including Covanta and Wheelabrator facilities. Holcim cement contacted Vexor Fuels in 2005 concerning supplying engineered fuel to the Holly Hill cement plant. Vexor then purchased an existing alternative fuel processing facility in Dorchester SC specifically for Holly Hill supply. Holcim now owns this facility and Vexor Fuels is contracted as an operations consultant. The Dorchester facility manufactures 6,500 BTU per pound calorific value alternative fuel. The alternative fuel is fed into the preheater/precalciner of the Holly Hill cement kiln.

Vexor Fuels is supplying engineered fuel to cement kilns in Pennsylvania located close to Medina OH. These cement kilns are wet kilns without preheater/precalciners. Therefore the engineered fuel must be delivered into the kiln along with the coal. Engineered fuel therefore must have different characteristics for wet kilns than for preheater/precalciner kilns.

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The CEMEX plant in Wampum PA conducted a test program using Vexor engineered fuel in July 2007. The "engineered fuel" looks like mulch, has a minimum calorific value of 10,000 BTU per pound, 10 percent moisture or less, and can be conveyed into the kiln through a four inch pipe. The CEMEX Wampum plant test was successful, and the facility is now permitted by the Pennsylvania Department of Environmental Protection (PADEP) to use Vexor engineered fuel. Vexor Fuels indicated that they would commence delivering engineered fuel to the CEMEX plant in mid May 2008. Vexor Fuels anticipated a 60,000 tons-per-year delivery contract with the Wampum plant. Vexor Fuels anticipated that the ESSROC cement kiln in Bessemer PA will be performance tested using for Vexor engineered fuel in mid-2008. The ESSROC kiln is also a wet kiln and engineered fuel would be delivered to the kiln along with the coal.

The cost to make engineered fuel for a wet kiln is higher than for a preheater/precalciner kiln, because for a wet kiln the engineered fuel has to meet 10,000 BTU per pound spec. For a preheater/precalciner kiln the spec is 6,500 BTU per pound to 8,000 BTU per pound, therefore Vexor Fuels can mix more wet material into the fuel; mixing this fuel is much easier than making fuel for wet kilns, because for wet kilns the fuel has to be like coal and there is only one fuel entry point into the kiln. Vexor Fuels can put inorganic material into the wet kiln fuel as long as they meet the 10,000 BTU per pound spec. For dry kilns Vexor Fuels can develop both types of fuel for precalciner and for the kiln itself. The difference in spec is moisture content and particle size for the wet kiln fuel and the dry kiln fuel. The ash content is silicates and aluminates and lowers the calorific value of the engineered fuel, but the ash content is also raw material for the cement kiln.

For wet kilns, any ash in the fuel goes into the clinker, so the ash content in the fuel for wet kilns has to be controlled. Engineered fuel cannot replace all of the coal; coal generates 10-12 percent ash, which goes into clinker; Vexor engineered fuel has 3 to 8 percent ash; therefore the cement kiln would be missing some clinker production from burning Vexor engineered fuel rather than coal. The target for engineered fuel is 50 percent replacement of coal.

The average coal calorific value is 12,000 BTU per pound (Western PA). A 10,000 BTU per pound spec is established for wet kiln engineered fuel. The spec is not as high as coal (e.g., 12,500 BTU per pound) because making engineered fuel at this higher spec is more difficult, and difficult to make consistently.

One issue encountered by Vexor Fuels is that wet cement kilns could not build a separate delivery system for this material; the existing delivery systems could not handle the material. Vexor Fuels therefore had to develop the equipment to blow the material into the wet kiln right beside the coal feed; precalciner feed equipment design is much easier; Holcim did this modification themselves for the Holly Hill cement kiln.

For introduction of engineered fuel with the coal, the introduction cannot change the flame shape because this would change the clinker production characteristics. Introduction of engineered fuel also cannot create gas flow backpressure in the kiln because this would also change the flame characteristics.

Market Characteristics

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The Vexor Fuels Medina OH facility can easily supply wet kilns because they are close to the facility. However, wet kilns are being phased out in favor of precalciner kilns that can burn 1/3 as much coal as a wet kiln does. Vexor Fuels can supply both the wet kiln and dry kiln markets with different spec products. However, wet kiln operators particularly want waste fuels to remain cost competitive with kilns that are more modern. Vexor Fuels worked on how to deliver a non-hazardous engineered material consistently with a narrow range of spec, consistent quality, and consistent supply.

The Vexor Fuels Medina OH facility can produce sufficient engineered fuel to feed one or two wet kilns. Vexor Fuels plans to build additional facilities at cement kilns in Eastern Pennsylvania and other locations. Landfill prices are $60-$80 per ton in Eastern Pennsylvania and coal prices are high, but Vexor Fuels still cannot economically transport their engineered fuel 400 miles to cement kilns in Eastern Pennsylvania. Therefore, they have to build facilities in Eastern Pennsylvania to service this market.

Raw Materials and Suppliers

Non-hazardous alternative fuel material comes from many types of facilities to the Vexor Fuels facility. Vexor Fuel's customers supply this material because they want to deal with a "best practices" plant and avoid landfill disposal. Suppliers include petrochemicals, rubber, tire manufacturing scrap, pharmaceuticals, plastics, paper, food, and fragrance chemicals, and consumer products manufacturers. Vexor Fuels is now looking to obtain unrecyclable papers and plastics from MSW recyclers. This unrecyclable material has a high calorific value, good particle size, and other favorable qualities; but the material is very cheap because this material can go to landfill. Vexor Fuel's customers are paying them for "complete elimination of their waste" Including elimination of the need for ash disposal. Cement kilns don't generate ash. "Waste-to-Energy" facilities generate 10 -15 percent ash that still has to be landfilled.

For precalciner kiln fuel, Vexor Fuels is incorporating aqueous waste, latex paint, epoxies, and related materials into the feedstock. Approximately 85 percent of materials coming into the Vexor Fuels facility can be blended into precalciner fuel. For wet kiln fuel, less aqueous material can be added to the feedstock. For both precalciner kiln fuel and wet kiln fuel, PVC plastics cannot be used because cement kilns have to control the feed rate of halogens to the kilns.

Vexor Fuels has established direct relationships with suppliers. Some suppliers are contracted to supply material, while some are not contracted and the material is purchased on a spot basis. One issue with establishing supplier relationships is that until Vexor Fuels has a supply agreement it is difficult for them to establish a contract with a cement kiln, and vice versa. Vexor Fuels cannot simply approach DuPont and say that Vexor Fuels will dispose of all their byproduct materials unless they first have a contract with a cement kiln.

Vexor Fuels is not overly concerned with volume of supply of feedstock for engineered fuels because they understand the alternative fuel materials business and markets. Some

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streams are priced high because generator can't easily manage them; other streams are priced low because they can go to landfills.

Vexor Fuels indicated that markets for alternative fuel materials (feedstock) and engineered fuel product vary by region. For example, South Florida does not have industrial base to generate plastics; but South Florida does have lots of MSW. MSW is cheap, but coal costs $80 per ton in Miami, so the supply and demand costs for engineered fuel balance out to some extent. Vexor Fuels is competing with low landfill costs and relatively low coal costs in some areas. Coal is $40 per ton in western PA; Coal is $80 per ton in southern CA.

Every material that comes into the Medina OH facility is "preapproved" by Vexor Fuels; there are standard approval procedures and an Ohio EPA-approved Waste Analysis Plan (WAP); each waste is given a unique Waste Approval Number. Shipments are subject to 100 percent QA/QC using fingerprint analysis on every container to ensure that the material shipped is what the generator identified and what the WAP approved; generators are notified within 24 hours of any discrepancies and the material must then be removed from the site within 10 days; these procedures ensure that Vexor Fuels does not inadvertently process hazardous waste.

Regulatory Barriers

Vexor Fuels has encountered regulatory barriers mainly at state level, and indirectly with EPA through implementation of the CAAA Title V Program. One issue is that Vexor Fuels is blending feedstocks to make a specification-driven engineered fuel product. Therefore, Vexor Fuels is unique operation. The quality of the engineered product supplied to the cement kiln is not going to vary regardless of the specific alternative fuel materials used to produce it; the calorific value, particle size, and carbon hydrogen nitrogen ratios are all controlled product specifications. One regulatory agency from which Vexor Fuels was seeking a permit (to supply a lime kiln) did not clearly understand at first that the engineered fuel product spec doesn't vary regardless of the variability of the specific feedstocks used to make the material.

Vexor Fuels also identified an issue that there are different testing protocols for different kilns in different regions; a uniform testing program would help to allow testing first and then allow modeling for new permits after a certain number of tests were conducted; at present Vexor Fuels has to test each kiln every time a new alternative fuel is introduced; stack testing is expensive for cement kilns. In recent performance testing for Vexor Fuels, stack testing has shown either no increases in emissions or increases below action levels and Title V operating permit thresholds. The cost of testing is $30,000 to $100,000 per stack test per kiln, and despite the consistent results, each kiln has to be tested before engineered fuel can be introduced.

Vexor Fuels also identified as an issue at the municipal and local government level concerning the definition of "solid waste" and what gets paid for. The "unrecyclable" material generated by MSW authorities is classified as "waste." If the state regulatory agency requires "solid waste fees" and "solid waste facility permits" for facilities that are handling this unrecyclable material, the material may not be able to be used for recycling.

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South Carolina was very proactive on this issue. The Vexor Fuels facility in South Carolina did not need to be regulated as a "solid waste facility;" South Carolina regulations are that if 75 percent of the solid waste material is "recycled" including used as a fuel, the facility is exempt from state solid waste regulations.

Lafarge, Seattle, WA

Biodiesel

The Lafarge Seattle plant permit process does not prevent the plant from using alternative fuels and raw materials; the plant is investigating some new opportunities such as biofuels. If state agencies determine that a material is a "waste," then cement kilns are capped as to the number of tons per day they can use. There is no corresponding cap on use of materials that are "fuels." Glycerin generated from biodiesel plants, for example, has a high calorific value, but the mid-level state environmental agency staff want to classify this material as a "waste" rather than as a fuel. If the plant was designed as a biodiesel plant, it is uncertain whether the glycerin produced by the plant a "byproduct" or a "waste."

Used Oil

The Lafarge Seattle plant uses "used oil" including tank bottoms oil and used motor oil, and other types of non-hazardous oils. This material comes from intermediate sources; a supply contractor brings in loads in range of 4000 gallons, two to three truckloads per week. The Lafarge Seattle plant reported that the used oil market is dynamic and that there is competition for used oil. Because of rising energy costs, pricing of used oil is starting to rival coal and petroleum coke in some places, and other industries are competing for the used oil, specifically the asphalt industry.

California Portland Cement, Colton, CA

Latex Paint Solids

The California Portland Cement Colton plant uses processed latex paint solids as a raw material. This material is obtained from paint recycling company that conducts household paint waste collection. Household recycling of non-hazardous waste is common in California. This material does not include oil-based paint, only latex paint. The recycling company separates the latex paint solids from the paint waste and resells the liquids as "graffiti removal paint." California Portland Cement adds CKD to the latex paint solids, and then the CKD/latex paint solids mixture is fed into kiln. The latex paint solids are "sticky" and aggregate the CKD; this allows recycling of more CKD into the kiln. The methylcellulose content of latex paint is made into a grinding agent and plasticizing agent for cement.

Holcim/Geocycle, Midlothian, TX

Oil Filter Fluff

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The Holcim Midlothian plant has been using oil filter fluff as an alternative fuel for the past ten years. Oil filter fluff is generated from used vehicle motor oil filters after the free oil and the metal parts are removed. The remaining oil-soaked paper is used as an alternative fuel. The oil filters are generated by automobile service centers in the Dallas and Houston metropolitan areas. The oil filter fluff market is relatively stable and the plant does not have any supply issues

Holcim/Geocycle, Devil's Slide, UT

Scrap Carpet

Geocycle is responsible for supplying alternative fuels and raw materials to Holcim cement plants in Utah, Montana, and Colorado, including the Utah Devil's Slide plant. None of the Holcim Mountain State plants are permitted to accept hazardous waste. Geocycle operations receives alternative fuel materials and conducts preprocessing / blending operations to prepare "engineered fuel." Geocycle delivers "engineered fuel" to the Devil's Slide cement kiln.

The Devil's Slide plant is more than 100 years old; updated in 1998 to dry process plant. Alternative fuels and raw materials are used at the Utah plant: scrap tire chips and diaper scrap (cubed) have been used for about 15 years. The new dry process plant was designed to accommodate these alternative fuels. The Utah operation also uses plastics and scrap from mattress companies, including fluff, foam, fabric, etc. after wood and metal (frames) are removed. The fuel mix for the Utah plant is approximately:

- 15,000 tons of tire chips per year
- 6,000 tons of plastics per year
- 2,000 tons of textiles and carpet per year

This constitutes approximately 30 percent of the heat input into the kiln. Geocycle / Holcim has a goal to increase this number. Utah was at 20-25 percent for years before Geocycle started adding new alternative fuels. Holcim recently invested 2 million dollars for installing another feeding point at the Utah kiln. Holcim could install a second additional feeding point to feed wood or some other type of material if the material is available.

Geocycle processes scrap carpet into alternative fuel. Geocycle first analyzes the scrap carpet to create a "profile" both for the purposes of material management and process control/cement clinker quality control. Geocycle then shreds the material and sends it to the Utah cement plant.

Geocycle receives carpet pad/cutting scrap, e.g., from regional carpet supplier RC Willey and Company. This includes old carpet pads, cutting scraps, rolls, etc. from residential and commercial carpet replacement. Geocycle preprocesses the scrap carpet to remove metal strips, nails, wood, etc. from the carpet prior to processing. Scrap carpet has 12,000 – 15,000 BTU per pound. Geocycle is working with CARE, a national carpet recycling organization, on carper recycling issues.

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Geocycle has found it difficult to find suppliers for scrap carpet; small carpet installers cannot manage consistent production of quality scrap carpet material because it is difficult to control the practices of their installers. The installers need to separate the scrap carpet from other debris generated from the installation job. This segregation of material involves time and cost, and the need for separate transportation of the scrap carpet from the installation site to the cement kiln also involves time and cost. Large carpet companies can coordinate better because they send out carpet installers from central location.

Geocycle takes whatever scrap carpet installers bring them at the moment, approximately 2,000 tons of textiles and scrap carpet per year. Geocycle can use different types of scrap carpet, but Geocycle cannot accept "trash" that is mixed with scrap carpet. The customer (e.g., carpet installers) pays Geocycle for taking the scrap carpet material for material disposal, as opposed to paying a local landfill a tipping fee for material disposal. CARE is waiting to see if Geocycle can make relationships with "big companies" and work out issues with processing and transportation of the material.

The cost of transportation of scrap carpet is an issue: the hauling capacity of a truck may be only three to five tons of carpet, as opposed to a truck hauling capacity of 20 - 25 tons of tire chips. Landfill cost involves tipping fee and transportation, and scrap carpet takes up a lot of space in landfills because it is loose. Therefore, there is a cost for landfilling this material.

Geocycle's price for services takes into account transportation distance to the cement kilns. Geocycle is targeting customers close to Geocycle, e.g., within a 50 mile radius of the cement kiln. Geocycle's major "competitor" for waste carpet is the relatively low cost of landfill disposal in Utah. If there is a landfill close to the carpet installation site, the carpet installer would ordinarily send the material there. Therefore, Geocycle deals with corporate sustainability goals, etc., and sells a "value added" service to divert scrap carpet and other materials away from landfills. .

Geocycle has service agreements with customers, some are multi-year, and some are for a specific event, such as a ski resort changing their carpet. Service agreements with individual companies may have an estimated tonnage per month and quality specification, e.g., waste volume not to exceed 20,000 pounds per year.

The Devil's Slide plant has a CAAA Title V operating permit that lists the conventional and alternative fuels that the plant can accept individually. Conventional fuels, such as TDF or diaper scrap, are separately listed in the permit. The permit has various specifications, such as maximum percent sulfur in coal and specifications on used oil. Up to 15 percent "coal additives" can be added under the permit. Holcim can request addition of additional alternative fuels to permit, working under the "15 percent" threshold limit.

For introduction of a new alternative fuel, Holcim submits "ultimate/proximate" analysis of fuel to the state regulatory agency. Geocycle does a more detailed analysis of the material beyond an "ultimate/proximate" analysis because of process control reasons. So far, no stack tests have been needed to introduce new fuels under the Title V operating permit limits for emissions of criteria pollutants, PM, SO_2, NO_x, etc.

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8. Appendix B: Study Contacts

Company	City	State
Ash Grove Cement	Foreman	AR
Ash Grove Cement	Overland Park	KS
California Portland Cement	Glendora	CA
CEMEX	Knoxville	TN
GRR: Giant Resource Recovery	Harleyville	SC
Lafarge	Seattle	WA
Lafarge	Sugar Creek	MO
Lafarge	Tulsa	OK
Lafarge	Tulsa	OK
Lehigh Cement Company	Fleetwood	PA
Lehigh Cement Company	Allentown	PA
Lehigh Cement Company	Glens Falls	NY
Lehigh Cement Company	Redding	CA
Texas Industries	Midlothian	TX
Holcim	Morgan	UT
Geocycle (Holcim)	Devil's Slide	UT
Geocycle (Holcim)	Midlothian	TX
Geocycle (Holcim)	Dundee	MI

Supplier and Other Contacts	City	State
Exxon Mobil	Baytown	TX
Shell	Houston	TX
Marathon Oil	Houston	TX
Vexor Fuels	Medina	OH

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Regulatory Agency Contacts		
Agency	**City**	**State**
Texas Commission on Environmental Quality (TCEQ)	Austin	TX
Shasta Air Quality District	Redding	CA
Missouri Department of Natural Resources (MoDNR)	Columbia	MO
California Integrated Waste Management Board (CA IWMB)	Sacramento	CA
California Integrated Waste Management Board (CA IWMB)	Sacramento	CA
Pennsylvania Department of Environmental Protection (PADEP) South Central District	Reading	PA
Puget Sound Clean Air Agency	Seattle	WA
Washington Department of Ecology (WDOE) Solid Waste/Financial Assistance	Lacey	WA
Texas Commission on Environmental Quality (TCEQ)	Austin	TX
Texas Commission on Environmental Quality (TCEQ)	Austin	TX
Texas Commission on Environmental Quality (TCEQ)	Austin	TX
Pennsylvania Department of Environmental Protection (PADEP) Northwest District	Meadville	PA
South Carolina Department of Health and Environmental Conservation (SCDHEC)	Columbia	SC
South Carolina Department of Health and Environmental Conservation (SCDHEC)	Columbia	SC
California Department of Toxic Substance Control (CA DTSC)	Sacramento	CA

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9. Appendix C: Kiln Types

9.1 Wet Process

The wet process is so named because the proportioned raw materials mixed with water and fed into the kiln in the form of a slurry. The amount of water varies depending on the physical and chemical properties of the raw materials, and the raw meal typically contains 30 to 40 percent moisture.[210] Wet grinding of hard minerals is usually much more efficient than dry grinding, and wet processing might be preferable when raw materials contain high moisture content.

The kiln is generally larger in plants using the wet process because the water is first evaporated in the lower temperature zone. The length to diameter ratio may be up to 38, with lengths up to 252 yards.[211] Also, more fuel is needed to create sufficient energy to evaporate the water. Fuel use in a wet kiln can vary between 4.6 and 6.1 MBtu per ton clinker.[212] The capacity of large units may be up to 3,970 short tons of clinker per day.[213]

9.2 Long Dry Process

In dry processing, the materials are ground into a flowable powder in horizontal ball mills or in vertical roller mills. The feed material has about 0.5 percent moisture content and is pneumatically or mechanically conveyed to the upper end of the kiln. Two types of dry process plants predominate: (1) preheater and precalciner kilns (discussed below) and (2) long dry kilns.

Dry process kilns operate with a high exit gas temperature of approximately 449° C and typically employ water sprays to cool the gas before it enters the dust control equipment. The fast-flowing combustion gases tend to blow the powdery raw meal out from the kiln.

Cyclones are used to collect cement kiln dust (blown out by the heat of the kiln) from the exhaust gas in order to facilitate the return of the particulate back to the kiln. Additional dust is collected as the exhaust gas enters a baghouse. The CKD collected is then fed back into the kiln, recycled in other processes, or disposed.

9.3 Variations of the Dry Process

Preheaters and precalciners are modifications of the dry process. With these processes, operators preheat and calcine the raw meal before it enters the kiln – using some heat that escapes from the kiln, which reduces the energy demands of the pyroprocess.

The preheater and precalciner process kilns have only calcining and clinkering zones, because the material has been dried before entering the kiln. Accordingly, these kiln types may in some cases be very short (under 61 meters).[214] The wet process was initially used to improve the chemical uniformity of raw materials being processed; however, it requires 47 percent more energy per ton of clinker production than the average for dry processes.[215] Technological improvements have allowed cement makers to utilize the dry process without quality deficiencies, and no new wet kilns have been built in the United States since 1975.[216] Some plants are switching from the wet to the dry process.[217] About 80 percent of U.S. cement production capacity now relies on the dry process technology.[218]

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9.4 Dry Process with Gas-Suspension Preheaters:

Suspension preheater kilns preheat and partially calcine raw meal by passing it through a system of heat exchange cyclones before it enters the kiln. In traditional dry process kilns, the intense heat causes dust-laden gas to escape the kiln. To collect the escaping dust, operators used "cyclones." The cyclone is conical vessel into which a dust-bearing gas-stream passes tangentially, producing a vortex within the vessel. The solids are thrown to the outside edge of the vessel by centrifugal action, and leave through a valve in the vertex of the cone.

Because of the heat associated with the escaping gas, operators can send the raw materials through the cyclone, resulting in a heat exchange. The gas is cooled, producing less waste of heat to the atmosphere, and the raw materials are heated.

Fans draw the gases through the string of cyclones. The number of cyclones stages used in practice varies from 1 to 6. Generally, the cost of powering the fans outweighs the benefits when more than 6 cyclones are used. Typical fuel consumption of a dry kiln with 4 or 5 stage preheating can vary between 2.7 and 3.0 MBtu per ton of clinker, and the most efficient preheater, precalciner kilns use approximately 2.5 MBtu per ton clinker.[219]

A disadvantage of the preheater kiln is that plug-up problems can occur at he lower cyclone stage and the kiln inlet due to high concentrations of volatile constituents such as alkalis, sulfur, and chlorides in the kiln exit gases. To mitigate this problem, alkali and sulfur bypass systems allow evacuation of some of the kiln exit gases before they reach the preheater cyclones.

9.5 Precalciner Kilns

Precalciner technology involves a second combustion chamber added between the kiln and a conventional pre-heater, allowing for further reduction of the kiln fuel requirements. Precalciner systems associated with kilns with tertiary air ducts are supplied with air from the exhaust gases from the clinker cooler. Precalciner kilns without tertiary air ducts receive air that passes through the kiln itself.

Precalciners using the hot air from the kiln use that air to ignite fuel in a combustion chamber at the base of the preheater. Less expensive, lower grade fuels such as sub bituminous coal, lignite, and oil shale, as well as tires and waste oil, can be burned in the auxiliary firing unit, reducing fuel cost per unit of clinker.

The hot combustion air for precalciners with tertiary air ducts arrives in a duct directly from the cooler, bypassing the kiln. The feed entering the rotary kiln is 92-98 percent calcined (100 percent calcined meal would be sticky and cause feed pipe plugs), so the kiln has only to raise the feed to sintering temperature. An advantage of this type of precalciner is that a large proportion of the alkali-laden kiln exhaust gas can be taken off as alkali bleed. Because this accounts for only 40 percent of the system heat input, it can be done with lower heat wastage than in a simple suspension preheater bleed.

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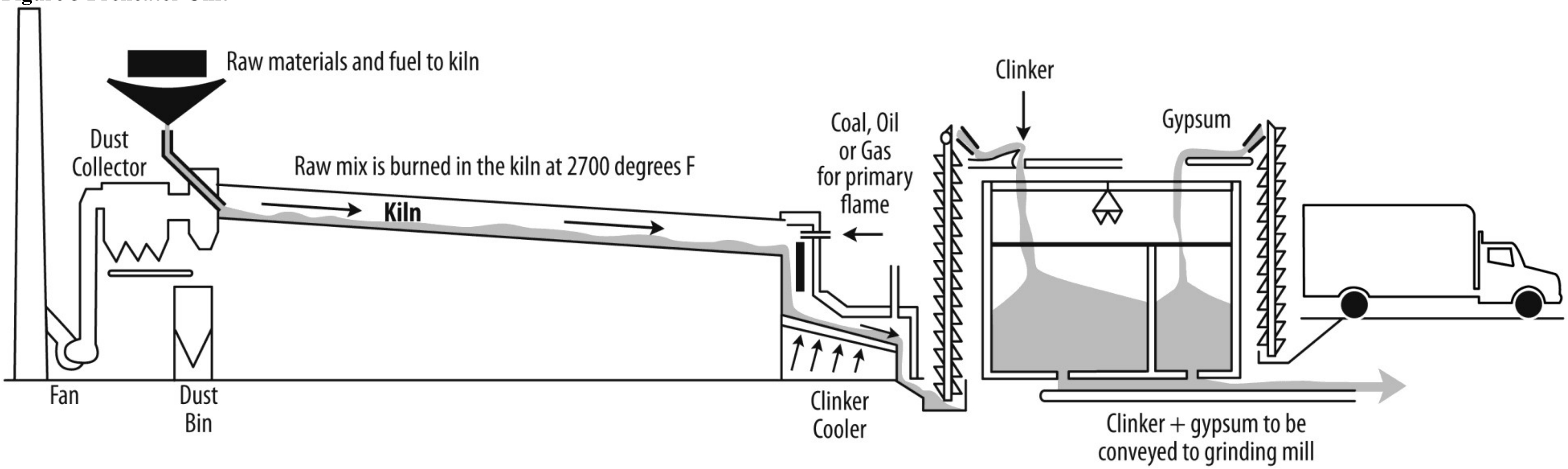
Figure 5 Preheater Unit



Source: California Environmental Protection Agency, Compliance Assistance Program, *Cement Kilns*, October 1996, excerpted from Figure 300.5

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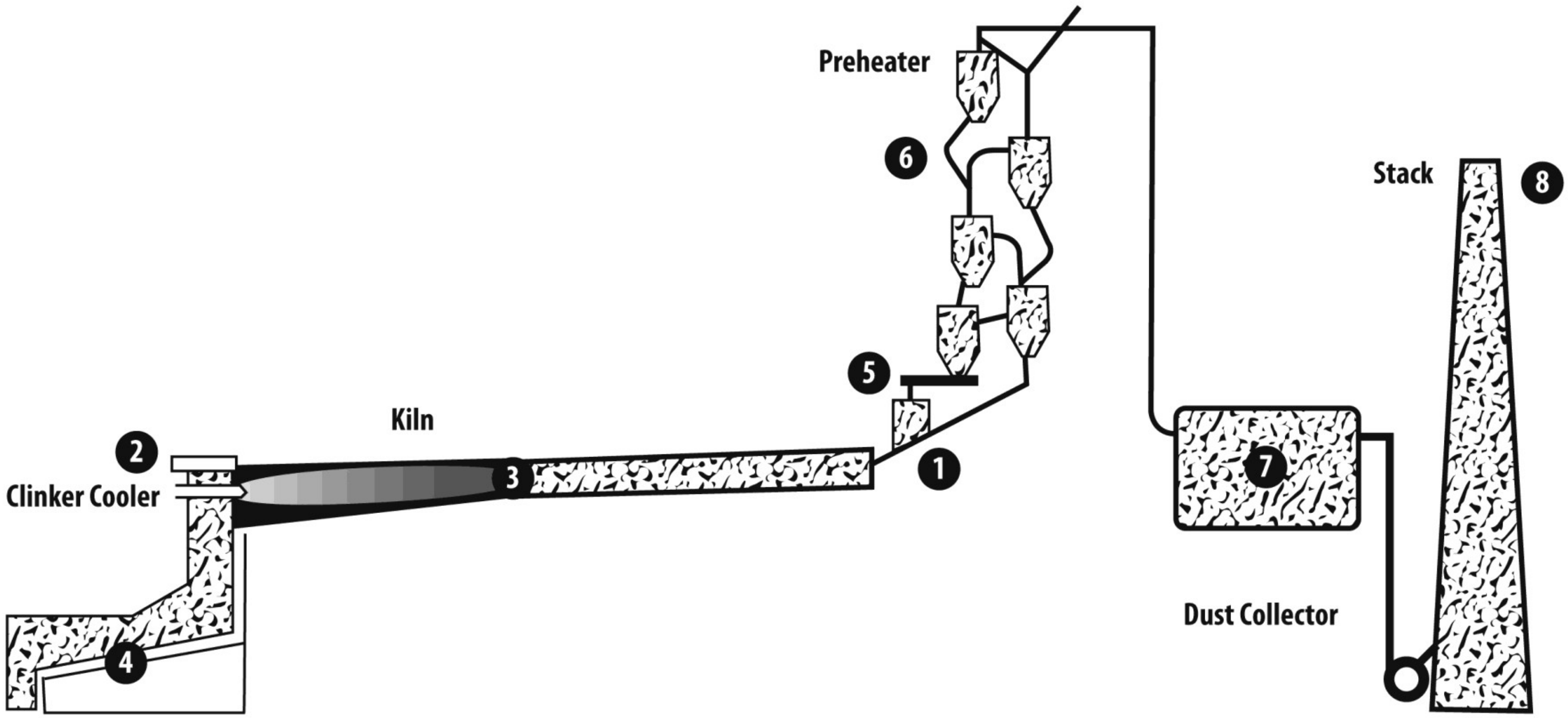
Figure 6. Basic Workflow with Preheater unit



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