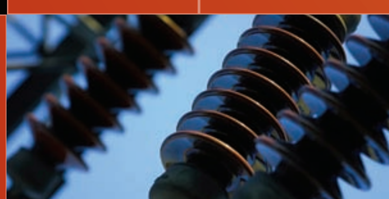
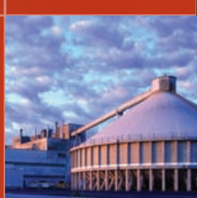
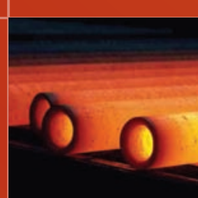
Beneficial Reuse of Industrial Byproducts in the Gulf Coast Region









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Beneficial Reuse of Industrial Byproducts in the Gulf Coast Region

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List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ACAA	American Coal Ash Association
ACC	American Coal Council
ADEM	Alabama Department of Environmental Management
ADOT	Alabama Department of Transportation
AFS	American Foundry Society
AISI	American Iron & Steel Institute
AMD	Acid mine drainage
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
BOF	Basic oxygen furnace
BOG	Basic oxygen process
BMRA	Building Materials Reuse Association
BTU	British thermal unit
BUD	Beneficial Use Determination (Mississippi)
C&D	Construction and demolition
C^2P^2	Coal Combustion Products Partnership (EPA)
CAA	Clean Air Act
CAIR	Clean Air Interstate Rule
CCP	Coal combustion product
CKD	Cement kiln dust
CMRA	Construction Materials Recycling Association
CO_2	Carbon dioxide
CSI	Cement Sustainability Initiative (World Business Council for Sustainable Development)
DOE	U.S. Department of Energy
DOT	Department of Transportation (federal or state)
EAF	Electric arc furnace
EERC	Energy and Environmental Research Center (University of North Dakota)
EGU	Electric generating unit
EIA	Energy Information Administration (DOE)
EJ	Environmental justice
EPA	U.S. Environmental Protection Agency
EPP	Environmentally Preferable Purchasing
EPRI	Electric Power Research Institute
FAA	Federal Aviation Administration (DOT)
FAQMP	Fly Ash Quality Monitoring Program (Texas)
FEMA	Federal Emergency Management Agency (U.S. Department of Homeland Security)
FDOT	Florida Department of Transportation
FGD	Flue gas desulfurization
FHWA	Federal Highway Administration (DOT)
FIRST	Foundry Industry Recycling Starts Today

FL DEP	Florida Department of Environmental Protection
FR	Federal Register
GGBFS	Ground granulated blast furnace slag
GHG	Greenhouse gas
GRI	Gypsum Recycling International Company
HAP	Hazardous air pollutant
HMA	Hot-mix asphalt
HWC	Hazardous waste combustor
ITP	Industrial Technologies Program (DOE)
LA DEQ	Louisiana Department of Environmental Quality
LEED	Leadership in Energy and Environmental Design
LOI	Loss on Ignition
LPPA	Louisiana Pulp and Paper Association
MACT	Maximum Achievable Control Technology
MassDEP	Massachusetts Department of Environmental Protection
MMT	Million metric tons
MS DEQ	Mississippi Department of Environmental Quality
MSW	Municipal solid waste
MW	Megawatts
OPEI	Office of Policy, Economics, and Innovation (EPA)
OSM	Office of Surface Mining (U.S. Department of Interior)
OSW	Office of Solid Waste (EPA)
NAICS	North American Industrial Classification System
NCASI	National Council for Air and Stream Improvement
NCEI	National Center for Environmental Innovation (EPA)
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NPDES	National Pollutant Discharge Elimination System
NSA	National Slag Association
PCA	Portland Cement Association
PCB	Polychlorinated biphenyl
PE	Professional engineer
RCC	Resource Conservation Challenge
RCRA	Resource Conservation and Recovery Act
RENEW	Resource Exchange Network for Eliminating Waste (Texas)
RMDB	Recycling Market Development Board (Texas)
RMRC	Recycled Materials Resource Center
RRC	Railroad Commission of Texas
SCA	Slag Cement Association
SO_2	Sulfur dioxide
SQG	Small quantity generator
SRI	Steel Recycling Institute
TAC	Texas Administrative Code
TAPPI	Technical Association of the Pulp and Paper Industry
TCAUG	Texas Coal Ash Utilization Group
TCEQ	Texas Commission on Environmental Quality
TCLP	Toxicity Characteristic Leaching Procedure

TPH	Total petroleum hydrocarbons
TxDOT	Texas Department of Transportation
USACE	U.S. Army Corps of Engineers
USBCSD	U.S. Business Council for Sustainable Development
USGBC	U.S. Green Building Council
USDA	U.S. Department of Agriculture
USGS	United States Geological Survey (U.S Department of the Interior)
WBCSD	World Business Council for Sustainable Development
WGBC	World Green Building Council
WWTP	Wastewater treatment plant

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Executive Summary

> **Nine Industrial Sectors Examined in This Report**
> - Cement Manufacturing
> - Chemical Manufacturing
> - Construction and Demolition
> - Electric Power Generation at Fossil Fuel Plants
> - Forest Products: Pulp, Paper and Paperboards
> - Iron and Steel Mills
> - Metal Casting – Foundries
> - Oil and Gas Extraction
> - Petroleum Refining

Almost everything we do leaves something behind, from household trash – often referred to as municipal or solid waste – to industrial waste. Industrial waste, which includes both nonhazardous materials and hazardous waste, is a major component of landfills. In fact, for every ton of municipal solid waste there are more than 30 tons of industrial waste in the nation's landfills.[1]

Industries are finding new ways to use materials that would otherwise be discarded. Facilities are reusing byproducts or waste materials in their own operations or sending them elsewhere for reuse as a substitute raw material or as a fuel. This is known as beneficial reuse – turning would-be waste into a valuable commodity.

The concept of beneficial reuse is quite simple; however, in some areas there is very little reuse occurring. When asked at conferences and discussion forums, most stakeholders agree that reuse of industrial material is a great idea. Businesses like beneficial reuse because it reduces their waste costs and in some cases provides a new viable product to sell. EPA and environmentalists like the idea because safe, environmentally sound use of industrial materials reduces demand for natural resources and reduces the load on landfills. Is this a gold mine or fool's gold? If beneficial reuse of industrial materials is such a great idea, why isn't more of it happening?

Beneficial reuse is very much a geographic issue. In most cases, the biggest economic obstacle is that companies cannot afford to ship byproducts further than their immediate region. By concentrating this analysis on the Gulf Coast, we hope to make a contribution to the ongoing issue of waste management in the region following the devastating hurricanes of 2005. We believe that lessons learned for the Gulf Coast may provide useful insights for other regions of the country.

Objective

The objective of this analysis is to assist the U.S. Environmental Protection Agency (EPA) in developing strategies to promote greater rates of beneficial use of industrial materials in the Gulf Coast region and elsewhere. It is intended to increase understanding of byproducts and beneficial reuse opportunities in several major industries, and assess drivers and barriers to their reuse.

Approach

We selected nine sectors for analysis based on their affiliation with EPA's Sector Strategies Program (eight of the nine sectors are part of the Program) and the amount and type of their byproducts (or wastes). We examined Census economic data, researched literature, and conducted interviews for information on facilities, byproducts generated, byproduct reuses and the potential for further reuse. The sectors and materials we analyzed are shown in Table ES-1.

Table ES-1: Gulf Coast Manufacturing Sectors and Byproducts Addressed in This Analysis

Sector (NAICS)	Materials Generated by Industry and Selected for Analysis	Materials Reused by Industry and Selected for Analysis
Cement Manufacturing (NAICS 327310)	▪ Cement Kiln Dust (CKD)	▪ Wood Waste (fuel) ▪ Fly Ash (Coal Combustion Product, CCP) and Flue Gas Desulfurization (FGD) Gypsum (raw material) ▪ Bottom Ash (CCP) ▪ Forest Product Causticizing Residue (raw material) ▪ Granulated Blast Furnace Slag (raw material) ▪ Other Blast Furnace Slag, Steel Slag, and Electric Arc Furnace (EAF) Dust/Sludge from EAF Gas Cleaning & Collection (raw material) ▪ Foundry Sand (raw material) ▪ Petroleum Refining Sulfidic Caustics (fuel)
Chemical Manufacturing (NAICS 3251, 3252, 3253)	▪ Focus on Dow Byproduct Synergy projects	
Construction and Demolition (C&D) (NAICS 236, 23891)	▪ Asphalt Shingles (from demolition and roof replacement) ▪ Concrete (from demolition) ▪ Wood (from demolition and construction) Gypsum Wallboard (from demolition and construction)	▪ Foundry Sand (raw material) ▪ Iron and Steel Slag (raw material)
Electric Power Generation at Fossil Fuel Plants (NAICS 221112)	▪ Fly Ash ▪ FGD Gypsum	▪ Wood Waste (fuel)
Forest Products: Pulp, Paper and Paperboards (NAICS 3221)	▪ Wastewater Treatment Plant (WWTP) Residuals (Wood Fibers, Minerals and Microbial Biomass) ▪ Boiler Ash (Noncombustible Materials Left after Burning of Coal, Wood, Other Fuel) Causticizing Residues (i.e., lime mud, lime slaker grits, and green liquor dregs)	
Iron and Steel Mills (NAICS 3311)	▪ Slag (Slag from Basic Oxygen Furnace (BOF) and EAF Mills (Steel Slag); Blast Furnace Slag; Ground Granulated Blast Furnace Slag (GGBFS); other) ▪ EAF Dust/Sludge (from EAF Gas Cleaning and Collection) ▪ Spent Pickle Liquor	
Metal Casting – Foundries (NAICS 3315)	▪ Foundry Sand	
Oil and Gas Extraction (NAICS 211111, 211112, 213111, 213112)	▪ Drill Cuttings Nonhazardous Tank Bottoms (sediments and water)	
Petroleum Refining (NAICS 32411)	▪ Sulfidic Caustics Nonhazardous Tank Bottoms	

We limited the scope of our analysis to the exchange of materials within the nine industries. We did not look at reuses of materials within a single facility.

We looked at government programs and regulations that affect industrial materials reuse in each of the Gulf coast states. We then investigated how these government programs as well as economic and environmental considerations serve as drivers for or barriers to reuse of the materials. After identifying sector-specific drivers and barriers, we examined common themes that recur among the sectors.

Findings

"Overarching" drivers and barriers. The common factors that play significant roles in driving or discouraging reuse of industrial byproducts are summarized below.

- ***Geographic distribution and associated costs of transportation.*** A barrier associated with many of the sectors is the long distance between byproduct generators and potential end users. Factors affecting the possibility of byproduct exchanges between distant facilities include access to transportation (highway, rail) and material hauling costs.

- ***Relative convenience and lower cost of landfilling.*** Cheap disposal costs inhibit beneficial reuse. Unless a material has an inherent market value, a generator is more likely to dispose of it in the nearest landfill. Landfill tipping fees tend to be low in the southeastern states, where land is relatively cheap and landfills are plentiful. When tipping fees increase and become expensive enough for generators to consider alternatives to disposal, beneficial reuse should become a more desirable option.

- ***Inconsistent quantity and composition of byproducts due to relative size of sector facilities.*** Beneficial reuse projects often require a minimum quantity of material and a specific composition and consistency to make reuse in a manufacturing process feasible. Most of the sectors we examined have numerous small- to medium-sized facilities, making accumulation of significant amounts of byproduct challenging. Materials generated from one or even a few facilities may be insufficient for beneficial reuse in certain processes. Transportation of one large shipment can be much more cost effective than pickup and transportation of multiple small shipments. The prevalence of small generators may also contribute to inconsistent physical and chemical compositions of byproducts. Although consolidation and blending of byproducts could address these barriers, establishing a network to accomplish this task can be daunting.

- ***Standards and specifications.*** Availability of manufacturing specifications can be a driver or barrier. The absence of specifications for reused materials can create a barrier because manufacturers may be unwilling to stake the quality of their product on an uncertain input material. Published manufacturing specifications for input of reused materials diminishes the uncertainty.

- ***Awareness and marketing.*** Lack of awareness of the connections between generators and potential end users creates another barrier to beneficial reuse. Material generators may not be aware that potential end users are located nearby, and end users may not know that byproducts can be used in their manufacturing process. Matching up generators and end users can be a challenging process; generators incur marketing costs to find end users or third parties who will broker their byproducts to potential end users. Several industry trade associations and beneficial reuse organizations have led awareness and marketing efforts to address this barrier.

- ***Core competency.*** Beneficial reuse is not a core competency for many manufacturing facilities because it is not in their primary line of business. Overcoming misperceptions about the time and cost involved to beneficially reuse materials can be challenging. The cement sector is an example of an industry that has made reuse of materials from other sectors part of its core competency, meeting and even exceeding industry goals for beneficial reuse.

- ***State requirements.*** State regulations in Florida, Alabama, Texas, Louisiana, and Mississippi vary in their complexity, their levels of allowable material reuses, and their mechanisms for approval. Some state regulations contain provisions that encourage reuse of byproducts, whereas others lack such drivers. For example, Alabama allows mixing or blending of certain byproducts to facilitate reuse, while others do not. Inconsistent state regulations and approval processes can inhibit reuse when generators in one state and end-users in another state must be compliant with different sets of regulatory requirements.

- ***Government resources.*** Limited money and staff are available for state and local governments to run beneficial reuse programs. Median income levels in the Gulf Coast states are lower than in many other areas of the country, which limits the tax revenue available for non-mainstream environmental programs. Although government agencies may not have adequate resources to support beneficial reuse programs, some industry organizations have stepped in to fill this need, conducting research and education on beneficial reuse opportunities.

Drivers and Barriers, Sector-by-Sector

Table ES-2 summarizes the economic/market, regulatory/programmatic, and environmental barriers to reuse of each sector's byproducts.

Economic/market considerations include such factors as geographic dispersion of facilities and associated transportation and disposal costs; generation of byproduct of a consistent quality and quantity; specifications or desired byproduct characteristics; price of virgin material compared to the byproduct; and awareness and marketing efforts.

Regulatory/programmatic elements focus on state regulations, programs and resources, as well as federal regulations, programs, and resources.

Environmental effects represent the potential positive and negative impacts from beneficial reuse. Environmental considerations, while often not barriers or drivers for individual firms decisions, can factor into establishment of beneficial reuse programs and regulations.

Some economic, regulatory, or environmental barriers may be viewed as both major and minor, depending on individual facility perspectives, or have had mixed effects; we indicate these entries with a "mixed" in the table.

Table ES-2: Barriers Affecting Cross-Sector Beneficial Reuse

Byproduct	Economic/Market						Regulatory/Programmatic		Environmental Effects
	Lack of Education/ Awareness for Generators and End Users	Lack of Usable Quantities and/or Inconsistent quality	High Geographic Dispersion and/or Excessive Transportation Costs	Lack of Specifications or Desired Characteristics	Industry Lacks Core Competency	Low Cost of Landfilling or More Convenient to Landfill	Stringent and/or Unclear State Programs and Resources	Stringent and/or Unclear Federal Regulations, Programs, and Policies	Concern about potential negative effects
Cement Industry									
Cement Kiln Dust	Minor	Major	Major		Minor		Major	Minor	Major
Alternative Fuels Used in Cement Production	Minor				Minor		Major	Mixed	Mixed
Chemical Industry									
Manufacturing Byproducts	Minor						Major	Major	Minor
Construction and Demolition									
Asphalt Shingles	Minor	Major	Major	Mixed			Major		Major
Concrete	Minor		Major				Major		Minor
Wood	Minor	Major	Major				Major		Mixed
Gypsum Wallboard		Major					Major		Mixed
Electric Power Generation									
Fly Ash	Minor			Mixed			Mixed	Mixed	Major
FGD Gypsum			Mixed	Major			Mixed	Minor	Minor
Forest Products: Pulp, Paper and Paperboard									
Wastewater Treatment Plant Residuals	Minor			Major			Major	Mixed	Major
Boiler Ash	Minor	Major					Major		Major
Causticizing Residues	Minor	Major		Major			Major		
Iron and Steel Mils									
Slag	Minor	Major		Major			Major		Minor
EAF Dust							Major	Major	
Spent Pickle Liquor		Major					Major	Major	Minor
Metal Casting-Foundries									
Foundry Sands	Major	Major	Major	Mixed	Major	Major	Major	Minor	Mixed
Oil and Gas Extraction									
Drill Cuttings		Major	Major	Major			Major	Major	Major
Nonhazardous Tank Bottoms		Major		Major			Major	Minor	Minor
Petroleum Refining									
Sulfidic Caustics			Mixed				Major	Minor	Minor

1.0 Introduction

Chapter 1.0 Introduction
1.1 Objectives
1.2 Research Scope and Boundaries
1.3 Data Sources and Methodology
1.4 Organization of the Report

1.1 Objectives

EPA's Sector Strategies Division in the Office of Policy, Economics, and Innovation commissioned this analysis to meet the following objectives:

- Facilitate a general understanding of byproduct generation in major industries and beneficial reuse opportunities in the Gulf Coast region, specifically Texas, Louisiana, Mississippi, Alabama, and Florida.

- Assess economic, market, regulatory, and programmatic drivers and barriers to beneficial reuse of selected byproducts within the major industries of interest.

- Determine common themes affecting beneficial reuse in the Gulf Coast region.

This analysis focuses on the Gulf Coast region, because the devastating impacts of Hurricanes Katrina and Rita on infrastructure created new challenges and opportunities for beneficial reuse.

This report is an analytical document. It does not convey EPA policy decisions. The report's findings and conclusions are based on the data used in this analysis. EPA hopes this report will enlighten discussion of material reuse issues between EPA, state and local governments, and industry stakeholders.

1.2 Research Scope and Boundaries

1.2.1 Definition of Beneficial Reuse

"Beneficial reuse" is a term that can hold various meanings and can be broadly defined as turning would-be waste into a valuable commodity. For the purposes of this paper, beneficial reuse is more narrowly defined as: the reuse of byproducts from one manufacturing process in another manufacturing process. To further refine the scope of analysis per this definition of beneficial reuse, this paper:

- Focuses on reusing byproducts from one sector by another sector and therefore excludes beneficial reuse of byproducts within the same facility. We want to establish collaborative relationships among sectors. Furthermore, a reuse that could occur within a facility is more likely to be identified and implemented than potential exchanges of materials between facilities in different sectors. We decided to focus on opportunities that need the most encouragement.

- Excludes reuse of commodities with a strong market in place, such as metals that are recovered from scrap metal, petroleum coke, and other byproducts. The valuable nature of these byproducts presents less of a challenge for beneficial reuse, as there is a clear economic incentive to recover and sell the materials for financial gain.

1.2.2 Sectors Addressed in This Analysis

The scope of this paper is limited to industries in Alabama, Florida, Louisiana, Mississippi, and Texas. To select industry sectors for analysis, we first analyzed North American Industrial Classification System (NAICS) codes from the 2002 Census to determine the top manufacturing industries in each state by number of establishments, revenue, and number of employees. Once we identified the top manufacturing sectors, we then examined the types and quantities of byproducts generated in each sector, and the potential for beneficial reuse of each byproduct based on the quantity and types of reuse presently occurring across the United States and in other countries.

Using this information, we selected nine sectors for analysis, displayed in Table 1-1. Eight of these sectors are participating in EPA's Sector Strategies Program: cement, specialty batch chemicals (within broader chemical manufacturing), construction (including construction and demolition), forest products (pulp, paper, and paperboard manufacturing), iron & steel, metal casting, oil and gas extraction, and petroleum refining.

Table 1-1: Gulf Coast Manufacturing Sectors Addressed in This Analysis

Sector	NAICS
Cement Manufacturing	327310
Chemical Manufacturing	3251, 3252, 3253 [with a focus on beneficial reuse in the Dow Byproduct Synergy projects]
Construction and Demolition (C&D)	236, 23891
Electric Power Generation at Fossil Fuel Plants	221112
Forest Products: Pulp, Paper and Paperboards	3221
Iron and Steel Mills	3311
Metal Casting – Foundries	3315
Oil and Gas Extraction	211111, 211112, 213111, 213112
Petroleum Refining	32411

Additional sectors that we evaluated and deemed outside of the scope of this analysis include:

- **Metal Mining (NAICS 2122) and Support Activities (NAICS 213114).** Preliminary research indicates that processing tailings are mainly reused to recover metals for profit.

- **Automotive Debris.** Although automotive debris is a concern in the EPA Regions, currently 95 percent of all scrapped cars are recycled, and markets exist for materials recovered from cars. It appears that this is the case in the Gulf Coast region.

- **Architectural and Structural Metals Manufacturing (NAICS 3323) and Machine Shops (3327).** The many small machine shops that are prevalent in Gulf Coast states appear to already reuse scrap metals, spent coolant, and waste oil. Architectural and structural metals manufacturers reuse scrap metal within the same facility or sell it to other manufacturing facilities.

- **Printing and Related Support Activities (NAICS 3231).** Research indicates that most print shops reuse solvents and rags within their own shops.

1.2.3 Byproducts Addressed in This Analysis

Each of the nine sectors produces numerous byproducts. We examined all byproducts generated by each of these sectors and then selected specific "byproducts of interest" for in-depth analysis using the following criteria, more than one of which may apply to each sector. If a byproduct did not meet all of the criteria, it was not necessarily excluded from the analysis. Rather, we developed these criteria as general guidelines to set the scope of the paper and examine potential reuses.

1. **Is the byproduct produced in sufficient quantities (tons) to facilitate beneficial reuse in manufacturing processes?** Byproducts of interest should be produced in quantities large enough to facilitate beneficial reuse in other manufacturing processes. Moreover, the materials should have beneficial reuse opportunities that could curb significant waste disposal and environmental impacts.

2. **Is there potential for increased beneficial reuse of the byproduct?** If the byproduct is being reused already at significant levels (i.e., more than 85 percent), then we determined that a market either already exists or the material is close enough to acceptance in the marketplace that further study is unwarranted. Several byproducts examined for this paper can be reused as fuel and can also be reused as inputs in place of raw materials. Although use of byproducts as fuel for energy recovery may be economically preferable, use as an ingredient is often the preferred environmental outcome. Therefore, the analysis includes byproducts of interest that are currently reused as fuel but have significant potential for other types of beneficial reuse.

3. **Can the byproduct replace virgin materials in manufacturing?** If the material is only replacing another recycled material, then the environmental outcome of reducing the demand on natural resources is not achieved.

4. **Does byproduct generation or reuse occur within sectors of interest for the analysis?** Our interest in this analysis is to encourage cross-sector collaborations, using industries in EPA's Sector Strategies Program as a starting point given our well-established contacts and connections in those sectors. Byproducts of interest for this paper are being reused across or within sectors where the generator and/or end user are in our nine sectors of interest. Beneficial reuses on-site at the same facility are generally not included in this analysis because these reuses do not include the mechanisms and challenges associated with cross-sector beneficial reuse.

5. **Does byproduct generation or reuse occur across other sectors, even beyond the nine sectors included in this analysis?** In order to provide a clear and accurate picture of cross-sector reuse, we also selected byproducts of interest where the end user is not in one of the nine sectors of interest for this analysis.

6. **Is the byproduct a result of manufacturing or is it a post-consumer byproduct?** Beneficial reuse of post-consumer products (such as scrap tires) is very important. However, the reuse of those materials has different collection and reuse mechanisms than

manufacturing byproducts. We decided to limit the analysis to potential material exchanges between manufacturing sectors.

1.3 Data Sources and Methodology

This analysis relies on the best available and most recent data from the following sources:

- Websites and publications on beneficial reuse associated with EPA's Sector Strategies Program, Office of Solid Waste, and the Resource Conservation Challenge.
- State publications and regulations pertaining to beneficial reuse, with follow-up calls to specific contacts.
- Contacts with associations addressing beneficial reuse of industrial byproducts.
- Other federal agencies, including the U.S. Geological Survey and U.S. Department of Energy.
- Contacts in academia with specific expertise in beneficial reuse of industrial byproducts.

This analysis also incorporates data and findings from previous Sector Strategies publications, including the *2006 Sector Strategies Performance Report* and the 2007 *Energy Trends in Selected Manufacturing Sectors: Opportunities and Challenges for Environmentally Preferable Energy Outcomes*. The most recent published data for the sectors are for 2004 or 2005, which generally represents the sectors in 2007. One exception is the construction and demolition industry in the Gulf Coast states, which has seen a good deal of change since Hurricanes Katrina and Rita in late 2005.

1.4 Organization of the Report

The major sections of this report are organized as follows:

- Chapter 2, *State Beneficial Reuse Programs and Regulations*, examines the state regulatory and programmatic features addressing beneficial reuse of industrial byproducts in Alabama, Florida, Louisiana, Mississippi, and Texas. The chapter analyzes drivers and barriers arising from state regulations and programs.
- Chapter 3, *Sector Traits and Trends, Drivers and Barriers in Beneficial Reuse*, characterizes the nine industrial sectors' manufacturing processes, byproduct production, and potential for materials reuse. The chapter looks at traits and trends related to beneficial reuse in each sector and examines the drivers and barriers for reuse of each selected byproduct.
- Chapter 4, *Discussion and Findings*, summarizes the drivers and barriers to beneficial reuse and provides our conclusions from this analysis.

2.0 State Beneficial Reuse Programs and Regulations

Well crafted regulations combined with sufficient implementation outreach can positively affect the extent of beneficial reuse within and across sectors by providing assurance to generators and end users that the beneficial reuse is safe and legal. Assuming that the state has credibility for protecting the environment, regulations can help mitigate any negative stigma and liability issues associated with reuse of a material that was once considered a regulated waste stream. Highly stringent regulations, however, can have the opposite effect. Although intended to protect human health and environment, stringent regulations can inhibit reuse if compliance is too costly or time consuming. A lack of beneficial reuse regulations can have a similar discouraging effect. Some might argue that a lack of regulations might encourage end users by leaving reuse options open and minimizing compliance burden. However, in conversing with generators and end users, we have found that a lack of regulations could also discourage beneficial reuse by not providing a level of security for generators and end users to address their liability concerns.

Chapter 2 first provides a detailed overview of each of the Gulf Coast states' programs and regulations and then details how each state's regulations and program lowers or raises barriers to beneficial reuse. In some cases, programs may even drive beneficial reuse by addressing economic/market concerns, such as connections between generators and end users.

2.1 Beneficial Reuse Regulations and Programs in the Gulf Coast States

Five states are included in this regional analysis: Alabama, Florida, Louisiana, Mississippi, and Texas. Three states, Alabama, Florida, and Mississippi, are in EPA Region 4, while two states, Louisiana and Texas, are in EPA Region 6. The following discussion of each state's regulations and program is organized by six major program features:

- Program structure;
- Siting/location restrictions;
- Level of state review;
- State response;
- Initial sampling and testing; and
- Ongoing sampling, testing, and recordkeeping.

2.1.1 Alabama

The state of Alabama does not have an organized beneficial reuse program for industrial byproducts. According to contacts at the Alabama Department of Environmental Management (ADEM), the agency has received inquiries from industry expressing the need for a central system or clearinghouse to match generators with end users and track reuse activities.[2] At this time, however, no such central management system exists.

ADEM regulations establishing the state's solid waste program, however, specify requirements for the reuse of foundry sand through its "Requirements for Management and Disposal of Special Waste" in Chapter 335-13-4.26 (3).

Program Structure

Alabama has a single-tiered waste classification structure for foundry sands. Foundry sands that exhibit less than 50 percent of toxicity characteristic (TC) levels for metals as defined by EPA's Toxicity Characteristic Leaching Procedure (TCLP) may be beneficially reused. If foundry sands do not meet this requirement, they must be managed at an approved recycle/reuse facility or a landfill approved and permitted for the disposal of foundry sands. For beneficial reuse of industrial wastes other than foundry sand as a fill material, Alabama applies the foundry sand criteria (less than 50 percent of toxicity characteristic (TC) levels for metals as defined by EPA's TCLP) to the waste before allowing reuse. If the reuse activity is something other than fill material, then the state uses a case-by-case approach to review and approve or deny the reuse.[3]

Siting/Location Restrictions

Alabama's regulations also specify location restrictions for foundry sand reuse activities. Beneficial reuse activities are restricted from floodplains, wetlands, residential zones, and areas less than five feet above the uppermost aquifer.

Level of State Review

To initiate beneficial reuse, Alabama requires analysis and certification of the foundry sand waste composition. To certify the foundry sands, the generator submits a completed Solid and Hazardous Waste Determination Form and a TCLP analysis for metals. Once the state receives this information from the generator, the state reviews the documentation. ADEM reviews the constituent concentration levels, but does not review the generator's proposed beneficial reuse activity.

ADEM staff explained that the foundry sand regulation was developed to allow foundries to use their sand as fill material either onsite or offsite. ADEM staff stated that they have received inquiries from foundries about other potential beneficial reuses. For example, a foundry recently contacted ADEM to inquire about reuse of sands as road base. The state acknowledged that as long as the project complies with the existing rule requirements, then the beneficial reuse is allowable. Therefore, although the regulation was originally designed to cover one beneficial reuse activity (fill material), ADEM applies the regulatory requirements to other proposed beneficial reuse activities.

State Response

Although the regulation does not specify that ADEM send a written response to generators, ADEM staff clarified that the beneficial reuse approval process does include a written reply from the agency. The agency sends a certification letter to the applicant, approving of the generator's Solid and Hazardous Waste Determination Form and TCLP analysis.

Initial Sampling and Testing

Alabama's Administrative Code specifies maximum allowable constituent thresholds, based on Resource Conservation and Recovery Act (RCRA) TC levels, to determine if a waste is beneficially reusable. To be determined reusable, foundry sands must demonstrate constituent levels less than 50 percent of the TC levels for metals. The TCLP analysis must be submitted to ADEM along with a Solid and Hazardous Waste Determination Form. The form must provide the name of the generator and describe the waste generating process, the physical state, and whether the sand will be used as a fill material.

Additionally, the generator must contact the Water Division of ADEM to obtain any necessary General Stormwater and/or National Pollutant Discharge Elimination System (NPDES) permits for the reuse sites.

Ongoing Sampling, Testing, and Recordkeeping

Alabama requires quarterly testing of foundry sands to ensure that the waste continues to meet the required constituent concentration levels. The generator must also report the results to ADEM. In Chapter 335-13-4-.26(3)(c), the regulations state that a Solid and Hazardous Waste Determination Form and a TCLP analysis be submitted to ADEM quarterly or whenever the production process changes in such a manner that would significantly alter the test results. According to ADEM, all generators that are reusing foundry sand must comply with the quarterly testing and reporting requirements, regardless of the volume being reused.

The regulations also require that each foundry maintain related records at the manufacturing facility. These records include a description of the site where beneficial reuse occurs, the site's location within a specific township and range, and the volume of sand at the location. When multiple foundries send sand to a particular reuse location, these sands may be mixed together and reused as long as each foundry maintains proper documentation and recordkeeping.

2.1.2 Florida

Florida also does not have an organized beneficial reuse program for industrial byproducts. However, the Florida Department of Environmental Protection (FL DEP) provides some information on beneficial reuse on their website.[4] FL DEP acknowledges receiving numerous requests to use various solid waste materials as products or raw materials in the manufacturing of other products rather than disposing of the byproducts in landfills.[5] Some of the proposed byproducts include recovered screen material from processing construction and demolition debris, coal ash from power plants, and wood ash.

Program Structure

According to FL DEP, beneficial reuse requests are generally handled on a case-by-case basis. A contact at FL DEP explained that staff conducting the case-by-case reviews may use Florida's statutory industrial byproducts exemption as a guiding principle when reviewing beneficial reuse proposals. The industrial waste proposed for reuse does not need to meet the exemption requirements outlined in Section 403.7045(1)(f). Rather, Florida developed the exemption as a part of the Florida Air and Water Pollution Control Act. Nonetheless, the industrial byproducts exemption provides established criteria that the FL DEP has found useful when reviewing proposed beneficial reuse activities. The statute states that industrial byproducts are not regulated under the Florida Air and Water Pollution Control Act if:

"1. A majority of the industrial byproducts are demonstrated to be sold, used, or reused within 1 year.

2. The industrial byproducts are not discharged, deposited, injected, dumped, spilled, leaked, or placed upon any land or water so that such industrial byproducts, or any constituent thereof, may enter other lands or be emitted into the air or discharged into any waters, including groundwater, or otherwise enter the environment such that a threat of contamination in excess of applicable department standards and criteria is caused.

3. The industrial byproducts are not hazardous wastes as defined under s. 403.703 and rules adopted under this section."

Siting/Location Restrictions

The state does not have any formal siting or location restrictions. The state might impose siting conditions on a case-by-case basis, depending on the industrial byproduct or beneficial reuse activity.

Level of State Review

The FL DEP collects information regarding the proposed beneficial reuse activity and industrial byproduct from the generator and conducts a case-by-case review.

State Response

For each proposed beneficial reuse activity, the FL DEP responds in writing to the generator. If the FL DEP approves of the reuse activity, the state's letter will officially authorize the reuse activity and may outline conditions of reuse.

Initial Sampling and Testing

To assess whether the industrial byproduct exemption criteria are met, the state generally requires a generator to analyze the industrial waste for contaminants and provide information regarding the proposed reuse activity. FL DEP staff may apply an existing set of standards that the state developed for soil cleanup activities. In reviewing proposed beneficial reuse activities, the FL DEP may use its Soil Cleanup Target Levels to benchmark constituents and acceptable concentration levels. Chapter 62-777, Table II provides a listing of contaminants and concentration limits which apply to soil cleanup projects in Florida. The FL DEP explained that these guidelines are not used in every beneficial reuse case, but state officials may refer to them when reviewing beneficial reuse proposals for industrial byproducts.

Ongoing Sampling, Testing, and Recordkeeping

In its authorization of beneficial reuse activities, the FL DEP may require conditions such as ongoing sampling, testing, and recordkeeping requirements. Because the state does not have a formal beneficial reuse program, these conditions are applied on a case-by-case basis. Occasionally, the state may require generators to regularly test the industrial waste bound for reuse and keep records associated with the testing and reuse activities. In other cases, the state may not require ongoing testing and recordkeeping.

FL DEP provides some guidance documents for particular byproducts (water treatment plant sludge, street sweepings, catch basin sediments, storm water system sediments, and recovered screen material from construction and demolition (C&D) debris).

2.1.3 Louisiana

The Louisiana Department of Environmental Quality (LA DEQ) revised its solid waste regulations in June 2007. One of the actions taken in the new rule text is to repeal the beneficial reuse regulations and replace them with new language that will not require permitting for beneficial reuse activities.[6]

Program Structure

In Title 33, Part IV, Subpart 1, Section 1105, the regulations outline how solid waste may be beneficially reused. Generators must submit an application to LA DEQ before initiating beneficial reuse of an industrial byproduct. This application must include a wide variety of information, such as the applicant's contact information, the origin of the solid waste proposed for beneficial reuse, the chemical and physical characteristics of the material to be beneficially reused, and a demonstration that the end use of the material is protective of public health, safety, and the environment. These elements of the application are reviewed on a case-by-case basis.

Siting/Location Restrictions

Louisiana's regulations do not specify siting or location restrictions for beneficial reuse activities. However, the state will impose siting or location restrictions on a case-by-case basis if the LA DEQ believes they are necessary.

Level of State Review

The LA DEQ reviews the generator's application to decide whether the beneficial reuse activity is allowable. The state reviews applications on a case-by-case basis rather than applying a set of criteria to the proposed beneficial reuse activity.

State Response

New regulatory language states that the LA DEQ approves applications for beneficial reuse. Once approved, the material must be handled, processed, stored, and managed in accordance with the proposed plan outlined in the application.

Initial Sampling and Testing

The LA DEQ requires generators to provide "the chemical and physical characteristics of the material to be beneficially used." The regulation does not provide guidelines on what contaminants to test for or what concentration levels are acceptable.

Ongoing Sampling, Testing, and Recordkeeping

In the regulations, the LA DEQ requires generators to describe in their application how periodic testing for quality control will be employed. The LA DEQ will impose ongoing sampling, testing, and recordkeeping requirements on a case-by-case basis if it believes they are necessary.

In addition, the Louisiana Pulp and Paper Association (LPPA) and LA DEQ have an established agreement on beneficial reuse of materials produced by the pulp and paper industry. Under the proposed rule language, this agreement will be incorporated into the regulations under an appendix. The agreement allows the pulp and paper industry to pursue pre-approved reuse activities in lieu of submitting a beneficial reuse plan to the state (i.e., the application). The pre-approved byproducts are wood-fired boiler ash, coal-fired boiler ash, lime and lime mud, slaker grit, boiler gravel, wood fiber, recycled fiber, and mixtures of these materials. The pre-approved reuse activities involving these byproducts include beneficial reuse as ingredients, raw materials, or feedstocks in industrial processes to make products; effective substitutes for commercial products; and land application reuses. This program is similar to Pennsylvania's General Permit program, which addresses beneficial reuse for all industries.

2.1.4 Mississippi

The Mississippi Department of Environmental Quality (MS DEQ) adopted a regulatory program in June 2005 called "Beneficial Use of Nonhazardous Solid Waste."

Program Structure

According to the regulations, a generator, distributor or supplier, or end user of a byproduct must submit a Beneficial Use Determination (BUD) application to the state. The applicant must prove that the material and its beneficial use are safe, suitable (chemically and physically), and nonhazardous, and that the material is being used as a replacement of another product.

Siting/Location Restrictions

MS DEQ's regulations do not specify any siting or location restrictions for beneficial reuse activities.

Level of State Review

The Mississippi regulations include four basic categories of beneficial reuse activities: (I) standing uses; (II) construction use (highways, roads); (III) soil amendments (nutrients, etc.); and (IV) miscellaneous/other. MS DEQ reviews the application and then issues a BUD. If approved, beneficial use is a conditional exclusion, which means the material is excluded as solid waste and is instead considered a product. For potential beneficial reuses that do not have a demonstrated reuse and/or market, called unproven uses, MS DEQ requires a site-specific demonstration project, which can take as long as three years. For engineered construction or other civil engineering uses, a professional engineer (PE) must certify that the byproduct has physical or chemical properties suitable for the proposed use. For soil amendment uses, the Mississippi Department of Agriculture and Commerce must also certify the proposed reuse.

> "Standing Use Determination" means a Beneficial Use Determination approved by MS DEQ for a specific by-product/use combination or for a category of by-product/use combinations that are contained or conducted in such a manner that does not offer potential for adverse environmental or public health impacts. Uses with standing determinations do not require a use specific application nor review and approval by the Department under these regulations.

State Response

The MS DEQ responds to the applicant in writing with their determination. If the application is consistent with Mississippi's regulations, then the MS DEQ issues a BUD to the applicant, and the reuse activity may commence. The MS DEQ also notifies the applicant in writing if the agency denies the applicant's proposed reuse activity.

Initial Sampling and Testing

Industrial byproducts that fall within Categories II – IV require initial sampling and testing as part of the application process. The regulations contain constituents and concentration limits that must be met in order for a byproduct to qualify for reuse.

Ongoing Sampling, Testing, and Recordkeeping

Mississippi's program also requires an annual report from each registrant that has received a BUD. The annual report must include the quantity of byproduct used within the past year, a physical and chemical characterization of the approved byproduct, and any other information that the MS DEQ specified as a reporting requirement within the BUD.

2.1.5 Texas

Texas does not have a general regulatory program to encourage beneficial reuse of byproducts. However, the state reviews and approves beneficial reuse activities for various byproducts through its industrial waste recycling program.[7] As discussed in more detail in relevant parts of Section 3, Texas regulations and specifications also specifically address beneficial reuse of asphalt shingles and coal combustion products (CCPs).

Program Structure

Texas conducts case-by-case reviews of proposed beneficial reuse activities. The generator of the industrial byproduct and the proposed end user of the byproduct must submit notification forms to the Texas Commission on Environmental Quality (TCEQ) for their review. These forms disclose several facts about the beneficial reuse activity. The generator's form must include the location of the reuse activity, the recycling method (i.e., feedstock/ingredient, road base, alternative daily cover, soil amendment), and supplemental information to completely describe the process. The end user's form must include the type of material to be recycled, how the byproduct will be stored, how the material will be recycled, and the purpose/function the reused material serves.

Siting/Location Restrictions

The TCEQ does impose siting or location restrictions on industrial waste recycling activities. These restrictions are stated in regulation and on the end user's notification form. The TCEQ states that: "Materials which are recycled remain subject to the General Prohibitions of 30 TAC 335.4. As described in this Section, recyclable materials may not (1) threaten the waters of the state, or (2) cause a nuisance, or (3) endanger human health and/or welfare."

Level of State Review

Once the state receives the notification forms from the generator and the end user, TCEQ closely reviews the information. The state must confirm that each constituent in the reused material must also normally be found in the raw material it is replacing. If not, the byproduct must not present an increased risk to human health, the environment, or waters of the state.

State Response

The TCEQ responds to the generator and end user after completing their review of the proposed reuse activity. If necessary, in their response letter, the TCEQ may tell the generator and end user that they need a permit before initiating the reuse activity.

Initial Sampling and Testing

As required by the generator's notification form, the generator must fully describe the recycled material. This would include a characterization of the constituents found in the industrial byproduct proposed for reuse.

Ongoing Sampling, Testing, and Recordkeeping

The TCEQ does not require generators or end users to conduct ongoing sampling and testing of the recycled material. In addition, the state does not impose ongoing recordkeeping requirements on the generators or end users.

In addition to the industrial waste recycling program, since 1988, TCEQ has implemented a program called Resource Exchange Network for Eliminating Waste (RENEW), which is a marketing channel for industries, business, and governmental units that want to sell surplus materials, byproducts, and wastes to users who will reclaim or reuse them. TCEQ acts as a facilitator, not a regulator; there are no regulations for this program. Twice a year, TCEQ publishes a catalog, which is mailed out to subscribers (membership is free) and posts the catalog on the TCEQ website, which contains links for the following: materials available, materials wanted, and waste management services and products. The website also provides information about reducing waste, increasing business productivity, determining if industrial or hazardous waste can be reused or recycled, and participating in the RENEW program.

2.1.6 Summary

Table 2-1 summarizes each state's beneficial reuse program for industrial byproducts.

Table 2-1: Summary of Gulf Coast State Regulatory Program Features

State	Program Structure	Siting or Location Restrictions	State Response	Initial Sampling and/or Testing	Ongoing Sampling, Testing, Recordkeeping
Alabama	Waste Classification (Foundry Sand only)	Yes (Foundry Sand only)	Yes (Foundry Sand only)	Yes (Foundry Sand only)	Yes (Foundry Sand only)
Florida	Case-by-Case Reviews	Not mandated	Yes	Not mandated	Not mandated
Louisiana	Case-by-Case Reviews	Not mandated	Yes	Yes	Recordkeeping
Mississippi	Waste Classification	Not mandated	Yes	Yes	Yes
Texas (CCPs have separate regulatory program)	Case-by-Case Reviews	Yes	Yes	Yes	Not mandated

2.2 Federal Programs Encouraging State Program Improvements

Several federal programs are encouraging beneficial reuse of byproducts and, in many cases, bringing together federal and state governments with industry stakeholders to address the issue.

- EPA’s Sector Strategies Program, with cooperation from industries in numerous sectors, is pushing to increase reuse of byproducts.

- EPA has worked with several federal agencies to develop and implement Environmentally Preferable Purchasing (EPP) guidelines, which help procurement officials consider the environmental aspects of purchasing materials and equipment, including those that incorporate beneficial reuse in the manufacturing process. The federal government Comprehensive Procurement Guidelines encourage the use of concrete containing fly ash, blast furnace slag, and other CCPs.

- EPA’s Resource Conservation Challenge (RCC) is a national effort to conserve natural resources and energy by managing materials more efficiently and has, as one of its four main goals, the recycling of industrial materials. The program’s Industrial Materials Recycling effort focuses on three industrial non-hazardous wastes: coal combustion products, construction and demolition byproducts, and foundry sands.

3.0 Sector Traits and Trends, Drivers and Barriers in Current Beneficial Reuse

Beneficial reuse within and across sectors is shaped by certain factors, deemed drivers and barriers in this paper:

- Drivers are market characteristics, regulations, policies, guidance, and other factors that lead or can lead to increased beneficial reuse of byproducts.

- Barriers are market characteristics, regulations, policies, and other factors that inhibit or discourage beneficial reuse of byproducts.

Chapter 3.0 Sector Traits and Trends, Drivers and Barriers in Current Beneficial Reuse

An understanding of industry characteristics and beneficial reuse opportunities is essential to fully understand what factors are encouraging or discouraging reuse within or across sectors. Sections 3.1 through 3.9 discuss each industry's geographic and size characteristics, industrial processes, beneficial reuse traits and trends (where data are available), and drivers and barriers to reuse.

3.1 Cement Manufacturing (NAICS 327310)

The cement production process begins with finely ground raw materials such as limestone, clay, shale, sand and may include beneficial reuse materials such as fly ash, bottom ash, blast furnace slag, and steel slag that substitute for virgin materials. Raw materials are fed into the high end of a cylindrical rotary cement kiln either in solid form in a dry process kiln or as a slurry in a wet process kiln. Conventional fuels such as coal, petroleum coke, and natural gas are fed into the low [opposite] end of the rotary kiln. Beneficial reuse also takes place in the form of using scrap tires or liquid waste as alternative fuels in the cement production process. The rotary kiln is heated to temperatures in excess of 2,700 degrees Fahrenheit, causing the raw materials to calcine into cement clinker. Cement clinker is the principal raw material in Portland cement, which also includes gypsum and other solid materials. A byproduct of the cement production process is cement kiln dust (CKD), which is created when clinker is formed in the rotary kiln and is exhausted from the kiln with the exhaust gas. CKD is captured from the exhaust gas with electrostatic and bag filters and is generally recycled back into the rotary kiln as a raw material.

A more detailed study of the alternative fuels and raw materials is under development at EPA in the Office of Policy, Economics, and Innovation and a report is expected in Spring, 2008.

3.1.1 Beneficial Use Traits and Trends in the Cement Sector

As shown in Table 3-1, the cement industry in the Gulf Coast states is comprised of 24 Portland cement manufacturing facilities. While this is a small number of facilities, these facilities still present a significant opportunity for the beneficial reuse of manufacturing byproducts within the cement industry and reuse of byproducts from other industry sectors in the cement manufacturing process, whether as raw materials or as fuels.

Table 3-1: Number of Cement Manufacturing Facilities in the Gulf Coast States as Characterized by Cement America's 2005 North American Cement Directory[8]

State	Cement Manufacturing Facilities
Alabama	5
Arkansas*	1
Florida	6
Louisiana	0
Mississippi	1
Texas	11
Total	**24**

* Arkansas is included in the table because one facility is located within 100 miles of Shreveport, LA.

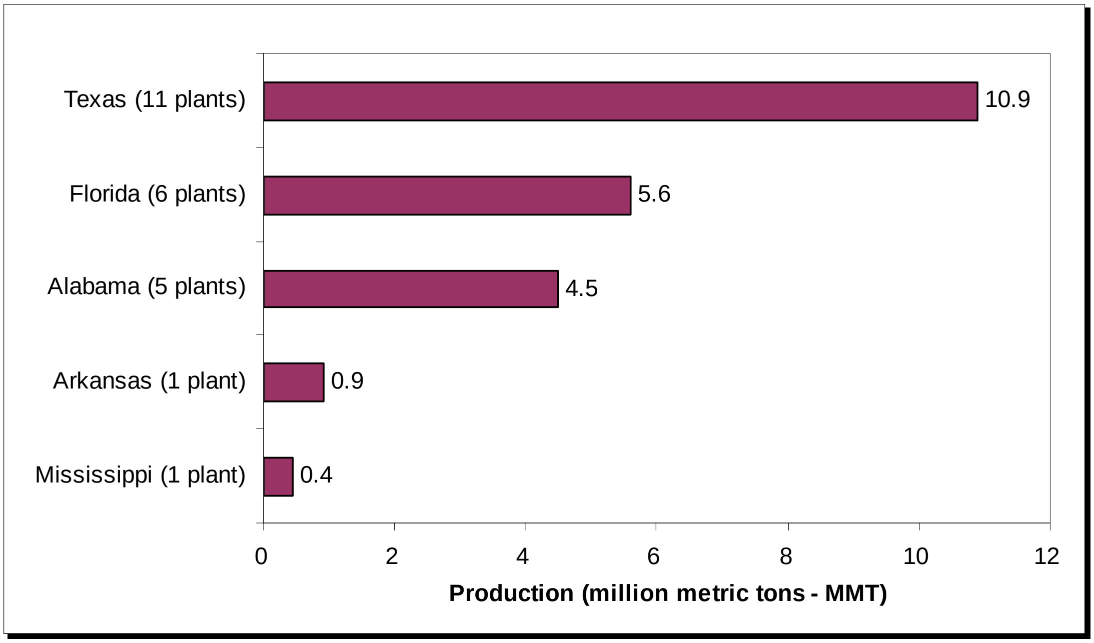
The discussion of traits and trends in the Gulf Coast states' cement industry is divided into three parts to address the issues most relevant to the sector:

- Cement kiln dust.
- Alternative raw materials from other industries used in the cement production process (including coal combustion products (CCP) and iron and steel byproducts).
- Alternative fuels from other industries used in the cement production process.

Cement Kiln Dust (CKD)

The principal byproduct of cement clinker production is cement kiln dust. The amount of CKD generated at a facility is a function of the amount of cement clinker produced, which is trending up according to U.S. Geological Survey (USGS) data. According to the USGS, U.S. cement clinker production has steadily increased from 1995 through 2005: 69.98 million metric tons (MMT) in 1995; 77.337 MMT in 1999; 86.66 MMT in 2004; and 87.405 MMT in 2005.[9,10] Figure 3-1 presents 2005 cement clinker production data obtained from Cement Americas 2005 North American Cement Directory for states in the Gulf Coast region. There is evidence that the correlation between CKD generation rates and clinker generation rates is changing. Cement facilities are using technology and operating practices to minimize generation and/or reuse CKD on-site.

Figure 3-1: Cement Clinker Production Gulf State Region (2005)[11]



* Arkansas is included in the table because one facility is located within 100 miles of Shreveport, Louisiana. There are no facilities in the scope of interest in Louisiana.

Cement manufacturing plants have three options for CKD generated during the cement production process: (1) recycle CKD as a raw material back in the cement production process, (2) landfill CKD (either on-site or off-site), or (3) make CKD available for beneficial reuse by other sectors.

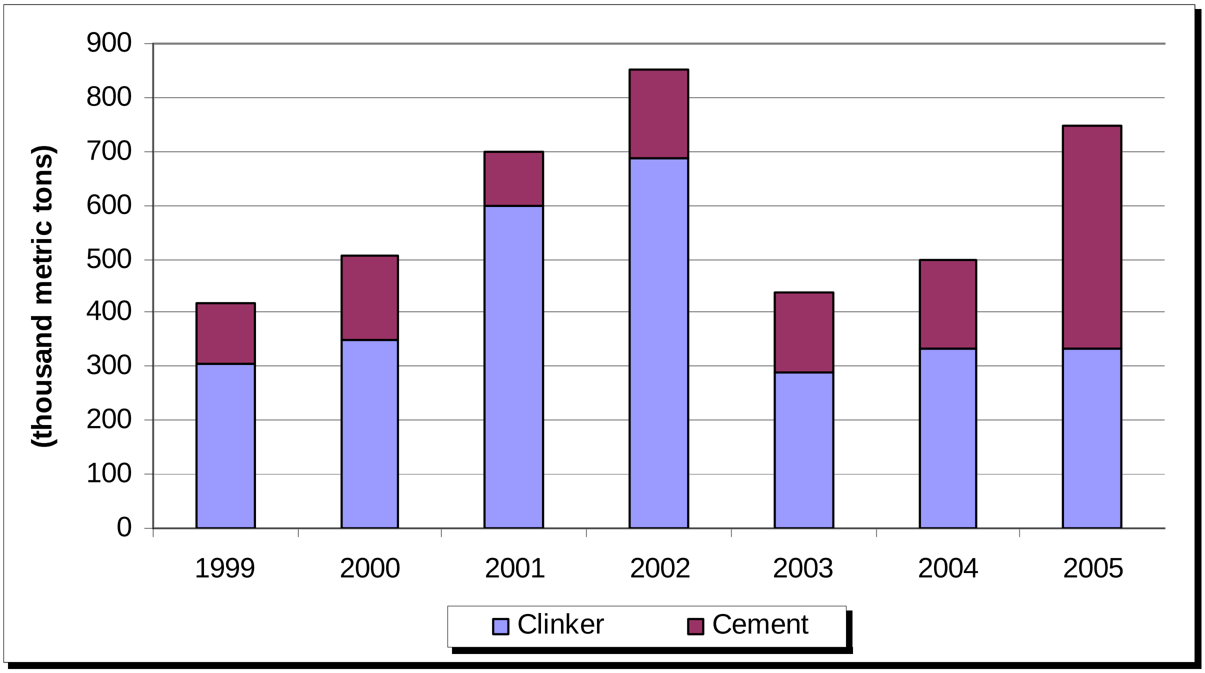
Depending on process conditions and market conditions, individual cement plants can avoid having to landfill CKD either by increasing the amount of CKD reused on site and/or by providing CKD to other sectors for beneficial reuse.

Increasing reuse of CKD on site is a result of changes to cement manufacturing operations. As shown in Figure 3-1, the amount of CKD recycled onsite in cement production is trending up according to USGS data, which indicate the amount of CKD being recycled increased almost 80 percent from 1999 to 2005. USGS has reported, based on informal data from cement manufacturers, that 60 to 70 percent of CKD generated at is reused on site, corresponding to 7 to 8 MMT of the 12 to 15 MMT per year CKD generated; 10 percent of CKD generated is used for other purposes; and the remainder is landfilled.[12] According to PCA data, the cement sector recycles on site approximately 75 percent of the CKD generated.[13]

Historically, most CKD produced by cement kilns in the U.S. is recycled directly back into the cement kiln; nearly 8 million tons/year (75%), which reduces the need for limestone and conserves energy.[14] Data reported by the PCA indicate the amount of CKD landfilled has decreased from 2.6 MMT in 1990 to 1.25 MMT in 2006 (after reaching a high of 3.25 MMT tons in 1995). In 1990, U.S. cement kilns landfilled 60 kilograms of CKD per metric ton of cement clinker produced; by 2006, the amount landfilled decreased to less than 15 kilograms of CKD per metric ton of cement clinker produced.[15] This significant reduction in the amount of CKD landfilled per ton of cement clinker produced is attributable to the increased amount of CKD reused in cement kilns and to the increased beneficial use of CKD by other sectors.

This reduction resulting in part from the U.S. cement industry adopting a voluntary 60 percent reduction target (from a 1990 baseline) in the amount of CKD disposed per ton of clinker produced by 2020.[16] According to 2006 data published by the PCA, the cement sector has already exceeding the reduction target (73 percent from the 1990 baseline).

Figure 3-2: Cement Kiln Dust Use in Clinker and Portland Cement Production in the U.S.[17]



As discussed in the case study in the text box, a cement plant (one of many) is actually providing CKD to other industry sectors from both ongoing generation and from an onsite CKD stockpile. This dual approach could potentially increase the amount of CKD available for beneficial use. The amount of CKD potentially available from onsite stockpiles at cement plants will, of course, depend on site-specific and market conditions. However, PCA reports that in 2006, over 1.1 million metric tons of CKD were removed from the kiln systems and used for soil stabilization and consolidation, waste stabilization and solidification, and mine reclamation.[18]

Case Study: CKD Available for Beneficial Reuse In Other Manufacturing Sectors

PCA reported that the St. Lawrence Cement plant in Hagerstown, Maryland, is providing CKD for use as an agricultural lime material and as a material for stabilization of wastes generated by other industrial facilities. CKD from the St. Lawrence Cement plant is also being blended into specialty cement sold in the local construction market. As a result, the plant is beneficially reusing 100 percent of the CKD it is generating and is now also removing the CKD from its existing CKD stockpile to support these beneficial uses

Alternative Raw Materials from Other Industries Used in the Cement Industry

In addition to CKD, alternative raw materials used in cement production include: (1) coal combustion products (including fly ash and bottom ash); and (2) iron and steel byproducts (including ground granulated blast furnace slag (GGBFS), steel slag, other blast furnace slag, and other types of slag). Slag is being reused as a raw material at five plants in Texas, three plants in Alabama, and three plants in Florida (3).[19] Fly ash and/or bottom ash are being reused as raw material at two plants in Texas, four plants in Alabama, and seven plants in Florida (7).[20] These industrial byproducts may be introduced as raw materials into cement kilns or may be blended with clinker produced by cement kilns.

Coal Combustion Products

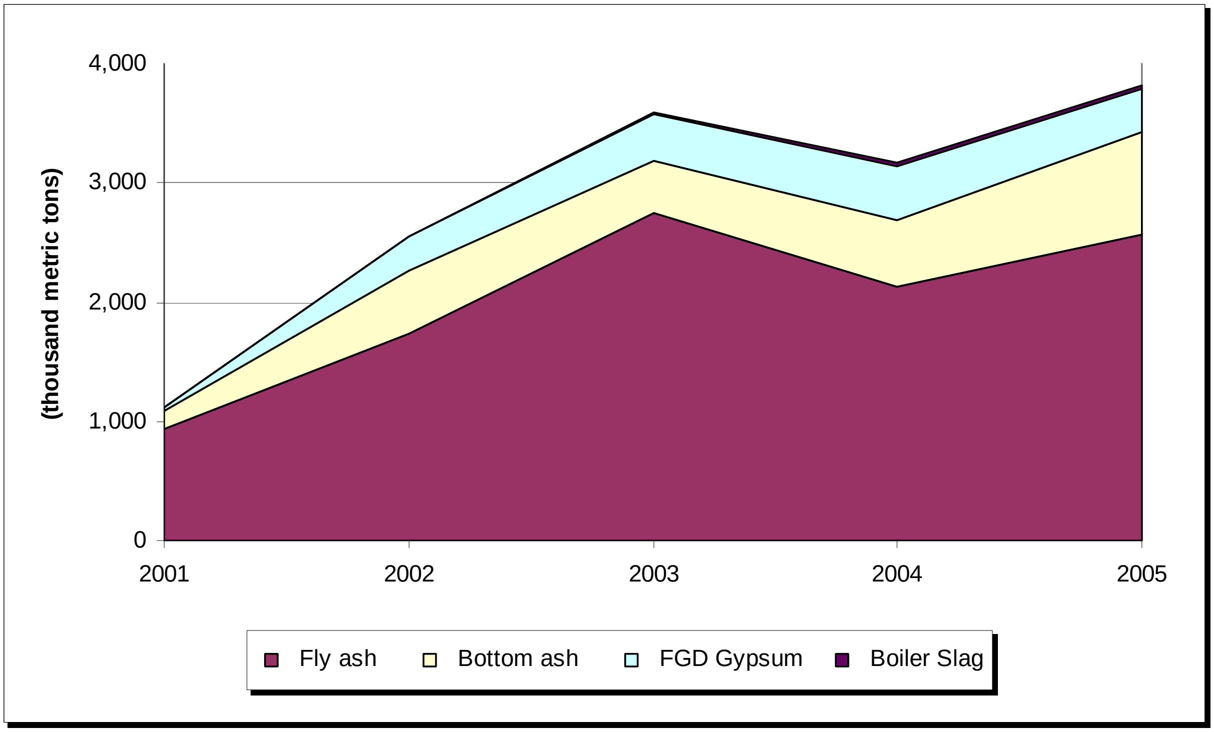
The amount of fly ash and bottom ash generated from coal-fired electric power plants has been increasing by several percent per year over the past 10 years because of increased coal utilization in electric power production and as a function of changes in the quality of the coal being used. In fact, the amount of fly ash generated increased from 49.2 million metric tons (MMT) in 1995 to 64.3 MMT in 2004. Of these amounts, 25 percent (12.3 MMT) was reused in all industry sectors in 1995, increasing to 40 percent (25.5 MMT) reused in 2004.

The amount of bottom ash generated by coal-fired power plants increased from 13.2 MMT in 1995, to 15.6 MMT in 2004 (after reaching 18 MMT in 2002). Of these amounts, 35 percent (4.6 MMT) was reused in all industry sectors in 1995, increasing to 47 percent (7.4 MMT) in 2004.

Fly ash generated from coal combustion is used as a raw material in cement kilns and as an additive to the cement clinker. According to USGS data, most fly ash is used as a raw material in cement production and bottom ash is only used as a raw material in cement production (not as an additive to the cement clinker).

Figure 3-3 presents data from the American Coal Ash Association on coal combustion products use in clinker and Portland cement production. As evident the graph, the use of CCPs as raw materials in clinker and Portland cement production has increased substantially, from 1,113 thousand metric tons in 2001 to 3,824 thousand metric tons in 2005. Fly ash comprised the most significant portion of this CCP beneficial reuse from 2001 through 2005.

Figure 3-3: Coal Combustion Products Used in Producing Clinker and Portland Cement in the U.S.[21]



National data from PCA for 2006 indicated that, of the 115 operating Portland cement plants reporting in the PCA report, 55 plants used blast furnace or iron slag as a raw material and more than 50 plants used fly ash or bottom ash from electric power plants.[22]

The potential for beneficial reuse of fly ash and bottom ash in cement production is partly a function of the amount of cement clinker produced, which is trending up according to USGS data. As previously noted, total cement clinker production has increased from approximately 69.98 MMT in 1995 to 87.41 MMT in 2005.[23,24] However, 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. Clinker production increased by 13 percent from 1999 to 2005, while the amount of fly ash used in cement production increased 93 percent during this period, and the amount of other ash, including bottom ash, increased 59 percent over this period.

Iron and Steel Sector Byproducts

Iron and steel byproducts include GGBFS, steel slag, other blast furnace slag, and other types of slag. The cement production process can use iron and steel byproducts as raw materials in cement kilns and as additives to cement clinker. USGS data for 2005 indicate that:

- Steel slag is only used as raw material in cement clinker production.

- Ground and unground granulated blast furnace slag are used as raw materials in cement clinker production and as an ingredient in Portland cement (post-kiln production).

- Other blast furnace slag is only used as a raw material in cement clinker production.

- Other slags (a category not further disaggregated in the USGS data) are used as raw materials and additives in the cement production process.[25]

USGS trend data for GGBFS, other blast furnace slag, steel slag, and other slag are shown in Figure 3-4 and Table 3-2. All of the byproducts, except steel slag, show a marked increase in beneficial reuse from 1999 to 2005. Steel slag shows an 11 percent decrease during the same time period.

According to USGS data, the total amount of iron and steel sector byproducts beneficially reused in cement production (of which GGBFS is a subset) was relatively flat between 1999 and 2004, at approximately 1.1 MMT per year, but increased to approximately 1.5 MMT per year in 2005 – an approximate 40 percent increase in one year. However, based on the discussion of data in the *USGS Minerals Yearbook*, these published USGS data may not be fully representative of iron and steel sector byproduct utilization in cement production. The cement clinker production data and slag utilization data reported by the USGS do not include the direct use of GGBFS as a component of "slag cement." Slag cement does not contain cement clinker and represents a small fraction of total cement production, according to USGS.[26] USGS reported that some slag used to manufacture GGBFS for use as a component of slag cement is imported, and some is domestically produced. According to USGS, there are two pathways by which GGBFS is used: 15 percent of the total GGBFS sold in 2005 was used by cement producers and the remaining 85 percent was sold as a "substitute" for Portland Cement as "slag cement."[27]

Figure 3-4: Utilization of Iron and Steel Sector Slag in Cement Clinker Production in the U.S. (1999-2005)[28]

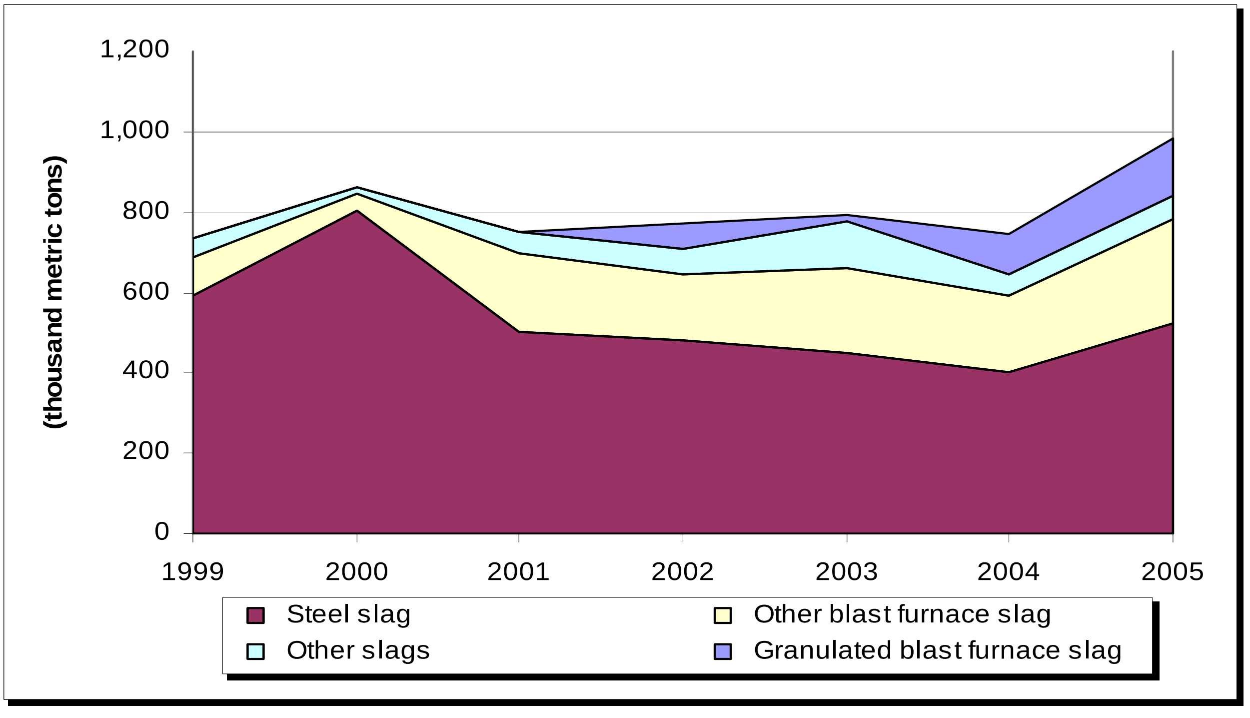


Table 3-2: Utilization of Fly Ash and Blast Furnace Slag in Cement Clinker and Portland Cement Production (1999 – 2005)[29]							
Raw Material	**Thousand Metric Tons**						
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Fly Ash [for Portland Cement Production]	85	88	70	64	39	77	153
Fly Ash [for Cement Clinker Production]	1,521	1,679	1,600	1,960	2,250	2,890	2,950
Granulated Blast Furnace Slag [Portland Cement Production]	349	303	300	369	333	345	521
Granulated Blast Furnace Slag [Cement Clinker Production]	--	--	--	60	17	104	144
Total	**434**	**391**	**370**	**433**	**372**	**422**	**673**

Historically, the Mid-Atlantic and North Central states have reused most iron and steel slag in the vicinity of iron and steel mills. In 2001, the last year USGS published these data, 87 percent of the blast furnace slag reused was reused in these states with the remaining 13 percent of the material used in the South (Alabama, Kentucky, and Mississippi) and West (California and Utah). This is a function of the material transportation costs. Approximately 80 percent of the iron and steel slag reused in 2001 was transported by truck.[30]

Alternative Fuels from Other Industries Used in the Cement Industry

Historically, cement plants have used conventional fossil fuels (coal, petroleum coke, fuel oil, natural gas) in cement kilns. In 2006, according to data in the U.S. and Canadian Labor-Energy Input Survey published by the Portland Cement Association, U.S. cement plant energy consumption consisted of 76 percent coal and petroleum coke, 9 percent waste (including scrap tires and various forms of liquid and solid waste) 3 percent natural gas, 1 percent petroleum products, and 11 percent electricity (from operating machinery, etc.). One apparent trend regarding fuel use in cement production is that alternative fuel use in cement kilns has increased substantially over the past 10 years. These alternative fuels include waste oils, hazardous waste, solid waste, wood waste/waste paper, and scrap tires.[31]

In 2006, according to the 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). The use of alternative fuels was distributed as: 48 plants using scrap tires; 16 plants using waste oil; 10 plants using solvents; 25 plants using solid waste; and 15 plants using other unspecified types of waste. The 65 plants reporting alternative waste fuel use in 2006 represents an increase from the 54 cement plants reporting alternative waste fuel use in 2000.[32] In 2007, PCA reported that scrap tires are being reused as fuel at six plants in Texas, three plants in Alabama, and two plants in Florida.[33]

USGS reports data on the utilization of “solid waste” (other than scrap tires) and “liquid waste” (including waste oils and hazardous waste) in cement kilns but does not disaggregate these data by the industry sector(s) generating the waste. Therefore, solid and liquid wastes may include industrial wastes generated from sectors beyond the focus of this report (e.g., post-consumer waste).

Utilization of solid waste (other than scrap tires) in cement kilns is variable but still relatively low: 90,000 metric tons in 1993; 74,000 metric tons in 1994; 317,000 metric tons in 2003; and 125,000 metric tons in 2004. Several cement plants reported using wood waste and/or scrap paper/cardboard as alternative fuel; but no trend data were available on the utilization of these alternative fuels. At a July 2005 EPA/PCA Workshop, one cement plant in California and one in Michigan were identified as using wood waste from forest products as a supplemental fuel. One cement plant in Iowa reported using scrap paper and cardboard waste as a supplemental fuel.[34]

Liquid waste utilization in cement kilns shows a variable but increasing trend from approximately 745 million liters in 1993 to approximately 999 million liters in 2004.[35,36] USGS reported that approximately 1 billion liters (approximately 900,000 metric tons) of liquid waste were used as alternative fuels in cement kilns in 2004, while approximately 1.5 billion liters of liquid waste were used in cement kilns in 2005.

The chemical, petrochemical, and petroleum refining industries are significant sectors in the Gulf Coast region. These sectors generate a significant quantity of liquid organic waste, which could be used as alternative fuels in cement kilns. Increased utilization of alternative fuels from these sectors in the Gulf Coast region could replace conventional fuels and decrease the amounts of coal, petroleum coke, and fuel oil used in cement kilns in the Gulf Coast region.
Historically, cement plants have not used significant quantities of construction and demolition (C&D) debris material in cement clinker production or Portland cement production. The presence of large quantities of C&D debris will continue to be an ongoing issue, however, as hurricanes and tropical storms strike the Gulf Coast in the future. These events create significant amounts of C&D debris, which could be used as alternative fuels in cement kilns. Depending on circumstances, C&D debris could be retrieved from landfills for use in the kilns. Such debris would need to be segregated and processed prior to utilization in cement kilns to provide material of consistent quality (e.g., British thermal unit (BTU) content). Transportation issues would need to be addressed in such a reuse scenario, because as shown in Table 2-1, there are relatively few cement plants in the Gulf Coast states.

3.1.2 Beneficial Reuse Drivers and Barriers in the Cement Sector

As discussed in Section 3.2.1, the cement sector has implemented a number of measures that have led to successful beneficial reuse of byproducts from other industrial sectors, as well as tremendous beneficial reuse of CKD in other sectors. The cement production process can beneficially reuse a number of byproducts from other industries. However, the materials chosen for this analysis are produced in the greatest volumes and have the greatest potentials for beneficial reuse. Table 3-3 lists the cement industry byproducts selected for analysis in this paper, along with the rationale for their selection. The following sections describe the drivers that have contributed to this success, barriers that the cement sector has addressed in order to increase cross-sector beneficial reuse, and barriers that the industry will need to address as facilities increase their beneficial reuse of byproducts, whether as raw materials or as fuels in cement kilns.

Table 3-3: Byproducts from Cement Manufacturing (NAICS: 327310) Selected for Analysis		
Byproducts	**Reuse**	**Rationale for Inclusion**
Cement Kiln Dust (CKD)	• Waste solidification/soil stabilization • Hydraulic barrier in a landfill/liner cover • Land application as agricultural soil amendment • Flowable fill (also called Controlled Low-Strength Material), is a mixture of Portland cement, coal combustion fly ash, sand, and water that flows as a liquid and sets as a solid • Mineral filler in hot-mix asphalt (HMA) paving • Mine reclamation[37] • Fertilizer manufacturing • Road construction sub base • Waste treatment Reuses within same sector: • CKD can be recycled on site as a raw material for cement clinker production (raw material feed to cement kiln) • Replacement for Portland cement (in concrete block manufacturing) • Replacement for Portland cement (in redi-mix concrete)	• Produced in quantities significant enough for beneficial reuse • Potential for more reuse to occur: 748,000 metric tons used in production of cement and clinker in 2005[38] and about 2 MMT was sent to landfills in 2005 (vs. 3.25 MMT in 1995); [39] [40] In 2006 about 1.1 MMT CKD was used for off-site beneficial uses including soil stabilization and mine reclamation and about 1.3 MMT CKD was landfilled.[41] 75 percent of CKD generated is recycled/reused onsite[42] • Can be reused across sectors for nonfuel purposes
BYPRODUCTS FROM OTHER SECTORS USED IN CEMENT MANUFACTURING		
From Construction and Demolition		
Wood Waste	• Note here that C&D debris is different from wood waste under Forest Products	See C&D for rationale
From Electric Power Generation		
Fly Ash (CCP)	• Raw material for Portland cement production • Portland cement additive	See Electric Power Generation for rationale
Bottom Ash (CCP)	• Raw material for Portland cement production	See Electric Power Generation for rationale
FGD Gypsum	• Raw material for Portland cement production • Portland cement additive[43]	See Electric Power Generation for rationale
From Forest Products		
Causticizing Residue	• Raw material for Portland cement production	See Forest Products for rationale
Wood Waste	• Alternative fuel for Portland cement production	See Forest Products for rationale
From Iron and Steel Mills		
Granulated Blast Furnace Slag	• Raw material for Portland cement production • Portland cement additive	See Iron and Steel Production for rationale
Other Blast Furnace Slag	• Raw material for Portland cement production	See Iron and Steel Production for rationale
Steel Slag	• Raw material for Portland cement production	See Iron and Steel Production for rationale
EAF Dust/Sludge from EAF Gas Cleaning & Collection	• Raw material for Portland cement production	See Iron and Steel Production for rationale

Table 3-3: Byproducts from Cement Manufacturing (NAICS: 327310) Selected for Analysis		
Byproducts	**Reuse**	**Rationale for Inclusion**
From Metal Casting – Foundries		
Foundry Sand	• Raw material for Portland cement production	See Metal Casting for rationale
From Petroleum Refining		
"Sulfidic caustics"	• Alternative fuel for Portland cement production	See Petroleum Refining for rationale
Other byproducts from petroleum refining are beneficially reused by the cement sector but do not meet criteria for selection.		

3.1.2.1 Cement Kiln Dust

Economic/Market Drivers and Barriers

Organizations such as PCA, World Business Council for Sustainable Development (WBCSD), the Cement Sustainability Initiative (CSI), and the EPA Sector Strategies Program are working in a collaborative manner to educate generators and users of CKD about markets and possibilities for reuse. Numerous studies have been performed on the physical, chemical, and engineering properties of CKD and its suitability for reuse in road construction, flowable fill, soil amendment, and other reuses. Therefore, construction managers are more likely to accept use of the material. Indeed, as mentioned in Section 3.2.1, the cement industry has far exceeded its goal for reduced landfill disposal of CKD.

On a more regional basis, there are challenges to cross-sector beneficial reuse in the Gulf Coast states. Of the 115 cement plants in the U.S., most are concentrated in the Eastern, Midwestern, and Pacific Coast States, which could present a barrier to cross-sector beneficial reuse in the Gulf Coast states. Twenty percent of U.S. cement kilns are in the Gulf Coast states, corresponding to approximately 20 percent of U.S. cement clinker production capacity. This limits the quantities of CKD generated by cement kilns available for beneficial reuse in the Gulf Coast region.

According to the PCA, cement plants currently reuse approximately 75 percent of CKD generated on site as raw material feed for cement clinker production (USGS estimates between 60 to 70 percent), and the amount of CKD landfilled per ton of cement clinker produced has been trending down. Increased recycling of CKD on site limits the availability of CKD for offsite markets. Data on the amount of CKD generated by the cement kilns in the Gulf Coast states and data concerning the amount of CKD being beneficially used in these states are not available due to protection of confidential and proprietary business information. National data may not be representative of CKD generation and use in the Gulf Coast.

Regulatory/Programmatic Drivers and Barriers

CKD disposal is largely controlled by state regulations and, as a result, the wide variation in state regulatory requirements may present barriers to exchange of materials across state lines. Certain states, such as Texas, allow cement plants to dispose of CKD on their own property without a state permit. Other states, such as Alabama, regulate CKD under generic solid waste rules; therefore, any landfill in the state could accept CKD for disposal. These low regulatory barriers for disposal lower the economic incentive for offsite beneficial reuse of the CKD. However, offsite landfill disposal costs would still be a driver for cement plants to increase the amount of CKD recycled on site as a raw material into the cement kilns.

Environmental Effects

Certain cement kilns, including cement kilns in Texas, burn hazardous waste as supplemental fuel. This practice potentially increases the analytical testing requirements for offsite beneficial use of the CKD. Otherwise, CKD is considered a low-hazard material that is not regulated as a RCRA hazardous waste. Requirements to obtain and maintain a hazardous waste combustor (HWC) Maximum Achievable Control Technology (MACT) permit include monitoring, reporting, and recordkeeping requirements and periodic comprehensive performance testing of the cement kiln and byproduct materials.

3.1.2.2 Alternative Fuels and Raw Materials from Other Industries Used in the Cement Industry

Economic/Market Drivers and Barriers

Development of innovative, and proprietary, technologies can lower barriers to beneficial reuse for the technology owners, but may create barriers to beneficial reuse by other facilities. Cement kilns in Texas are using patented proprietary technologies (e.g., CemStar™, developed by TXI) to beneficially reuse electric arc furnace (EAF) steel slag and fly ash in their cement products.[44,45] TXI discovered, and patented in the CemStar™ process, that the steel slag does not require fine crushing and grinding in order to be used as a raw material in the cement kilns. The use of only coarse crushing of the slag removed a significant cost barrier to increased utilization of steel slag as a raw material in cement kilns.[46] The TXI cement plant in Midlothian, Texas, is using approximately 90,000 tons per year of steel slag as a raw material for clinker production and has the capacity to use 135,000 tons per year.[47] USGS reported that the CemStar™ technology can increase cement clinker production by up to 10 percent with a commensurate reduction in cement plant CO_2 emissions.[48]

The fact that the CemStar™ technology is patented and proprietary has been a barrier to other cement companies adopting the technology. Other users of the technology are required to pay a licensing fee to TXI based on the amount of byproduct used in the cement production process. However, as a representative of the National Slag Association (NSA) noted, cement companies are typically reluctant to report production data directly to a competitor. Recent establishment of a third-party licensing mechanism may lessen this barrier.[49]

A cement plant in Florida is testing a proprietary technology to use processed fly ash material from a coal-fired power plant in cement production. The potential capacity is 60,000 tons per year of processed fly ash material.[50] This technology is potential transferable to other cement kilns located in the Gulf Coast region and elsewhere, which could significantly drive beneficial reuse.

Education and research are critical to increasing beneficial reuse and developing technologies to address the issue. Organizations such as PCA, WBCSD, CSI, and EPA's Sector Strategies Division are working in a collaborative manner to educate generators of materials about markets and possibilities for beneficial reuse in cement production. Beneficial use of fly ash, bottom ash, blast furnace slag, steel slag, and other types of slag in cement production have been demonstrated and process test data for these beneficial use applications are available. The availability of these data can lower barriers for entry into beneficial reuse.

Finally, byproduct quantities can drive or inhibit beneficial reuse. Cement kilns are "high throughput," continuous operations. From an economic/market perspective, cement plants are most interested in byproduct generators that can supply a large quantity of material of consistent quality over an extended period (e.g., a steel mill or a coal-fired power plant), rather than material generated on an intermittent basis or in smaller quantities. Cement kilns may use quantities of material on the order of 20,000 cubic yards per year. However, certain beneficial use materials (e.g., foundry sand) are generated in relatively small quantities by a relatively large number of generators, and the quality of the material varies by generator. Therefore, consolidation and blending of the material is desirable in order to provide cement kilns with a steady supply of consistent quality material. Some state regulations prohibit consolidation and blending or impose expensive testing requirements for consolidated material.[51] Alabama is one state that allows such blending or mixing from multiple facilities.

Regulatory/Programmatic Drivers and Barriers

Amendments to the federal National Emissions Standards for Hazardous Air Pollutants (NESHAP) for mercury that apply to the Portland cement manufacturing industry ban the use of fly ash from utility boilers as a cement kiln raw material if the mercury content of that fly ash has increased as a result of certain utility mercury emission controls (such as activated carbon injection), unless a facility can demonstrate that use of the fly ash will not increase its mercury emissions. Approximately 34 cement manufacturing facilities are currently using utility boiler fly ash as a feedstock (71 FR 76522).[52] The ban on utilization of fly ash with elevated mercury content generated from sorbent-injection systems may limit feasibility of utilization of fly ash from some coal-fired boilers in cement kilns. EPA indicated in the preamble to the NESHAP Final Rule that the Agency does not believe this ban will significantly affect the ability of cement kilns to use fly ash, for several reasons: [53]

- EPA does not anticipate widespread use of sorbent injection in the utility industry until 2010 or later.

- Utility boiler operators that decide to use sorbent injection have the option of collecting the fly ash from the sorbent injection system separately from the rest of the facility fly ash (e.g., using Electric Power Research Institute (EPRI's) TOXECON control system).

- Technology is being developed that would allow utilities to separate the high carbon/high mercury portion of the fly ash from the rest of the facility fly ash.

- Cement kilns have the option of conducting testing to assess whether mercury emissions will increase above the baseline when using fly ash generated by sorbent injection systems.

3.2 Chemical Manufacturing (NAICS 3251, 3252, 3253)

The chemical manufacturing sector is enormously complex and varied in terms of the number and types of industrial processes, which can include manufacture of plastics, agricultural chemicals, and organic and inorganic chemicals. However, beneficial reuse of byproducts in the chemical manufacturing sector and from facilities in the sector is promising given the number of facilities in the sector, their distribution throughout the Gulf Coast states and the U.S., their level of economic output, and the types and quantities of byproducts generated throughout the production process. Rather than provide a detailed analysis of the myriad manufacturing processes and byproducts in the chemical manufacturing sector, this section provides economic and environmental data on the chemical industry and a general overview of its beneficial reuse opportunities and barriers, highlighting a specific beneficial reuse project of the Dow Chemical Company in the Gulf Coast area.

3.2.1 Beneficial Reuse Traits and Trends in the Chemical Manufacturing Sector

The American Chemistry Council (ACC) provides useful industry descriptive statistics to characterize the chemical manufacturing sector in the Gulf Coast States. As presented in Table 3-4, Texas and Louisiana rank first and second in the U.S. in terms of value of output in 2006. In comparison to other Gulf Coast states, Texas has more than four times as many establishments and more than double the value of output. In 2006, the Gulf Coast States collectively represented approximately 14 percent of chemical establishments in the U.S. and accounted for approximately 29 percent of the value of output for the U.S. chemical industry.

Table 3-4: Chemical Manufacturing Industry in Gulf Coast States in 2006 as Characterized by the American Chemistry Council[54]

State	Number of Establishments	Value of Output ($ mill)	Value of Output State Rank
Alabama	194	$ 8,557	18
Florida	548	$ 8,521	19
Louisiana	251	$ 39,912	2
Mississippi	104	$ 4,832	27
Texas	1,121	$ 90,170	1
Gulf Coast Total	**2,114**	$ 147,160	**-**
U.S. Total	**15,383**	**$ 516,000**	**-**

To further define the industry and maintain a manageable scope for this analysis, we focused on three NAICS codes in the chemical manufacturing sector: Basic Chemical Manufacturing (NAICS 3251), Resin, Synthetic Rubber, and Artificial Synthetic Fibers and Filaments (NAICS 3252), and Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing (NAICS 3253). We excluded Pharmaceutical and Medicine Manufacturing (NAICS 3254) due to the involvement of Food and Drug Administration (FDA) regulations and approvals, as well as

Paints, Coatings, and Solvents (NAICS 3255), because our research showed that much of the beneficial reuse occurring in this category is from consumers dropping off paints at collection centers, a recycling mechanism that is outside the scope of this paper.

As shown in Table 3-5, the three NAICS codes selected for this paper comprised almost 1,000 manufacturing facilities in the chemical industry in 2004. The sheer large number of facilities in this sector may present significant opportunities for beneficial reuse of other industries' byproducts within the sector, as well as reuse of chemical manufacturing byproducts by other industries. However, the wide ranging nature of chemical processes and resulting byproducts may create challenges in terms of matching up generators and potential end users.

Table 3-5: Number of Chemical Manufacturing Facilities in Gulf Coast States as Characterized by U.S. Census 2004 County Business Patterns[55]

State	Basic Chemical Manufacturing (NAICS 3251)	Resin, Synthetic Rubber, and Artificial Synthetic Fibers and Filaments Manufacturing (NAICS 3252)	Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing (NAICS 3253)	Total
Alabama	61	20	19	**100**
Florida	52	31	71	**154**
Louisiana	98	26	19	**143**
Mississippi	26	19	6	**51**
Texas	289	112	92	**493**
Total	**526**	**208**	**207**	**941**

Examining hazardous waste data that are available for NAICS code 325 gives an overall view of hazardous waste quantity and management by the chemical industry. The Hazardous Waste Report, also known as the Biennial Report (BR), must be submitted by large quantity generators (LQGs)[56] and treatment, storage, and disposal facilities (TSDFs) every two years. These facilities are required to provide EPA with waste generation and management information biennially.[57]

According to 2005 BR data, the chemical manufacturing sector nationally manages about 6 percent of its hazardous waste by reclamation or recovery. Most of this beneficial reuse occurs at the chemical facilities where the materials are generated, either through creation of new manufacturing feedstock (e.g., acid regeneration, organics recovery, etc.) or through energy recovery at the site as fuel. Some of this reused volume (approximately 1% of all hazardous waste generated) is used in fuel blending for off-site energy recovery. Although the reuse of these byproducts as fuel occurs primarily at chemical facilities, opportunities exist for cross-sector fuel use as well, particularly in cement manufacturing plants. For example, the TXI cement manufacturing facility in Midlothian, Texas, has permits to burn hazardous waste in its wet kilns and therefore could be a recipient of byproducts from chemical manufacturers in that region.[58]

Since 2005, the Dow Chemical Company has engaged in a major beneficial reuse project in the Gulf region. Dow's Byproduct Synergy project, co-sponsored by DOE's Industrial Technologies Program (ITP), has examined opportunities for the reuse of nonchlorinated wastes generated at six of their Gulf Coast manufacturing facilities (four in Texas and two in Louisiana). Using the byproduct synergy process developed by the U.S. Business Council for Sustainable Development (USBCSD), Dow examined a total of 40 manufacturing processes at these facilities, each of which produced more than 1 million pounds of non-chlorinated byproducts per year. The Byproduct Synergy process consisted of two very important initial steps: (1) assessing the byproducts produced and potential beneficial reuses for the byproducts as feedstocks in manufacturing and (2) obtaining the cooperation and collaboration of end users. The project identified six categories of potential byproduct reuse: hydrocarbons and spent solvents, sodium hydroxide byproduct, sulfuric acid waste, Methocel waste, ortho-toluenediamine (oTDA), and hydrogen byproduct.[59]

In the first phase of this long-term project, Dow and USBCSD identified opportunities to reuse as feedstock an estimated 155 million pounds of non-chlorinated byproducts each year, resulting in a potential annual cost savings of $15 million to Dow. They also identified beneficial reuse opportunities that could reduce fuel use by 900,000 million BTUs (MMBtu) per year and reduce carbon dioxide (CO_2) emissions by 108 million pounds per year.[60]

3.2.2 Beneficial Reuse Drivers and Barriers in the Chemical Manufacturing Sector

As a very large chemical manufacturing corporation, Dow had an advantage of being able to look for beneficial reuse opportunities within its own large and diverse corporate structure. This factor facilitated cooperation and agreement among generators and end users within the corporation, and mitigated concerns that Dow might have about sharing byproducts that could reveal proprietary information about manufacturing inputs and processes. In addition, Dow has spent considerable time and effort assessing byproducts reuse opportunities, including anticipated return on investment. This assessment process in the pilot program certainly was a necessary step, but one that represents a significant up-front resource investment.

Dow has the requisite resources, expertise, and internal corporate ‘customer’ base to successfully implement beneficial reuse among its facilities in the Gulf region. However, this type of project may not be directly applicable to other chemical manufacturing operations, especially small- to medium-sized chemical companies. Smaller chemical manufacturers without multiple facilities may not be able to find appropriate end-users. This problem could be due to a lack of information on possible end uses, or to concerns about sharing byproducts that could reveal proprietary information about manufacturing inputs and processes.

Small and medium-sized chemical manufacturing firms may also lack the financial resources or expertise to be able to assess reuse opportunities for their byproducts, or to obtain the necessary approvals for off-site transfers. These information and resource factors may be significant barriers to increased beneficial reuse of byproducts by all but the very largest firms in the chemical manufacturing sector.

3.3 Construction and Demolition (NAICS 236, 23891)

Construction and demolition (C&D) byproducts (also frequently known as C&D materials) are produced during new construction, renovation, and demolition of existing structures.[61] Construction byproducts result from the building of new structures and the renovation of existing structures while demolition byproducts results from renovation and demolition of existing structures. Typical byproducts from both activities include asphalt shingles, concrete, wood, gypsum wallboard, insulation, plumbing and electrical fixtures, vinyl siding, and masonry.

3.3.1 Beneficial Reuse Traits and Trends in the Construction and Demolition Sector

We analyzed the construction and demolition industry by focusing on NAICS 236, which includes establishments that construct buildings, and NAICS 23891, called "site preparation contractors," which includes firms that demolish buildings. To refine the scope of the analysis, we focused on home and commercial building construction and demolition. Transportation and infrastructure C&D, which have processes that differ significantly from building C&D, were not included in the analysis.

As shown in Table 3-6, there were more than 35,000 firms engaged in C&D in the Gulf Coast states in 2004. However, construction and demolition activities take place in locations that can vary greatly in distance from the location of company offices, which is the basis for the Census data. Therefore, Table 3-6 is not a true representation of the locations and amount of C&D activity, nor the locations of byproduct generation from the industry. US EPA has estimated that, nationally, more than 135 million tons of building-related C&D debris are generated annually.

Table 3-6: Number of Construction and Demolition Establishments in Gulf Coast States as Characterized by U.S. Census 2004 County Business Patterns [62]

State	Construction of Buildings (NAICS 236)	Site Preparation Contractors (NAICS 23891)	Total
Alabama	2,912	466	3,378
Florida	13,495	1,772	15,267
Louisiana	2,311	349	2,660
Mississippi	1,356	301	1,657
Texas	10,580	1,621	12,201
Total	30,654	4,509	35,163

Beneficial reuse in the sector can be challenging due to the fact that when demolition occurs, most materials are not separated, which is an essential step that must occur before beneficial reuse can take place. Although construction materials have fewer concerns associated with asbestos or lead-based paint, sources indicate that commingling and lack of separation are even more prevalent during construction. Several trends in the C&D industry show that firms are addressing this challenge and are likely to positive affecting future beneficial reuse of byproducts generated by the sector. First, "designing for deconstruction," a concept that is becoming more fully recognized in the industry, takes into account potential reuse of materials by ensuring that buildings are designed and constructed so that materials can be more easily separated when buildings are dismantled. This type of design and construction enhances the building materials' reuse potential, thereby lessening the need to mine, forest, and extract the materials needed to construct buildings (such as gypsum for gypsum wallboard, trees for lumber, and petroleum for asphalt shingles).[63] Deconstruction is becoming more prevalent in the industry, and it leads to many potential reuses of C&D materials as building materials. However, the concept does not fit within the scope of cross-sector beneficial reuse and is therefore not discussed in detail in this paper.

Leadership in Energy and Environmental Design (LEED) certification is another trend that can lead to an increase of beneficial reuse in the C&D industry. The U.S. Green Building Council (USGBC) and the LEED rating system consider material selection in construction, among other criteria, to rate energy efficiency and environmental benefits. Since its inception in 2000, LEED certification is creating a paradigm shift in beneficial materials use and how green construction is perceived. In addition, USGBC is helping drive the use of building materials with less impact to the environment, manage and reduce waste from construction, and reduce the amount of materials needed overall.[64] In fact, a study of beneficial reuse in North Central Texas concluded that although renovating under LEED waste minimization standards cost slightly more than traditional methods, the methods were able to divert up to 75 percent of waste by volume from landfills.[65]

Closely related to LEED efforts by the USGBC, the World Green Building Council (WGBC) is promoting green building and architecture. In this emerging field, which embraces deconstruction and LEED certification, architecture and construction include "the practice of creating healthier and more resource-efficient models of construction, renovation, operation, maintenance, and demolition."[66]

In the U.S., there has also been a change in how C&D byproducts are perceived, and research is ongoing to discover reuse potentials. This change was brought about through the concepts listed above, as well as economic reasons such as decreased land availability for landfills, higher tipping fees for C&D landfills, bans on certain materials in landfills, lower quantities of high quality virgin products, and the ability to generate more revenue by selling byproducts to reuse markets. These concepts are discussed in further detail in Section 3.4.2.

According to Mike Taylor, Executive Director of the National Demolition Association (NDA), about 115 million tons of demolition debris are generated each year in the U.S. Of this total, about 70 percent, or 80.5 million tons, is reused, according to NDA. According to NDA, 100 percent of scrap steel is being recycled, as is a large percentage of concrete as aggregate (particularly in South Florida where concrete aggregate is said to be of poor quality) and wood debris as a fuel supplement, sludge-drying agent, or raw material for new wood products such as particleboard.[67]

Supply side trends show a steady, and perhaps even increasing, supply of byproducts from C&D. As infrastructure is aging in the United States, it will need to be demolished and updated, resulting in tons of potentially reusable byproducts. The Gulf Coast states present a particular supply trend, as Hurricanes Rita and Katrina created a significant number of damaged homes and other buildings that required demolition. Although this seems to present the potential for beneficial reuse of thousands of tons of building materials, most accounts indicate that buildings were demolished and debris was swept into piles without regard for separation for potential beneficial reuse. Some information indicates that, in EPA Region 6, some separation and reuse were occurring, especially at landfills. As the Gulf Coast states are a hurricane-prone region, there will be future events that might lead to similar situations. Proactive planning and cooperation between the Federal Emergency Management Agency (FEMA) and EPA might create an alliance that could address potential beneficial reuse of materials from such an event. Rebuilding in the area presents opportunities for building and design with deconstruction in mind.

Conclusions on demand trends for C&D materials can be drawn based on resources from the Building Materials Reuse Association (BMRA) and the Construction Materials Recycling Association's (CMRA's) www.drywallrecycling.org, www.concreterecycling.org, and www.shinglerecycling.org. As awareness of beneficial reuses for shingles, drywall, wood, and concrete increases, demand for the byproducts will increase. Ongoing, well-organized outreach programs at the state, regional, and local levels can contribute to such awareness. The Gulf Coast region presents another important opportunity that could affect demand of C&D materials. In southeast Louisiana, more than 100 square miles of marsh and wetlands that were turned into open water by Hurricanes Katrina and Rita; as discussed in sections below, C&D materials can be used for restoration of these areas.[68]

One additional local factor that can affect the supply and demand for wood byproducts is the proliferation of pests that can infest building materials. For example, the Formosan termite infests wood in the Deep South, limiting its reuse outside of the area for fear of spreading infestation. This factor encourages local reuse of wood byproducts from C&D, which will most likely occur as combustion (i.e., C&D materials will be used as a fuel source) to curb spread of the infestation.

3.3.2 Beneficial Reuse Drivers and Barriers in the Construction and Demolition Sector

Table 3-7 lists the C&D byproducts selected for analysis in this paper, along with the rationale for their selection. As displayed in the table, various organizations are pursuing a number of creative beneficial reuse of C&D byproducts, and C&D firms are utilizing byproducts from foundries and iron and steel mills for fill and concrete made at construction sites.

As described in Section 3.4.1, the construction and demolition industry has seen some growth in levels of beneficial reuse, but still faces a number of challenges in cross-sector beneficial reuse. Several industries have found innovative uses for C&D byproducts and byproducts such as foundry sands and slag have been successfully used in C&D, mostly for site preparation activities such as fill and ready-mix concrete. The following sections describe the drivers that have contributed to successful beneficial reuse of C&D byproducts as raw materials, and sometimes fuel, in other industrial sectors. We also detail the barriers to beneficial reuse that the industry will face as they move forward in reusing industrial byproducts in construction and providing C&D byproducts for use in other sectors. The use of foundry sands in home construction is discussed in Section 3.8 and the use of slag in concrete production is discussed in Section 3.3.

Table 3-7: Byproducts from Construction and Demolition (NAICS: 236 (Construction of Buildings), 23891 (Site Preparation Contractors)) Selected for Analysis

Byproducts	Reuse	Rationale for Inclusion
Asphalt Shingles (from demolition and roof replacement)	• Hot and cold mix asphalt • Aggregate base • Used as fuel source in Europe[69] Does not meet definition of beneficial reuse for this paper: • Recycled into new roofing materials with minimum 20 percent content of asphalt	• Produced in quantities significant enough for beneficial reuse; 11 M tons into U.S. landfills each year; in top 4 debris streams by quantity in C&D sector (estimated 1-10 percent)[70] • Typically 95 percent of asphalt shingle waste ends up in landfills; if only 2 percent of the 500 M tons of asphalt produced each year was composed of recycled asphalt shingles, then all shingle waste could be beneficially reused[71] • Can be reused across sectors for fuel and nonfuel uses
Concrete (from demolition)	• Erosion control • Shoreline protection[72] • Aquatic habitat restoration Does not meet definition of beneficial reuse for this paper: • Road base, general fill, drainage media, pavement aggregate	• Produced in quantities significant enough for beneficial reuse; top debris stream by quantity in C&D sector (40-50 percent) • Potential for more reuse: studies estimate that 50 to 57 percent is currently reused.[73] • Can be reused across other sectors for nonfuel purposes
Wood (from demolition and construction of structures)	• Fuel source for electricity generation (mostly wood from truss manufacturers, log home suppliers, and modular home manufacturers) in boilers or electric utilities • Mulch and compost • Pulp for particle board, chip core, laminates, animal bedding, paper products, rayon, laundry detergent, camera film, tires, and transmission belts [74] • To reduce coastal erosion Does not meet definition of beneficial reuse for this paper: • Recovered lumber for flooring	• Produced in quantities significant enough for beneficial reuse; in top 4 C&D byproducts by quantity (20 to 30 percent) • In 2002, 35.7 MMT of wood waste was generated with 29.2 MMT available for recovery; possibly only 2.7 MMT was being actually recovered in new construction[75] • Reuses occurring across sectors of interest and other sectors for fuel and nonfuel purposes

Table 3-7: Byproducts from Construction and Demolition (NAICS: 236 (Construction of Buildings), 23891 (Site Preparation Contractors)) Selected for Analysis		
Byproducts	**Reuse**	**Rationale for Inclusion**
Gypsum Wallboard (from demolition and construction)	• Support for spray-on gunite (spray-on concrete) • Cement manufacturing • Agriculture and soil amendment[76,77] • Amendment for composting systems • Stucco additive • Sludge drying agent (option undergoing research) • Wastewater treatment to settle particles (option undergoing research) • Manure treatment • Animal bedding (in combo with wood shavings) • Athletic field line marker • Possible uses as preventative application for road salt leaching, component in flea powders, and Grease absorption agent[78] • Paper backing sold to paper mills or recycled into more paper backing Reuse within same sector: • Gypsum wallboard can be recycled to make new gypsum wallboard;[79 80] a pilot program is being operated in Boston, Massachusetts[81]	• Produced in quantities significant enough for beneficial reuse; in top 4 C&D byproducts by quantity (5 to 15 percent) • Over 14 M tons of gypsum wallboard waste are generated each year, with 64 percent from new construction, 14 percent demolition, 12 percent manufacturing scrap, and 11 percent remodeling;[82] potentially all of the new construction and manufacturing wastes can be reused using current technology; although there are technological barriers to recycling demolition and remodeling scrap, recycling facilities operating using these materials[83] • Reuses occurring across sectors of interest and other sectors for nonfuel purposes
Byproducts from Other Sectors Used in C&D		
Foundry Sands	• Fill	See Metal Casting for rationale
Slag (From Iron and Steel)	• Aggregate in concrete mixed on-site	See Iron and Steel for rationale; slag is included as a byproduct reuse for C&D as well as cement production, because concrete is used in construction

3.3.2.1 General C&D Byproducts

Economic/Market Drivers and Barriers

Beneficial reuse can be driven by byproducts that are less expensive than virgin materials. Recognizing this, some companies will sell gypsum manufacturers recycled gypsum powder at a price lower than that for virgin gypsum powder.[84] Education and research efforts can also drive reuse, such as efforts by organizations like the BMRA, CMRA, the Recycled Materials Resource Center (RMRC), EPA's WasteWi$e, Resource Venture, and the Turner-Fairbank Highway Research Center. In addition, the trend towards green building can drive reuse of construction and demolition byproducts.

Having sufficient C&D processing capacity to handle reusable materials in an efficient, economical manner lowers barriers to cross-sector beneficial reuse. For examples, Florida has 40 materials recovery facilities that process most of the C&D waste in the state. However, according to NDA, development of a C&D recycling facility can be expensive in terms of the necessary equipment, land, fuel, and labor needed, in addition to landfill disposal for the non-reusable materials that come through the facility. Also, according to NDA, the profit margins on these beneficial reuse facilities is often very low, therefore making the impacts of regulatory or programmatic barriers even more significant, because profits might not outweigh the time and costs necessary to comply.[85] Despite this challenge, a study of C&D waste minimization strategies in North Central Texas found that the total cost per ton to process material at materials recovery facilities was within the range of landfill tipping fees in the North Central TX region. The study also concluded that co-locating the materials recovery facility with an existing municipal solid waste (MSW) landfill offers several benefits.[86] When C&D facilities are faced with a beneficial reuse option that costs about the same as landfill disposal and requires no more transportation than disposal in the adjacent landfill, the facilities are much more likely to provide their materials for beneficial reuse through the facility.

Although there are economic and market drivers for beneficial reuse of C&D byproducts, several barriers also exist:

- The quantities of C&D materials available for reuse depend upon economic conditions, weather, disasters, special projects, and local regulations.

- Separation and proper storage of C&D materials are essential for beneficial reuse. The time and cost of separating co-mingled materials may make beneficial reuse more costly than disposal.

- Hurricanes and other disaster situations can lead to a large amount of mixed debris generation in a short amount of time, leading to a lack of staging areas for sorting and a lack of available processing facilities to handle large amounts of debris.

- Historically the population densities in Alabama, Mississippi, and Louisiana are small and with lower median incomes than the average U.S. state. Texas and Florida have consistently ranked second and fourth in population, respectively, however the large geographic area of Texas also results in lower population densities.[87] These factors result in a history of abundant land availability in all of the states except Florida, which could lead to an abundance of landfills due to lower costs. However, this barrier to beneficial reuse is mitigated in practice because landfills can be difficult to site due to public opposition and landfill regulations. In fact, when Florida instituted C&D landfill regulations requiring groundwater monitoring in the mid-1990s, the number of C&D landfills in that state dropped.[88]

Bans on C&D Disposal Increase Quantity of Byproducts for Reuse

State and local bans on disposal of C&D materials increase the supply of byproducts available for reuse. Bans may be enacted to address concerns about land availability and landfill capacity or specific health concerns. For instance, in 2005, Massachusetts Department of Environmental Protection (MassDEP) amended 310 CMR 19.017 to add C&D materials, including asphalt pavement, brick, concrete, metal, and wood to the list of items prohibited from disposal, transfer for disposal, or contracting for disposal. Internationally, Vancouver, British Columbia, Canada, banned disposal of gypsum wallboard in landfills in 1984.

As more localities enact these types of bans, the supply of C&D byproducts available for reuse will increase. As landfill space becomes scarcer, especially in metropolitan areas like New Orleans, where landfills have even raised environmental justice concerns, beneficial reuse may grow in importance as an alternative to disposal.

Regulatory/Programmatic Drivers and Barriers

Some Gulf Coast state programs are lowering barriers to beneficial reuse of C&D byproducts. Florida provides low interest rate loans through the Recycling Loan program to businesses that develop innovative recycling programs.[89,90] Texas provides a property tax abatement for facilities that purchase pollution prevention equipment, permit exemptions for some recycling generators, and has developed a recycling market development board. [91]

According to NDA, state regulations and programs are creating barriers to the beneficial reuse of C&D materials. According to the organization, states like Texas charge large fees for recycling site permits and licenses, have not developed statewide permits for mobile recycling plants that could facilitate beneficial reuse, have regulations that severely limit project-site recycling, and have attempted to promote local economic development by establishing flow-control ordinances.[92]

According to its Strategic Plan, the Alabama Department of Environmental Management (ADEM) was recommended to impose a state-wide per ton tipping fee on waste disposal, in addition to promoting the department's image. These recommendations seem to imply that Alabama does not have per ton tipping fees that are imposed by the state agency, the lack of which may make disposal much cheaper than beneficial reuse. If a state-wide surcharge were added to tipping fees, they could serve as a driver for beneficial reuse by increasing the cost of disposal and, even further, by funding beneficial reuse programs in the state.

Mississippi's Task Force on Recycling found the following barriers to recycling/reuse in its state: lack of funding for environmental recycling, education, or beneficial reuse programs and an abundance of inexpensive land, resulting in cheaper costs of disposal and less incentive to reuse materials.[93]

Environmental Effects

Beneficial reuse of C&D debris can have environmental or human health impacts in certain situations. For example, if the materials are contaminated with hazardous waste, as was the case in some Hurricane Katrina debris, reuse of such materials would not be advisable due to greater exposure risks compared to landfilling the contaminated materials. In addition, C&D debris with lead-based paint (i.e., painted wood), asbestos, and treated wood can not be readily reused, even for use as a fuel supplement, because of the human health and environmental impacts.[94]

3.3.2.2 Asphalt Shingles

Economic/Market Drivers and Barriers

Shingles are adhered to roofs, which can create a challenge for beneficial reuse because the adhesive can cause quality control issues when the shingles are reused in asphalt production. The stock of shingles to be beneficially reused may be also contaminated by fasteners, flashing, fiberglass reinforcement, and asbestos.[95] While the fasteners, flashing, and fiberglass are not necessarily issues for cement kilns, asbestos can pose challenges. However, this is a declining barrier, because asbestos was only used in asphalt shingles made prior to the 1970s. In fact, for one project that consolidated asphalt shingles for beneficial reuse in Massachusetts, less than 1 percent of asphalt shingles contained asbestos. To address this small percentage, the State of Massachusetts imposed testing requirements to screen out the asbestos-containing shingles.[96]

While there are barriers to reuse of asphalt shingles, organizations such as Asphalt Institute, Asphalt Alliance, and the Asphalt Recycling and Reclaiming Association are working to educate and research possibilities for beneficial reuse and drive the market for these opportunities. The Construction Materials Recycling Association (CMRA) hosts, along with EPA and FHWA, the web site www.shinglerecycling.org, which provides generators and end users with tools and resources to help them pursue beneficial reuse of asphalt shingles. Another driver for beneficial reuse is tied to fuel prices: asphalt shingles can be reused as a fuel source when traditional fuel source prices are high.

Regulatory Drivers and Barriers

Alabama and Texas have state programs that are driving beneficial reuse of asphalt shingles. Section 429 of the Alabama Department of Transportation (DOT) code allows up to 40 to 50 percent recycled asphalt pavement in base and binder layers; however, the code does not specify whether shingles are included in this percentage.[97] Alabama DOT allows 5 percent total weight of asphalt shingle waste from manufacturers in the pavement mix and 3 percent total weight of asphalt shingle waste from post-consumers in the pavement mix.[98] These types of specifications can lower barriers to beneficial reuse of the byproduct by bringing important clarity to both generators in the C&D industry and end users in other sectors. Alabama DOT has been experimenting with recycling asphalt shingles for the past two years and has steadily used shingles in recycled asphalt pavement for the last year without any problems.

Texas, which formerly held stringent requirements for the percentage of virgin materials used in construction projects, now promotes the use of asphalt shingles as aggregate in pavement by providing specifications for "asphalt content of 15-25 percent by mass of shingle."[99] There is, however, a potential barrier in this specification, because it contains many requirements as to how shingles may be used in construction projects. For instance, manufacturer and post-consumer shingle waste may not be mixed for beneficial reuse.[100]

Environmental Effects

Created from petroleum, asphalt shingles can be beneficially reused as fuel. As petroleum prices rise, more firms may look towards this beneficial reuse which could reduce the environmental impacts of petroleum extraction and processing. However, air emissions must be considered when shingles are used for fuel.

Despite this small and declining percentage of asbestos in shingles, as discussed above, asbestos is still present and encountered during demolition projects. As a result, beneficial reuse projects should account for the presence and potential environmental and health hazards associated with reuse of shingles that contain asbestos.

3.3.3.3 Concrete

Economic/Market Drivers and Barriers

Scrap concrete can be beneficially reused in creative ways, as listed in Table 3-2. However, if virgin materials are abundant and cheap in a locality and more convenient to transport and use, beneficial reuse would not be a lower cost alternative. The rate of beneficial reuse of scrap concrete in these situations is affected by the local availability of materials. In addition, the weight and mass of concrete could lead to high transportation costs, which could hinder beneficial reuse, especially if reuse locations are not near the construction or demolition sites generating the byproducts.

Regulatory Drivers/Barriers

In some cases, concrete can contain harmful chemicals, depending on the site in which it was originally used. Because of this potential, some state agencies, such as New Jersey Department of Environmental Protection, are restricting its reuse.[101] However, many states agencies, such as the Texas and Florida DOTs, support reuse of concrete as aggregate, base, or fill.[102] In addition, Louisiana is promoting the use of concrete to create artificial reefs/wetlands. In this type of beneficial reuse, sediments become trapped around the debris, creating conditions in which reef and wetland plants and organisms can thrive. Louisiana has a project to restore the Acadian Bay reef using concrete rubble and has been consulted in using concrete rubble more widely in its coastal restoration projects.[103] The state of Mississippi is using concrete from demolition sites as rip rap to counteract erosion along channels near the town of Gautier.[104]

Environmental Effects

As mentioned above, depending on the location where the concrete was originally used, it could possibly be contaminated with toxic or hazardous materials. In these cases, beneficial reuse could have environmental or human health impacts, and the concrete should not be reused near residential areas unless properly capped.[105] Ecosystems can be positively impacted, however, when scrap concrete is chosen and reused appropriately to construct artificial reefs/wetlands.

3.3.3.4 Wood

Economic/Market Drivers and Barriers

The beneficial reuse of wood from construction or demolition of structures for non-fuel purposes can be hindered by requirements for careful separation and clean storage. Additionally, after disasters, wood debris can be ruined or considered hazardous due to water damage and contaminants. However, it can be easily cleaned with germicidal bleach to remove mold if that step is deemed necessary prior to beneficial reuse.[106] The market for old wooden beams, siding, shingles, and other materials with historical value can drive beneficial reuse, especially in the Gulf Coast states Cypress wood is prevalent. Cypress has historically been used in the Southeastern U.S. due to its long life and termite-proof qualities. Consequently, the wood is in high demand even while Cypress forests are in decline throughout much of the Gulf Coast area.

Despite this demand for specialty wood and architectural items, locality characteristics may inhibit cross-sector reuse. For example, wood from New Orleans could not be transported to other regions for beneficial reuse because the Formosan termite, which is prevalent in the local area, might be spread to currently unaffected regions.

Regulatory/Programmatic Drivers and Barriers

State environmental agencies are driving beneficial reuse by promoting the use of wood, particularly Christmas trees in Louisiana, to create artificial reefs and wetlands. In this application, sediments are trapped, plants take root around the debris, and organisms are attracted, all of which aids in re-building damaged ecosystems in the form of reefs and wetlands. This type of creative beneficial reuse could also apply to wood from C&D operations.

Environmental Effects

Beneficial reuse of wood from construction and demolition can positively affect the environment by reduce the use of virgin materials and the environmental impacts of logging. Reusing native woods like Cypress can allow woodland ecosystems to remain untouched or be allowed to regenerate after extensive logging ventures. In addition, the ecosystem restoration efforts described above illustrate how beneficial reuse can positively impact the environment.

3.3.3.5 Gypsum Wallboard

Economic/Market Drivers and Barriers

Similar to wood, wallboard requires careful separation and clean storage to be beneficially reused. In addition, after disasters, C&D materials can be ruined due to water damage or considered hazardous due to contaminants. However, recovered gypsum wallboard may be more easily reused than other materials from C&D sites when it is removed separately by a drywall contractor and, therefore, is separated from other byproducts and potential contaminants.[107] In some cases though, each general contractor disposes of wastes, which may lead to wallboard being mixed in with other C&D materials.

Beneficial reuse opportunities are limited when gypsum wallboard has been painted, especially with lead-based paint. Current technologies in the United States are not effective at removing paint from wallboard (Canada, however, has a method of separating the paint from the paper on the wallboard).[108] Although there are technological barriers to recycling wallboard, European-developed technologies are providing more opportunities to beneficially reuse gypsum wallboard in the U.S.[109] Some companies have found success using recycled gypsum waste and selling it as a reprocessed raw material, such as Gypsum Recycling International (GRI).[110]

Regulatory Drivers/Barriers

Facilities that process gypsum wallboard for beneficial reuse may require an air emissions permit from the state.

Environmental Effects

The environmental and human health effects of landfilling gypsum wallboard are a strong driver for beneficial reuse. Under conditions that are often found at landfills, decomposing drywall can generate hydrogen sulfide, a gas that causes odors at low levels and health affects at high levels."[111] In fact, the City of Vancouver, BC, Canada, has banned landfill disposal of wallboard for this reason.

3.4 Electric Power Generation at Fossil Fuel Plants (NAICS 221112)

Burning coal in steam boiler furnaces at electric power plants produces coal combustion products. Coal is either injected or conveyed into the furnaces where it ignites and burns. When the coal is completely combusted, the coal combustion products (CCPs) (i.e., the non-combustible portions of the coal) either fall to the bottom of the boiler or exit the furnace in a flue gas stream that is captured by dust collection devises. Fly ash is the ash in the flue gas that is removed before the gas exits the chimney. Flue gas desulfurization (FGD) material is produced when sulfur dioxide is removed from the exit gas, in order to prevent acid rain.[112]

3.4.1 Beneficial Reuse Traits and Trends Electric Power Generation at Fossil Fuel Plants

In 2004, almost 400 fossil-fuel-burning electric power generation facilities operated in Gulf Coast states, as shown in Table 3-8. The large number of facilities in the Gulf Coast states could present significant opportunities for beneficial reuse of CCP byproducts from the facilities in this sector that are coal burning.

Table 3-8: Number of Fossil Fuel Burning Electric Power Generation Facilities in Gulf Coast States as Characterized by U.S. Census 2004 County Business Patterns [113]

State	Electric Power Generation, Transmission, & Distribution (NAICS 221112)
Alabama	11
Florida	122
Louisiana	75
Mississippi	13
Texas	175
Total	**396**

The American Coal Ash Association's (ACAA) *CCP Production and Use Survey* indicates a trend of increased beneficial reuse of fly ash and flue gas desulfurization (FGD) material from 1966 to 2004. The 2004 ACAA *CCP Production and Use Survey* reported CCP utilization at 49.1 million tons, a 6 percent increase from 2003. The survey also reported a 40.1 percent CCP beneficial reuse rate in 2004, up from 38.1 percent in 2003.

Figures 3-5 and 3-6 display the quantities of CCP produced and the relative amount of beneficial reuse in the Gulf States in 2004.[114] According to the American Coal Council (ACC), beneficial reuse of CCPs has seen slow but consistent growth from 2001 to 2003, in the following areas:

- FGD gypsum material for the production of wallboard, which increased 25 percent during the time period, was the most significant area of growth for the beneficial reuse of CCPs.[115] FGD gypsum is a synthetic material that results from the burning of coal for electricity. It is identical in chemical structure to mined gypsum.

- Total tonnage of FGD gypsum sold increase by approximately 11 percent, from 6.6 million tons in 2001 to 7.4 million tons in 2003.[116]

- Beneficial reuse of fly ash increased by 23 percent.[117]

- Total tonnage of fly ash sold increased 10 percent, from 17.8 million tons in 2001 to 19.5 million tons in 2003.[118]

Figure 3-5: Coal Combustion Products Produced by Coal-Fired Power Plants Located in the Gulf States in 2004 (metric tons)[119]

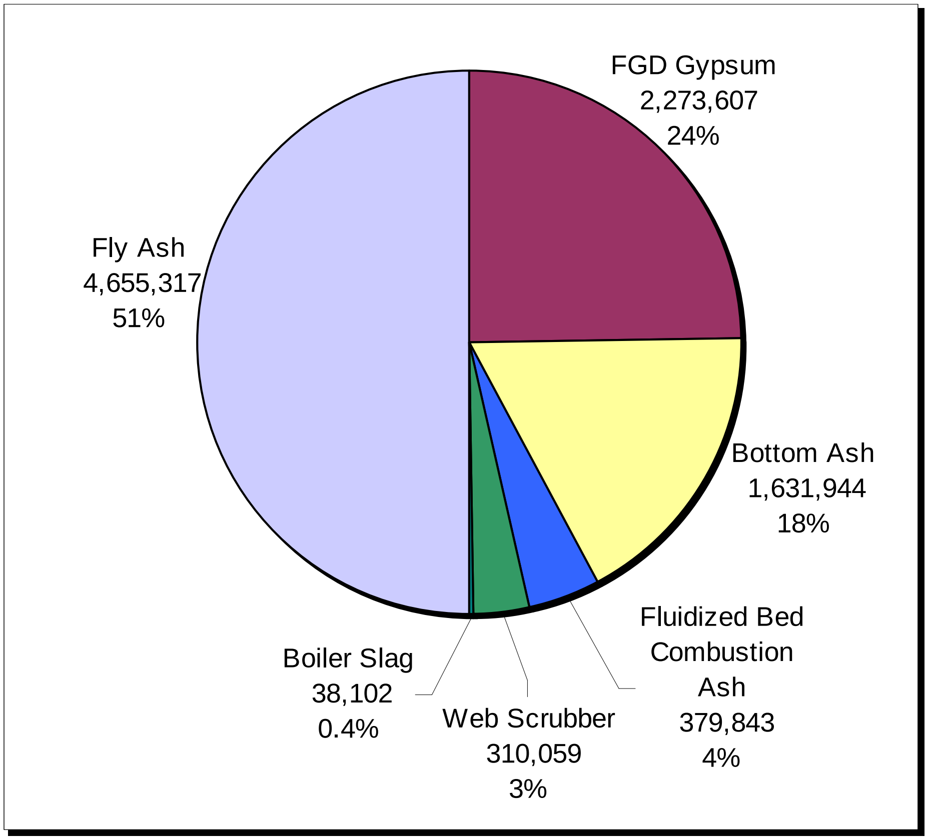
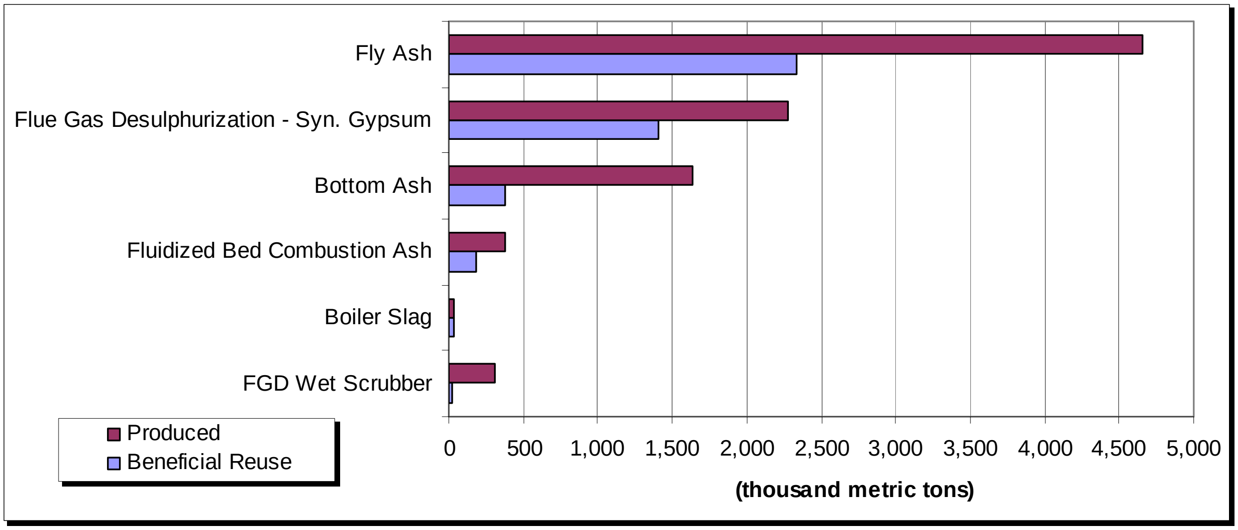


Figure 3-6: Coal Combustion Products Production and Beneficial Reuse in the Gulf Coast States in 2004[120]



National efforts such as EPA's Coal Combustion Products Partnership (C^2P^2) Program and regional/state efforts from groups such as the Texas Coal Ash Utilization Group (TCAUG) have surely contributed to this growth, with their focus on increasing the education and awareness of potential beneficial reuses for CCPs. However, the degree of understanding and acceptance of CCP beneficial reuse varies from state to state, resulting in very different practices in the regulation of CCP beneficial reuse, specifically for non-traditional reuses, such as land applications.

Table 3-9 displays the various reuses for CCPs and the quantities of each byproduct reused in the Gulf States in 2004. As discussed in Section 3.1 and shown in this table, the largest quantities of CCPs, almost 2 million metric tons, are reused in cement and concrete applications.

Table 3-9: Coal Combustion Products Beneficial Reuses in the Gulf States in 2004[121]

Beneficial Reuse	**Coal Combustion Byproducts (metric tons)**						
	Fly Ash	FGD Gypsum	Bottom Ash	FBC Ash	Boiler Slag	FGD Wet Scrubber	Total
Aggregate			16,121				16,121
Agricultural Uses	167	59,716	1,498			5,877	67,258
Blasting and Sanding					38,102		38,102
Concrete	1,678,206	130,805	59,979				1,868,990
Concrete Aggregate	231,176	46,592	62,032			21,128	360,929
Deicing and Traction	3,156		9,280				12,437
Flowable Fill	3,109						3,109
Mineral Filler	20,921						20,921
Road Base	232,497		185,952				418,449
Soil Stabilization	70,252		8,459	172,752			251,463
Structural Fill	1,568		12,825				14,392
Waste Stabilization	260						260
Miscellaneous	95,996		23,128	14,161			133,284
Wallboard		1,165,959					1,165,959
Total	**2,337,308**	**1,403,073**	**379,273**	**186,913**	**38,102**	**27,005**	**4,371,673**

Data on energy production indicate a continuing steady supply of CCPs. In 2005, coal-fired plants produced 50 percent of power. US Department of Energy's (DOE's) Energy Information Administration (EIA) projects that, in 2015, coal-fired plants will account for 49 percent of power generation. As natural-gas fired power plants add capacity over the next 10 years, electricity generated from coal is expected to decrease. However, as natural gas becomes more expensive, more coal-fired plants are expected to be built. Therefore, EIA projects that in 2030, 57 percent of electricity will be generated from coal and 16 percent will be generated from natural gas.[122] In addition, the United States has over 275 billion tons of coal reserves, which would last over 200 years at current usage rates.[123] Thus, in meeting future U.S. electricity needs, greater amounts of CCPs are likely to be produced, unless new coal-based technologies such as coal gasification take hold, new nuclear plants are built, and differing qualities of coal are used. In addition, ACC asserts that CCP management is increasingly becoming an important strategy to lower costs and generate revenue for power plants.[124]

Pollution prevention and air compliance measures have also had, and will continue to have, effects on the supply and composition of CCPs available for beneficial reuse:

- ACAA anticipates an increase in generation of FGD materials because of the application of the Clean Air Interstate Rule (CAIR), EPA's 2005 Clean Air Mercury Rule (CAMR), and the application of technologies to capture mercury and sulfur dioxide (SO_2). However, whether the additional byproducts are FGD gypsum or other FGD material will depend upon whether the coal-fired power plants select a forced-oxidation wet scrubbing technology (which generates gypsum) or a dry scrubber technology (which generates a lower value byproduct). Coal-fired power plants in the eastern U.S. more commonly use wet scrubbers, while coal-fired power plants in the more arid western U.S. more commonly use dry scrubbers.[125]

- Recent research suggests that some facilities will use activated carbon injection to control mercury emissions regulated through CAMR. The injection systems reduce the air entrainment potential of the fly ash, which reduces the structural rigidity when cured, producing unmarketable fly ash. A regulatory impact analysis developed for CAMR found that by 2020, utilities will likely use activated carbon injection in no more than 12 percent of their coal-fired generating capacity, potentially affecting only a small percentage of fly ash.[126]

- As explained in the opening paragraph of this section, power plants install FGD units to mitigate SO_2 emissions. In 2004, electric power companies announced 30,000 megawatts (MW) of FGD equipment to be added in coming years to meet SO_2 standards. As a result, ACC estimates that the largest area of increase in CCP production will likely be in the area of FGD materials, motivated by the next phase of the Clean Air Act (CAA) requiring further reductions in SO_2 emissions.[127]

- Some utilities may switch from high-sulfur to low-sulfur coal to control SO_2 regulated through CAIR. Research suggests that the quantity and quality of fly ash produced from low-sulfur coal combustion is not significantly different than the fly ash produced from high-sulfur coal.[128]

Literature reviews and discussions with contacts reveal that, currently, demand for CCPs appears to be growing as a result of increased efforts by utilities and marketing firms to promote beneficial reuse. Increased awareness of the potential for and benefits of beneficial reuse, along with clear state specifications (e.g., those required by DOTs) and regulations have led to increased utilization. A shortage of affordable raw and manufactured materials that are replaced by CCPs is also contributing to demand. ACC estimates that current and continued cement shortages will increase the use of fly ash in concrete applications with an expected annual growth around 2 percent.[129] Embodying this point, the state of Florida currently imports fly ash from other states for beneficial reuse in concrete manufacture.

One of the most significant areas for potential growth in the utilization of CCPs is in the production of synthetic gypsum for the wallboard industry. Recent trend data indicate a growing market for wallboard and synthetic gypsum used in the production of wallboard.[130]

3.4.2 Beneficial Reuse Drivers and Barriers in Electric Power Generation at Fossil Fuel Plants

Table 3-10 lists the electric power generation industry byproducts selected for analysis in this white paper, along with the rationale for their selection. As discussed in Section 3.5.1, cross-sector beneficial reuse of these coal plant byproducts is thriving and growing. Other industries, especially the cement industry, have found a number of uses for the byproducts as substitutes for raw materials. The following sections detail the drivers that have made these reuses successful, or at least lowered barriers to reuse, and the barriers that the electric power generation industry and other industries may have to face as they move forward in increasing beneficial reuse across sectors. Electric utilities are also engaged in cross-sector beneficial reuse by utilizing woods from the construction and demolition (C&D) and forest products industries as alternative fuel.

Table 3-10: Byproducts from Electric Power Generation at Fossil Fuel Plants (NAICS: 221112) Selected for Analysis[131]		
Byproducts	**Reuse**	**Rationale for Inclusion**
Fly Ash	• Mineral filler • Deicing and traction • Flowable fill • Structural fill • Waste stabilization • Agricultural uses • In concrete and road base aggregate Cement Sector • Raw material for Portland cement production[132] • Portland cement additive[133] • Building and transportation construction[134] • Substitute for Portland cement • Soil stabilization Does not meet definition of beneficial reuse for this paper because reuse occurs as same facility: • Mining uses (e.g., roads, ramps, construction, reclamation); the majority of coal mines in Texas have electricity generating units (EGUs) adjacent to the mine	• Produced in quantities significant enough for beneficial reuse: 5.1 M short tons in Gulf States in 2004[135] • Potential for more reuse to occur: about 2.5 M short tons (53.5 percent) currently being reused in Gulf States[136]; in EPA Region 6 (Louisiana, Arkansas, Oklahoma, New Mexico, and Texas), approximately 2 percent of the boiler ash generated and 2 percent of the fly ash in the Region was used for cement production[137] • Can be reused in sectors of interest and in other sectors for nonfuel purposes
FGD Gypsum	• Wallboard manufacturing[138] • Cement clinker additive[139] • Agricultural uses, such as soil amendment and nutrient source	• Produced in quantities significant enough for beneficial reuse: 2.5 M short tons in Gulf States in 2004[140] • Potential for more reuse to occur: about 1.5 M short tons (32.1 percent) currently being reused in Gulf States[141]; in EPA Region 6 (Louisiana, Arkansas, Oklahoma, New Mexico, and Texas), approximately 1 percent of FGD material produced in the Region was used for cement production[142] • Can be reused in sectors of interest and in other sectors for nonfuel purposes
BYPRODUCTS FROM OTHER SECTORS USED IN ELECTRIC POWER GENERATION AT FOSSIL FUEL PLANTS		
Wood (from Demolition and Construction and from Forest Products)	• Electricity generation	• See C&D and Forest Products for rationale

3.4.2.1 Fly Ash

<u>*Economic/Market Drivers and Barriers*</u>

The production of coal ash is greatest in the winter and summer months when consumers use electricity to heat and cool their homes. In other parts of the US, winter is a slow time for construction projects; therefore, electric power plants incur a storage cost to hold the fly ash until it can be reused in construction.[143] However, in the Gulf Coast states, construction typically takes place year-round, providing a consistent end use for coal ash. Selling fly ash as an additive to Portland cement or for use as flowable fill is profitable for electric power plants, and beneficial reuse of coal ash reduces purchasing costs of virgin raw materials for construction projects.[144,145]

Beneficial reuse of fly ash often requires that the byproduct meet certain specifications, which inhibit beneficial reuse. Consistency in composition of the fly ash is important for beneficial reuse, and Some electric power plants produce an inconsistent quality of fly ash due to combustion of non-homogeneous coal.[146,147] In addition, fly ash contains some volatile impurities that can cause violations of EPA's proposed mercury regulation.[148] This can increase the perception of liability risk associated with beneficial reuse of fly ash.

In terms of beneficial reuse of fly ash in concrete production, high carbon content in fly ash can prevent proper protection of concrete from damage caused by freeze-thaw cycles, thus reducing the value of fly ash as a raw material input.[149] The need for fast setting concrete also limits the amount of high carbon fly ash that can be used in some projects.[150] Finally, the use of high-carbon fly ash (that requires beneficiation) as an additive in concrete or cement requires processing to meet specifications, which creates a processing cost.[151] However, most fly ash requires no processing for reuse.[152]

Although these specifications can inhibit beneficial reuse of fly ash in concrete or cement, in Florida, architects, contractors, and ready-mix suppliers are generally accepting of the use of fly ash as a substitute for Portland cement in concrete[153] because certain physical properties of finished products can be enhanced by the introduction of fly ash as a component material. The use of fly ash as Portland cement additive can improve workability in the mixed cement and higher strength and increased longevity in the finished concrete product, increasing resistance to chemical attack, strength, and workability.[154] Fly ash can also be used in plastics production to increase the stiffness of plastic and reduce production costs by replacing plastic resin.[155]

Finally, several organizations are providing research and education to promote beneficial reuse of fly ash:

- The Texas Recycling Market Development Board (RMDB) primarily focuses on beneficial reuse of coal ash in concrete.
- The U.S. Department of Agriculture (USDA) is researching the use of fly ash as a soil amendment.[156]
- The Office of Surface Mining (OSM) is examining the possibility of utilizing fly ash in mine reclamation.[157]
- The University of North Dakota established the Energy and Environmental Research Center (EERC) and the Coal Ash Resources Research Consortium.[158]
- The state of Ohio supports Energy Industries of Ohio in their research to reduce the weight of automotive industry components using off-specification fly ash.[159]

- The American Coal Ash Association (ACAA) has put forth extensive research and education efforts to promote the reuse of coal ash and fly ash.

- The Recycled Materials Resource Center is a national center that promotes the appropriate use of secondary materials, including coal ash, in the highway environment. The Center is an active and viable partnership between FHWA, the University of New Hampshire (UNH), and the University of Wisconsin-Madison.

Regulatory/Programmatic Drivers and Barriers

Efforts to reduce and control air emissions from electric generating units (EGUs) may affect the quality and consistency of the coal ash produced.[160] The most significant example of such an effect results from the federal legislation on mercury emissions. Current mercury control techniques can contaminate fly ash with activated carbon and mercury and create a byproduct that may not meet beneficial reuse specifications.

Several states have regulations and programs that specifically address fly ash, in addition to their general beneficial reuse regulations discussed in previous sections of this paper. These regulations and specifications may be drivers for beneficial reuse of fly ash by creating a clear understanding of acceptable uses. However, regulations and specifications can be barriers if they limit the beneficial reuse of fly ash.

Alabama considers fly ash a “special waste” in certain circumstances, thereby requiring specific processing, handling, or disposal techniques.[161] These specific requirements can raise barriers to beneficial reuse. However, Alabama Department of Transportation (DOT) is lowering barriers to beneficial reuse by allowing fly ash to be used in concrete if it meets the requirements of the American Association of State Highway and Transportation Officials (AASHTO) M295, allowing fly ash to be used in roadbed and base stabilization, and providing specifications for fly ash use as mineral filler for hot mix asphalt (Special Provision No. 02-0130).

In Florida, a fly ash supplier must submit samples to a Florida DOT (FDOT) laboratory every three months to check for quality. High unburned carbon content can prevent the reuse of the ash, and FDOT does not allow fly ash to be used in flowable fill if it is designed to be excavated.[162] Despite these restrictions, FDOT defers to American Society for Testing and Materials (ASTM) C618 specifications for fly ash in concrete, and to AASHTO M85 specifications for cement. Incorporation of these commonly known standards can lower barriers to beneficial reuse. Finally, FDOT has an approved source list of concrete sources used in state projects including cement, boiler slag, and fly ash, further lowering barriers to beneficial reuse, and FDOT specifies 18 to 22 percent Class F fly ash replacement for Portland cement in regular concrete projects. Mass concrete and drill shafts can use up to 50 and 35 percent fly ash, respectively, because FDOT, ash marketers, and ready-mix suppliers find these percentages allow for the best durability in marine environments and create a superior product.[163]

Mississippi DOT has specifications for the use of fly ash, which can reduce the uncertainties associated with reusing the byproduct in engineering projects.

Texas has a number of specifications in place that appear to be lowering barriers to beneficial reuse of fly ash, based on success stories like the Xcel and LaFarge example described in the text box. These specifications include:

- Fly ash is considered nonhazardous recyclable material and has specifications for reuse under DMS-11000.
- Fly Ash Quality Monitoring Program (FAQMP) specifications (DMS – 4610 – Fly Ash) establish requirements for Class C, Class F, and ultra fine fly ash used in concrete products.
- FAQMP has specifications for fly ash used in sub-grade or base treatment (i.e., soil treatment) (DMS-4615).
- Texas DOT adopted coal ash specifications in 2004 on a district and statewide basis. The TxDOT specifications require a minimum of 20 percent fly ash and a maximum of 35 percent in concrete.
- Amendment to 30 Texas Administrative Code (TAC) Chapter 335 – Industrial Solid Waste and Municipal Wastes permits coal ash reuse in Texas if it meets eight criteria.[164,165]

Fly Ash Reuse in Texas

In the spring of 2002, Xcel Energy and Lafarge North America performed a trial highway project in Randall County, TX. using, among other materials, 200 tons of CCP material to stabilize a road base. The performance of the fly ash material was strong compared to the other tested materials. Lafarge subsequently witnessed geotechnical applications increase from 20 percent of stabilization work in the Amarillo market in 2002 to 90 percent in 2006.

Xcel Energy and Lafarge continue to beneficially reuse CCPs. Xcel's Harrington and Tolk power stations beneficially reuse all 500,000 tons of the CCPs that they produce annually. According to Xcel Energy's estimates, in 2003, Texas stabilization projects utilized an estimated 15,865 tons of these CCPs. "Assuming that 75 percent of fly ash used for soil stabilization replaces the use of lime, the corresponding ratio of CCP to lime use is about 2:1, and an emission factor for lime is 0.17 metric tones of carbon equivalent (MTCE) per ton, then greenhouse gas emissions attributable to this CCP use in stabilization projects can be reduced by 1,350 MTCE per year."

At the federal level, the Federal Highway Administration (FHWA) requires state highway departments to have specifications preferring cement and concrete containing coal fly ash for federally funded projects, and Federal Aviation Administration (FAA) standards allow for fly ash in certain concrete products.[166]

Environmental Effects

Some studies have shown that the use of fly ash in place of cement reduces carbon dioxide (CO_2) emissions by one ton for every ton of fly ash used.[167] In addition, a recent study by an EPA contractor cited limited energy and water use, reduced atmospheric emissions and waterborne and end-of-life waste, and improvements in overall human health from partial fly ash substitution in concrete parking lot pavements.[168]

On August 29, 2007, EPA Office of Solid Waste and Emergency Response (OSWER) published a "Notice of Data Availability on the Disposal of Coal Combustion Wastes in Landfills and Surface Impoundments" (72 FR 49714). The NODA conveys new information received since the Agency issued its May 2000 Regulatory Determination on coal combustion waste, which recommended that coal combustion product remain excluded from federal hazardous waste management, but indicated the Agency's commitment to review CCW for potential management under the federal Criteria for Solid Waste Landfills, RCRA Subtitle D. The August 2007 NODA was part of that continuing review,

In interviews with the American Coal Ash Association (ACAA), they acknowledge that there have been some situations historically where fly ash has been disposed inappropriately. However, for beneficial uses ACAA believes that current state oversight is sufficient to prevent future problems. It is important for states, material providers, and users to evaluate a beneficial reuse project from two perspectives: 1) evaluate the characteristics (geography, water sources, climatic conditions, etc.) of the site or project; and 2) evaluate the characteristics of the CCPs to make sure they are compatible with the intended use." This conscious effort to thoroughly evaluate the project and materials before placement will help prevent any environmental degradation in the future.[169]

3.4.2.2 FGD Gypsum

Economic/Market Drivers and Barriers

As reported in a National Council for Air and Stream Improvement (NCASI) white paper presented an industrial byproducts beneficial use meeting, FGD material from coal-fired power plants that contains significant amounts of calcium chloride is not usable as an additive in Portland cement.[170] However, for FGD material that does meet the appropriate specifications, the byproduct, depending on transportation costs, can be a less expensive raw material for Portland cement production than natural rock gypsum.

Regarding FGD gypsum reused in construction and demolition, synthetic gypsum is often preferred over natural rock gypsum by wallboard manufacturers because of its purity.[171] Also driving beneficial reuse, certain synthetic wallboard plants are located adjacent to power plants, and thus use all the wallboard-quality FGD gypsum from that particular plant.[172]

Regulatory/Programmatic Drivers and Barriers

As air emissions regulations increase, the amount of FGD material available for beneficial reuse could increase because more will be captured in systems designed to limit emissions.

Environmental Effects

Beneficial reuse of FGD gypsum can replace virgin gypsum in wallboard or Portland cement production, limiting the consumption of natural resources.

3.5 Forest Products: Pulp, Paper, and Paperboard (NAICS 3221)

The forest products industry includes the raising and harvesting of timber, as well as the paper and paperboard production process. Pulping, the first step in producing paper and paperboard, breaks down wood chips or recycled paper into individual fibers through chemical, semichemical, or mechanical methods. Chemical processes are most commonly used for wood chips. Chemicals are recovered in the chemical pulping process, and are commonly called causticizing materials. Most pulp and paper mills recycle water to conserve energy and raw materials. Excess process water is either treated on-site or off-site at a municipal wastewater treatment plant. If treated on-site, the excess water is usually treated through a clarification (primary) process and biological (secondary) treatment process which removes suspended solids and soluble organic materials. The solid materials, composed of wood fibers, minerals, and microbial biomass, are collected and usually dewatered into a cake-like consistency.[173] Biomass is typically used for energy recovery or feedstock for pulp and paper production within the facility that produced the byproduct, making it outside the scope of this paper.

Energy is essential for pulp and paper manufacturing. Energy is often generated on-site by power boilers, which burn coal, natural gas, wood, oil, and mixed fuels (e.g., coal, wood residues, process residues, tires, etc.). Boiler ash is the non-combustible material remaining after the fuels are burned.[174]

3.5.1 Beneficial Reuse Traits and Trends in the Forest Products Sector

As shown in Table 3-11, fewer than 100 pulp, paper, and paperboard mills were operating in the Gulf Coast states in 2004.

Table 3-11: Number of Pulp, Paper, and Paperboard Mills in Gulf Coast States as Characterized by U.S. Census 2004 County Business Patterns [175]

State	Pulp, Paper, and Paperboard Mills (NAICS 3221)
Alabama	25
Florida	14
Louisiana	15
Mississippi	11
Texas	20
Total	**85**

Available data indicate that the U.S. forest products industry is in decline. Although it remains the world's leader in the pulp and paper business, producing 28 percent of the world's pulp and 25 percent of the total world output of paper and paperboard[176], the industry is facing increasing competition from foreign competitors such as Canada, Scandinavian countries, Brazil, and Japan, which in some cases enjoy economic advantages in wood, labor, and environmental costs. Other competitive pressures include the growing use of electronic communications and advertising, product substitution, an aging process infrastructure, few technology breakthroughs, and scarcity of capital for new investments.[177]

Beneficial reuse of byproducts from pulp, paper, and paperboard mills is occurring, with most byproducts predominately used for energy and land applications. Many mills have focused on reusing their byproducts (e.g., biomass) for energy production to the extent possible, resulting in increased quantities of boiler ash.[178] Mills have found that, although boiler ash quantities are increased, using biomass is more economical than fossil fuels and is more likely to decrease a facility's carbon footprint. Programs like the Agenda 2020 Technology Alliance, an industry-led partnership with government and academia, focuses on improving processes, materials, and markets within the industry. Agenda 2020 listed creation of beneficial reuses for solid wastes as one of their focus areas in 2006.[179]

Generation rates in Canada (and likely elsewhere) for ashes from boiler combustion have increased substantially since the mid-1990s.[180] However, changes in energy supply and pollution prevention measures have had an effect on, and will continue to affect, the supply of byproducts from pulp, paper, and paperboard mills. Over time, byproduct quantities may decrease due to technology development focused on waste reduction through increased manufacturing efficiency. For example, Agenda 2020 projects focus on reducing waste from pulp and paper production through the development of more efficient manufacturing processes that reduce waste.[181] However, the exact effect and extent of this research on byproduct supply is unknown. EPA's Sector Strategies Program notes the following trends that may affect the supply of byproducts from the industry:

- Recovery furnaces, which burn spent liquor to recover chemicals used during the pulping process, are reaching the end of their useful life within the pulp and paper industry. However, no new technology currently exists to replace these furnaces. Should a new, cost-effective technology emerge, the supply of byproducts resulting from energy production may be affected.

- Within the pulp and paper industry, there is a constant push to decrease water consumption. A decrease in water consumption may, over time, impact the consistency and supply of wastewater treatment plant (WWTP) residuals. However, the exact effect on WWTP residual supply is unknown.[182]

On the demand side, there appears to be constant demand for fly ash and bottom ash/boiler slag for beneficial reuse by cement manufacturers. However, it is unclear how much of this demand is for ash from the pulp and paper industry, as United State Geological Survey (USGS) data on the use of ash by cement manufacturers do not differentiate between fly ash from electric power generation and boiler ash from pulp and paper mills.

Boiler Ash Reuse in Georgia

Georgia-Pacific's Savannah River mill (SRM) uses its petroleum coke fired boiler ash as aggregate for mill site roads and to support the wastewater sludge disposal cell structures at the landfill. The mill also sells its boiler ash to a local county, which uses it in road aggregate.

The Georgia Environmental Protection Division (GAEPD) granted approval for these beneficial reuses and the Georgia DOT implemented a specification for graded aggregate road bas material and listed SRM as a source. This specification was helpful to establish the value of the aggregate product and to gain the acceptance of the construction community.

SRM beneficially reused 477,160 cubic meters (624,102 cubic yards) of aggregate from September 2001 to January 1, 2003,

3.5.2 Beneficial Reuse Drivers and Barriers in the Forest Products Sector

Table 3-12 lists the forest products industry byproducts selected for analysis in this paper, along with the rationale for their selection. As shown in the table, much of the beneficial reuse of pulp, paper, and paperboard mill byproducts involves energy production or land application. Although many other innovative reuses are listed in the table, as described in Section 3.6.1, not much is known about the effects of efforts to increase beneficial reuse of byproducts from the forest products industry in other industries. The following sections explain the drivers that may encourage more beneficial reuse of pulp, paper, and paperboard manufacturing byproducts in other sectors and barriers that may discourage such cross-sector reuse. The forest products industry does not appear to be engaging in beneficial reuse of any byproducts that meet the selection criteria for this paper.

Table 3-12: Byproducts from Pulp, Paper, and Paperboard Mills (NAICS: 3221) Selected for Analysis

Byproducts	Reuse	Rationale for Inclusion
WWTP Residuals (wood fibers, minerals and microbial biomass)	• Energy (21.9 percent)[183 184] • Land application as an organic soil amendment[185], hydraulic barriers, strip mine caps (14.6 percent) • Other (11.7 percent) o Recovered papermaking fiber and filler (about 6 percent in 1995) o Industrial absorbent o Animal bedding o Lightweight/glass aggregate o Admixture in Portland cement concrete[186] o Raw material in Portland cement o Building board [187] o Agricultural chemical carriers o Roofing tar or felt o Fuel pellet ingredient o Manufactured soil o Compost feedstock o Low-permeability landfill and strip mine caps o Gasification fuel products o Chemical feedstock o Mulch ingredient o Plastic additive o Animal feed product	• Believed to be produced in quantities significant enough for beneficial reuse: in 1995, industry produced 5.5 M dry tons of WWTP residuals[188] • Believed to have potential for more reuse to occur: in 2002, 52 percent of byproduct landfilled and 48 percent beneficially reused[189] • Can be reused in sectors of interest and other sectors for fuel and nonfuel purposes
Boiler Ash (noncombustible materials left after burning of coal, wood, other fuel)	Coal-fired boiler ash (15 percent) • Mineral admixture in Portland cement • Grout • Mineral filler in asphalt paving • Flowable fill • Structural fill • Waste solidification/soil stabilizer • Soil amendment • Fine aggregate in asphalt paving • Granular base • Soil stabilization/waste solidification • Snow and ice control • Surface mine reclamation • Blasting grit • Stabilized base • Supplemental fuel Wood-fired boiler ash (22 percent) • Soil amendment • Compost • Soil waste stabilization • Compost • Supplemental fuel • Many of the same beneficial use options as	• Believed to be produced in quantities significant enough for beneficial reuse: in 1995, 4 M tons of ash* produced by energy generation in pulp and paper industry • Believed to have potential for more reuse to occur: in 2002, 65.4 percent boiler ash disposed in landfill or lagoon and 34.6 percent beneficially reused; land application utilized 9.3 percent of the material, and other beneficial reuses accounted for the other 25.3 percent; of this 25.3 percent, a 1995 survey indicated that 12 percent of the ash had application in earthen construction for roadbeds, berms, and other structures • Can be reused in sectors of interest and other sectors for nonfuel purposes *Coal-fired ash comprises 15 percent of

Table 3-12: Byproducts from Pulp, Paper, and Paperboard Mills (NAICS: 3221) Selected for Analysis

Byproducts	Reuse	Rationale for Inclusion
	listed under coal-fired ash; however, modifications to wood ash may be required before it can be used in many of these applications Mixed fuel source ash (63 percent) • See reuse options for coal-fired ash and wood-fired ash • Specific use option for each mixed fuel ash will highly depend upon relative proportions of the fuel	generated ash, whereas wood-fired ash comprises 22 percent of generated ash, of which: o 28 percent (0.8 M tons) beneficially reused o 2.0 M tons disposed in landfill or lagoon Mixed fuel source ash comprises 63 percent of generated ash
Causticizing Residues (i.e., lime mud, lime slaker grits, and green liquor dregs)	Lime Mud • Landfill/lagoon: 70 percent • Land application: 9 percent • Reuse in-mill: 1 percent • Other beneficial use: 20 percent Green Liquor Dregs • Landfill/lagoon: 95 percent • Land application: 3 percent • Reuse in-mill: 0 percent • Other beneficial use: 2 percent Lime Slaker Grits • Landfill/lagoon: 91percent • Land application: 5 percent • Reuse in-mill: 3 percent • Other beneficial use: 1 percent Other Beneficial Reuse • Soil amendment • Alternative daily cover for landfills • Waste stabilization • Raw material for Portland cement production • Clay brick ingredient • Road dust control • Removal of sulfur gases • AMD control amendment • Soil Stabilization • Fine aggregate in asphalt paving • Surface mine reclamation • Feedstock compost • Admixture to hydraulic barrier material • Settling aid in wastewater treatment • pH adjustment of process water ingredient in manufactured soil[190] • Management of acidic water in fish ponds[191]	• Believed to be produced in quantities significant enough for beneficial reuse: According to NCASI, 1.7 M dry tons/year produced in 2001[192] o Lime slaker grits (15 percent of waste) o Green liquor dregs (30 percent of waste) o Lime mud (55 percent of waste) • Believed to have potential for more reuse to occur: According to NCASI, 1.4 M tons (81 percent) landfilled in 2001 and 300,000 tons (19 percent) beneficially reused in 2001 • Can be reused in sectors of interest and other sectors for nonfuel purposes
Byproducts from Other Sectors Used in Pulp, Paper, and Paperboard Mills		
Byproducts reused in pulp, paper, and paperboard mills do not meet selection criteria.		

3.5.2.1 General Forest Products Beneficial Reuse

Economic/Market Drivers and Barriers

The prevalence of forest products manufacturers in the Gulf Coast states could help drive cross sector beneficial reuse. The forest products industry ranks as Alabama's number one manufacturing industry and ranks as one of the top manufacturing industries in Florida, Louisiana, Mississippi and Texas. It is a vital component in the economies of all five states.[193] The robust concrete market associated with economic development and rebuilding in the Gulf Coast states can drive the demand for pulp and paper byproducts that can be reused in cement manufacturing.[194]

Many pulp and paper companies have adopted goals to develop beneficial reuses for solid waste as part of corporate sustainability programs, potentially making information and case studies available to other companies interested in beneficially using similar byproducts.[195] In addition, some industry association programs are focusing on beneficial reuse of forest product manufacturing byproducts:

- The Agenda 2020 Technology Alliance is focusing on developing customer-focused beneficial use opportunities that make the use of mill residuals at lower cost than landfilling the byproducts. [196]

- NCASI, an environmental resource for the forest products industry, is promoting the beneficial use of byproducts of the pulp and paper industry.

- The Technical Association of the Pulp and Paper Industry (TAPPI) provides resources to the pulp and paper industry relating to beneficial use of pulp and paper byproducts.[197]

Regulatory/Programmatic Drivers and Barriers

As discussed in Chapter 2, Louisiana has an agreement in place with the Louisiana Pulp and Paper Association (LPPA) to encourage beneficial reuse of pulp and paper byproducts.

Pulp and paper industry byproducts normally do not meet the definition of RCRA hazardous waste, which makes disposal a less costly option and could discourage beneficial reuse.[198] Alternatively, not meeting the definition of RCRA hazardous waste could make reuse of byproducts easier, as generators and end users would not have to navigate rules on the definitions of solid waste and hazardous waste recycling.[199]

3.5.2.2 Wastewater Treatment Plant Residuals

Economic/Market Drivers and Barriers

As with some other byproducts discussed in this paper, the inability to easily separate reusable components from the overall waste stream can be a challenge for beneficial reuse of WWTP residuals.[200] In addition, some beneficial reuses require dewatered or dried residuals with 90 percent solids content, which can be cost prohibitive, thus presenting barriers to beneficial reuse.[201]

Studies have been undertaken to assess the performance characteristics of WWTP in the following beneficial reuses: cementitious products, light weight aggregate, and kitty or poultry litter.[202] Full-scale operations have successfully demonstrated pelletization of sludge and non-recyclable paper for beneficial reuse as fuel and beneficial reuse of sludge in cement kiln feedstock.[203] However, initial capital costs, distribution and marketing issues, and incompatibilities with company business strategies have inhibited some companies from pursuing the use of sludge to produce kitty or poultry litter.[204]

In terms of specific projects that are working to drive beneficial reuse of WWTP residuals, an Agenda 2020 project plans to incorporate the fibrous residuals from mills into ready-mixed concrete to improve the strength, durability, and life span of concrete structures.[205]

Regulatory/Programmatic Drivers and Barriers

No standards exist at the national level for reuse of forest byproducts, which could be viewed as a barrier, because there is a lack of guidance for potential end users to consult, which may lead them to perceive beneficial reuse as risky in terms of liability. However, a lack of regulations could also drive beneficial reuse, as it might open up more options to potential end users.

Environmental Effects

Potential environmental hazards are associated with trace constituents in WWTP residuals (dioxins and metals); however, recent trends away from chlorine bleaching have reduced the presence of dioxins in these byproducts. Potential end users must assess the mobility and leachability of these trace constituents before pursuing beneficial reuse.[206]

WWTP residuals can also be converted into fuel pellets. Most state regulatory agencies require end users to evaluate the combustion byproducts of alternative fuels before proposing them for widespread use; however, companies involved in both production and use of sludge and fuel pellets have indicated that regulatory reaction to trial burn data has generally been positive.[207]

3.5.2.3 Boiler Ash

Economic/Market Drivers and Barriers

Some sources found that, due to the variety of fuels used by forest product mills, maintaining a consistent quality of boiler ash is a challenge. As with coal combustion products, inconsistency of boiler ash can create barriers to beneficial reuse because it can limit the available reuse options.[208]

Real-world experience has shown success with beneficial reuse of boiler ash. Concrete of acceptable quality has been produced with wood ash from a mid-west U.S. pulp and paper mill.

Similarly, at another mill, boiler ash from the combustion of wood and wastewater treatment residuals was found to be suitable for cement and brick manufacturing.

Regulatory/Programmatic Drivers and Barriers

Wood ash has no national regulations restricting reuse, but Mississippi has state-specific standards for beneficial reuse of nonhazardous solid wastes. Chapter 2 provides a description of drivers and barriers arising from these regulations.

Environmental Effects

Although boiler ash can contain few potential environmental contaminants, in some cases unacceptably high levels of unburned carbon in ash have limited the beneficial reuse of this byproduct.[209]

3.5.2.4 Causticizing Residues

Economic/Market Drivers and Barriers

The beneficial reuse of causticizing residues shares the drivers and barriers discussed above for other forest industry byproducts. In addition, causticizing residues contain sodium and sulfur, which if in excess, can impair some manufacturing processes or product quality. In addition to this chemical composition, cement companies will consider quantity available, ease of material handling, and regulatory implications. [210]

At least two kraft mills in the U.S. use dewatered slaker grits for road construction. These mills can serve as examples for other mills wishing to undertake the same beneficial reuse. The projects did find a disadvantage of using dewatered slaker grits for road construction because the grit and sand road is finer and can migrate farther than that produced from native soil roads. [211]

Regulatory/Programmatic Drivers and Barriers

Research yielded little information on regulations concerning causticizing residues; however, one general U.S. standard for beneficial reuse of causticizing residues as alternative daily cover was identified. [212,213]

Environmental Effects

Pulp, paper, and paperboard mills generally try to lower the RCRA corrosivity characteristics of their causticizing residues. As a result, these byproducts generally do not exhibit significant environmental hazards, with their low concentrations of heavy metals and lack of RCRA corrosivity characteristics. [214]

3.6 Iron and Steel Mills (NAICS 3311)

Iron and steel mills use one of two processes in producing steel. Integrated steel mills use basic oxide furnaces (BOF) to produce steel from up to 30 percent steel scrap and at least 70 percent molten iron produced from blast furnaces (which use iron ore from mines, limestone from quarries, and coke from batteries of ovens). "Mini-mills" use electric arc furnaces (EAF) to recycle steel scrap into new steel products, and account for more than 50 percent of US steel production.[215] The largest byproduct from steel production is slag, a mixture of limestone and iron ore impurities, which is collected on top of the molten iron. Other byproducts include EAF dust, a combination of gaseous emissions and metal dust that is a byproduct from mini-mills, and pickle liquor that is used in steel finishing operations.[216]

3.6.1 Beneficial Reuse Traits and Trends in Iron and Steel Mills

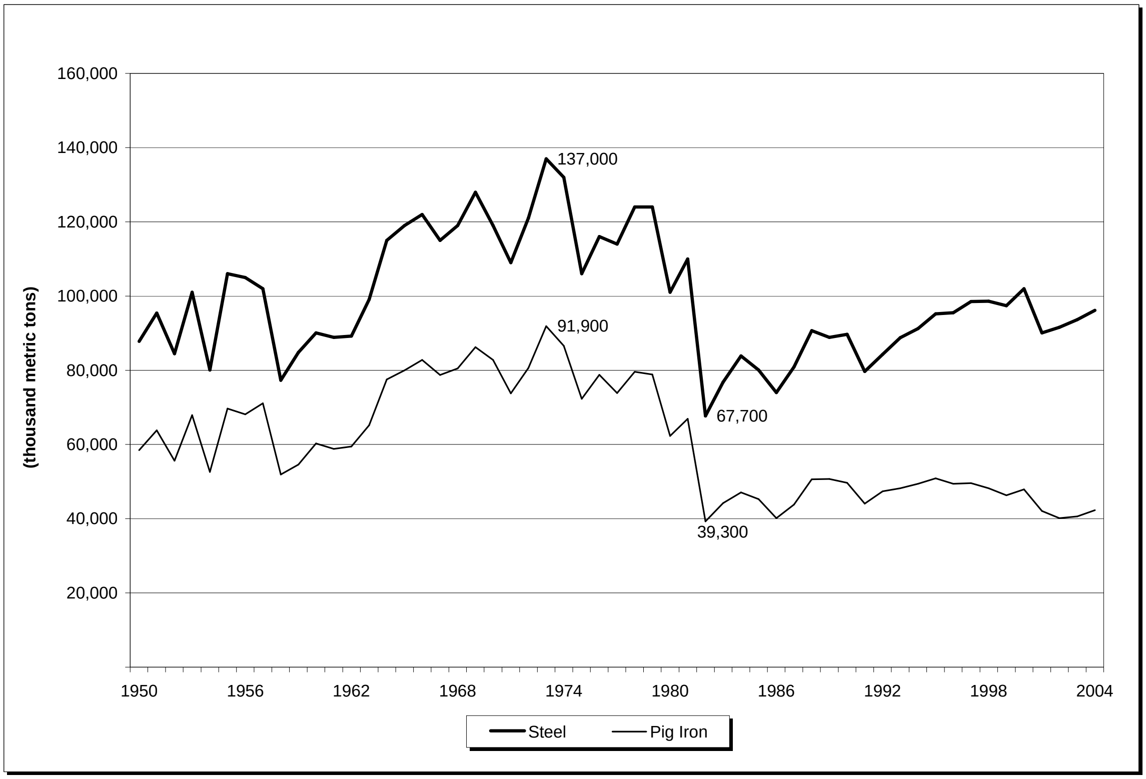
Only 17 iron and steel mills that generate new steel currently operate in the Gulf Coast states in 2004, as shown in Table 3-13. These data are a subset of the 91 facilities reported by the U.S. Census 2004 County Business Patterns because NAICS 3311 includes facilities other than integrated mills and mini-mills that use electric arc furnaces, which are the focus of this paper.

Table 3-13: Number of Iron and Steel Mills in Gulf Coast States as Characterized by EPA and U.S. Census

State	Integrated Mills[217]	Mini-mills (Electric Arc Furnace)	Iron and Steel Mills and Ferroalloy Manufacturing (NAICS 3311)[218]
Alabama	1	5	17
Florida	0	1	13
Louisiana	0	1	4
Mississippi	0	2	5
Texas	0	7	52
Total	**1**	**16**	**91**

With the advancement of free trade and globalization, iron and steel manufacturers in the United States have met international competition.[219] Although U.S. iron and steel production has been on an upswing in recent years, as shown in Figure 3-7, the U.S. world share of this market decreased to less than 10 percent in 2004. The U.S. steel industry generates about 30 million tons of byproducts each year, including 6 million tons of basic oxygen furnace (BOF)/basic oxygen process (BOP) slag.[220] In 2002, the U.S. industry produced steel in 373 locations, nine of which were fully integrated mills, 48 were partially integrated mills, and 316 were non-integrated mills.[221] To stay competitive, the remaining U.S. iron and steel factories have had to reduce expenses, one of which is generation and disposal of such byproducts. To achieve this goal, the sector has an incentive to creatively reuse its own byproducts or find available markets within other industries for reuse.

Figure 3-7: U.S. Domestic Production of Steel and Pig Iron[222]



Beneficial reuse of iron and steel byproducts within the industry, primarily for combustion in facilities' own furnaces, has taken place for decades.[223] The cement industry is also a significant end user of slag, as discussed in Section 3.1. In 2005, approximately 525,000 metric tons of steel slag were used in cement clinker production, and approximately 920,000 metric tons of blast furnace slag (granulated and other) were used in cement clinker production and cement production.[224] The Slag Cement Association (SCA) attributes this growth to increased availability of slag to more geographic areas, more widespread acceptance of the use of slag cement in concrete, efforts by the cement industry to educate construction professionals on slag cement's benefits, and a growing interest in green building construction.[225]

Government agencies also seem to be affecting demand for iron and steel byproducts. Alabama's and Texas' Departments of Transportation (DOTs) have shown particular interest in beneficially reusing iron and steel byproducts in highway and cement construction and production.

Despite these factors affecting demand for byproducts, regulations and pollution prevention measures may affect the quantities of iron and steel mill byproducts available for reuse. EAF dust and spent pickle liquor are listed as hazardous wastes under the Resource Conservation and Recovery Act (RCRA) and, as such, are subject to handling, treatment, and disposal requirements that can be costly for manufacturers. As a result, the industry has an incentive to reduce these byproducts or develop reuse options that can diminish the costs spent on disposal. In addition, the iron and steel industry has requested that EPA delist spent pickle liquor, which would decrease the regulatory barrier of RCRA regulation, thereby increasing the quantities available for beneficial reuse.

Demand for valuable components of byproducts can affect the supply available for reuse. For example, metals that can be recovered from EAF dust are in demand; as a result, EAF dust is being exported to Mexico for metals recovery. However, this removes the EAF dust from the pipeline for potential domestic beneficial reuse and removes its beneficial reuse from EPA's authority. [226,227]

The global iron and steel trade could potentially have effects on the supply of byproducts in the Gulf Coast region. If users of iron and steel are able to easily access cheaper supplies through the numerous large ports in the area (such as those in New Orleans), the Gulf Coast iron and steel mill industry might see a downturn.

3.6.2 Beneficial Reuse Drivers and Barriers in Iron and Steel Mills

Table 3-14 lists iron and steel mill byproducts selected for analysis in this paper, along with the rationale for their selection. As discussed in Section 3.7.1, iron and steel mills have been reusing their own byproducts for decades and the cement industry reuses a significant quantity of slag and EAF dust as substitutes for raw materials. The following sections discuss the drivers that are encouraging cross-sector beneficial reuse in the cement and other industry sectors, as well as barriers that may be inhibiting more beneficial reuse of slag, EAF dust, and spent pickle liquor in other industries' manufacturing processes. However, our research did not reveal that iron and steel mills are reusing any byproducts in their manufacturing processes that meet this paper's selection criteria.

Table 3-14: Byproducts from Iron and Steel (NAICS: 3311) Selected for Analysis

Byproducts	Reuse	Rationale for Inclusion
Slag (slag from BOF and EAF mills (steel slag); blast furnace slag; GGBFS; other)	• Road building aggregate[228] • Soil remineralization[229] • Raw material for Portland cement production • GGBFS in cement sector[230] • BOF slag recycling[231] • List of providers of fly ash and ground granulated blast furnace slag (GGBFS) (no date)[232] Does not meet definition of beneficial reuse for this paper: • In furnaces in-house	• Produced in quantities significant enough for beneficial reuse: 19.7 M tons of steel slag produced each year[233] • The U.S. steel industry generates about 30 M tons of byproducts each year, including 6 M tons of BOF/BOP slag[234] • Potential for more reuse: 7.7 to 8.3 M tons reused each year (approximately 39 - 42 percent)[235] • Can be reused across sectors of interest and other sectors for nonfuel purposes

Table 3-14: Byproducts from Iron and Steel (NAICS: 3311) Selected for Analysis		
Byproducts	**Reuse**	**Rationale for Inclusion**
EAF Dust/Sludge (from EAF gas cleaning and collection)	• Raw material for Portland cement production[236] • Raw material for bricks, sandblasting, or fertilizers (if metal content low enough)[237] • Trace metals [particularly zinc] are reclaimed; Horsehead Corp, for example, provides EAF recycling and metal recovery services[238] • Drinkard Metalox, Inc. (DMI) has developed a unique technology to completely process EAF dust into saleable products using a hydro metallurgical process[239] Does not meet definition of beneficial reuse for this paper: • In furnaces in-house (if metal content is sufficient)[240]	• Produced in quantities significant enough for beneficial reuse, with potential for more reuse: approximately 0.65 M tons of EAF dust disposed of annually in the U.S. and Canada with the remainder shipped to Mexico for metals recovery [241 242] • Can be reused across sectors of interest and other sectors for nonfuel purposes
Spent Pickle Liquor	• Ferrous sulfate product • Sewage treatment to break down detergents, washing powders, and fertilizers • Ferric oxide powder – manufacture of audio/visual tapes, electric motor cores[243,244,245] Does not meet definition of beneficial reuse for this paper: • Hydrogen chloride gas – returned to pickle line	• Produced in quantities significant enough for beneficial reuse: about 1.5 billion gallons produced annually[246] • Approximately 80 percent of spent pickle liquor is recycled industry-wide (in-house) or in wastewater treatment, but only 2 percent is reused in other industries[247] • Can be reused across sectors for nonfuel purposes
Byproducts from Other Sectors used in Iron and Steel Mills		
Byproducts reused by iron and steel mills do not meet criteria for selection.		

3.6.2.1 Slag

Economic/Market Drivers and Barriers

With only 17 integrated and mini-mills in the Gulf Coast, smaller quantities of slag may be available for beneficial reuse. However, organizations like the Steel Recycling Institute (SRI), and Slag Cement Association (SCA) are working to educate generators and end users of slag about markets and potential opportunities for beneficial reuse. In fact, in 2005, 3.5 MMT of slag cement, which incorporates ground granulated blast furnace slag (GGBFS), were produced in the United States, which is triple the amount produced in 1996.[248] SCA attributes this growth to increased availability of slag to more geographic areas, more widespread acceptance of the use of slag cement in concrete, efforts by the cement industry to educate construction professionals on slag cement's benefits, and a growing interest in green building construction.

> **EAF Steel Slag Reuse in Texas**
>
> EAF steel slag is being successfully reused in Texas cement plants using the patented CemStar™ process. In 2002, approximately 90,000 tons were reused at TXI Midlothian and 45,000 tons were reused at North Star Cement.

Currently, there are 12 Portland cement plants in the Gulf Coast that are using slag in the production of cement: 7 in Texas, 1 in Louisiana, 1 in Alabama, and 3 in Florida.[249] In Texas, slag is commonly used in concrete and hot mix asphalt, resulting in a lower barrier to beneficial reuse for this byproduct. Also in Texas, one cement kiln is using slag as a raw material for Portland cement, using a patented production process.[250] Once plants begin using slag in production of cement, others may learn lessons and best practices from the end users, which could lead to more reuse by other facilities. New end users can take advantage of other plants climbing the learning curve, which may drive the market for beneficial reuse.

Although slag is being reused in concrete, slag components are not uniform as a result of different raw materials used and final steel chemistry[251]; therefore, only slag with particular properties can be used in certain applications. For instance, slag with significant amounts of free lime or magnesia can cause cracking of pavements and therefore is not recommended for use in hot mix asphalt although these types of slag can be used for other applications such as soil stabilization.[252,253] To characterize and ensure that inferior slags are not used, special quality-control procedures are conducted such as petrographic examination, autoclave disruption testing, and allowing the slag to age.[254]

Regulatory/Programmatic Drivers and Barriers

If not beneficially reused, slag would have to be disposed of as solid waste, causing generators to incur tipping fees and transportation costs.

In Alabama, Section 429 of the Alabama DOT (ADOT) code allows the use of crushed slag in construction aggregate.[255] This opens up opportunities for generators of crushed slag to seek end users of it. Without specific regulatory permission, generators might be hesitant to seek out this particular reuse.

Although Alabama and Louisiana allow beneficial reuse, as noted above slag components are not uniform. Some application problems have resulted, such as deterioration and raveling, leading to some states restricting its use.[256]

Environmental Effects

Portland cement is produced from virgin materials in an energy-intensive process that generates greenhouse gases (GHG), which can be avoided by beneficially reusing slag instead of virgin materials. A quantity of 3.5 MMT of slag cement would avoid 3.0 MMT of CO_2 emissions, 15 trillion BTUs, and 5.2 MMT of virgin materials.[257] Although these effects are not likely drivers for individual utilities, the effects could drive regulatory or other programs aimed at environmental improvement.

3.6.2.2 Electric Arc Furnace (EAF) Dust

Economic/Market Drivers and Barriers

Heavy metals can be reclaimed from EAF dust and sold as commodities, which makes the dust valuable. In fact, metals are being recovered from EAF dust, [258] with EAF dust being exported to Mexico for metals recovery.[259] This decreases the quantity available for beneficial reuse in the

U.S. and, more specifically, in the Gulf Coast states. It also takes the management and beneficial reuse of the dust outside of EPA jurisdiction. However, it does ensure that the dust is not disposed of directly in a landfill.

Also driving its reuse, EAF dust provides a cheap and plentiful source of raw material for beneficial reuse, otherwise the byproduct would be treated and disposed of generally as hazardous waste. The Timken company in Ohio recycled over 6 million pounds of EAF dust, which saved the company $1 million in 1996.[260] Timken was successful in its recycling efforts by focusing on reducing releases of metals commonly found in EAF dust by recovering the metals under high temperatures at on- and off-site facilities.

Regulatory/Programmatic Drivers and Barriers

EAF dust is classified as hazardous waste under RCRA, which has hindered its potential beneficial reuse in the past. Because RCRA requires treatment of the waste to remove hazardous constituents before disposal, generators typically treat the waste with a high temperature metals recovery process or chemical stabilization before it is landfilled.[261] Such treatment would need to be considered in any beneficial reuse scenario. For example, generators and end users would be required to determine (1) where the waste falls under the RCRA regulatory definition of solid waste, and (2) whether this treatment, coupled with reuse, would be considered reclamation and would, therefore, not be permissible under the regulation. With EPA's re-proposal of the definition of solid waste in March 2007, generators and end users may see more opportunities for beneficial reuse provided they meet the conditions set forth in the rule.

In Alabama, Section 429 of the ADOT code allows EAF dust to be used as mineral filler in highway construction. Mineral filler is used to enhance certain engineering properties, such as stiffness of asphalt.[262] This approach creates clear opportunities for EAF dust generators to seek out potential reuses. Without this specific regulatory "permission," generators might be hesitant to seek out this particular reuse.

Environmental Effects

Untreated EAF dust typically contains hazardous levels of lead and cadmium and therefore treatment may be necessary, depending on the intended beneficial reuse, to remove heavy metals.[263]

3.6.2.3 Spent Pickle Liquor

Economic/Market Drivers and Barriers

With only 17 iron and steel mills in the Gulf Coast, smaller quantities of spent pickle liquor may be available for beneficial reuse.

Regulatory/Programmatic Drivers and Barriers

State agencies in Louisiana and Florida support using spent pickle liquor in wastewater treatment facilities, where it improves the quality of effluent by degrading detergents, washing chemicals, and fertilizers.[264,265] This endorsement may change perceptions of liability and therefore lower barriers to beneficial reuse. Louisiana requires National Pollutant Discharge Elimination System (NPDES) permits for any facility that discharges pollutants, including spent pickle liquor to be used in wastewater treatment facilities.[266,267]

On the federal level, most spent pickle liquor is listed as a hazardous waste under RCRA regulations and must be treated and disposed of under the definition of solid waste regulations. This listing limits its ability to be beneficially reused. Generators and end users would need to ensure that any treatment before reuse is not categorized as "reclamation" under the regulation, making reuse non-permissible. The iron and steel industry is petitioning EPA to delist the byproduct, which would open more avenues for beneficial reuse.

Louisiana does not list spent pickle liquor from the iron and steel industry as hazardous waste; rather, the state considers the material hazardous only if it exhibits one or more hazardous characteristics. Therefore, spent pickle liquor is not automatically considered a hazardous waste under state regulations and might be beneficially reused in some circumstances. [268]

Environmental Effects

Beneficial reuse of spent pickle liquor can have positive environmental effects. Adding spent pickle liquor improves the quality of wastewater effluent exiting treatment plants, which can reduce detrimental impacts to the aquatic system by removing substances that lead to eutrophication.[269]

3.7 Metal Casting – Foundries (NAICS 3315)

Industrial processes in the metal casting industry require pouring (or injecting) molten metal into a cast in the shape of the desired end-product. Casting methods include permanent mold, die casting, sand casting, shell casting, and investment casting. Sand casting is the most prevalent process, producing more than half of U.S. castings, followed by permanent mold, die casting, and investment casting.[270] In sand casting, a cast and/or core is made of sand bound together by any of several substances. "Green sands" are held together by bentonite clay, which makes up 4 to 10 percent of the blend that also includes 85 to 95 percent high-quality silica sand, 2 to 10 percent of a carbonaceous additive to improve the casting surface finish, and 2 to 5 percent water. Green sands are used to produce about 90 percent of sand-casted products in the U.S., and are generally the sands available in quantities and chemical constituents suitable for beneficial reuse. Resin sands are often used for cores and are bound together by organic compounds, which may make them suitable for fewer beneficial reuses.[271]

3.7.1 Beneficial Reuse Traits and Trends in Foundries

In 2004, more than 225 foundries operated in the Gulf Coast, with the majority located in Texas, as shown in Table 3-15. Such concentrated clusters of facilities could make consolidation of foundry sands more feasible for the industry, which could lead to more beneficial reuse by facilities in other sectors.

Table 3-15: Number of Foundries in Gulf Coast States as Characterized by U.S. Census 2004 County Business Patterns [272]

State	Foundries (NAICS 3315)
Alabama	57
Florida	41
Louisiana	12
Mississippi	9
Texas	117
Total	**236**

In recent years, foundry sands have gained increased recognition as suitable material for beneficial reuse applications such as flowable fill, asphalt, concrete, road construction, and soil amendments. The increased emphasis on reuse is partially due to state Departments of Transportation (DOTs) endorsing foundry sand reuse. In addition, the Federal Highway Administration (FHWA) has a policy to increase the use of recycled materials in construction, reconstruction, and maintenance of the nation's transportation infrastructure. Foundry sand is one of six target materials for FHWA's recycling efforts. EPA's Sector Strategies Program, the Resource Conservation Challenge (RCC) and other initiatives have made strides in educating potential users about the possibilities for beneficial reuse of foundry sands. Industry trade organizations, including Foundry Industry Recycling Starts Today (FIRST) and the American Foundry Society (AFS), have programs to promote proper management, marketing, and use of foundry sand.

The American Foundry Society reports that the metal-casting process generates approximately 9.4 million tons of foundry sand annually.[273] The extrapolated results from a survey by the American Foundry Society (AFS) indicate that approximately 2.6 million tons of foundry sand is beneficially used each year. Table 3-16 summarizes results of the 2007 AFS survey, which indicate that the most common beneficial use applications for foundry sand are use as construction fill (which includes both structural and flowable fill), use in asphalt pavement, and use in the manufacture of concrete. Daily landfill cover, although excluded from the 2.6 million ton estimate, may also be considered a beneficial use for foundry sands under certain circumstances.

American Foundry Society's August 2007 survey publication indicates an increase in foundry sand beneficial reuse: survey respondents indicated a total of 2.6 million short tons is reused annually, which is 28.2 percent of the sand available for reuse.

Table 3-16: Beneficial Reuses of Foundry Sands According to American Foundry Society Survey[274]	
Beneficial Use Application	**Quantity Beneficially Used (Tons)**
Construction fill[b]	1,140,914
Concrete	303,531
Not specified/Other	292,928
Road construction	144,288
Top soil mix/horticulture	220,949
Reuse at another foundry[c]	48,426
Asphalt	494,390
Total:	**2,645,427**[d]

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).

According to FIRST, because the cost of high-quality sand for use in metal casting is so high (about $45-60 per yard), foundries have an incentive to reuse sands as much as possible, which could decrease the quantity available for beneficial reuse by other industries. Also according to FIRST, over the past 10 years, many foundries have invested in thermal or mechanical reclamation systems, reusing much sand in-house and producing lower quantities of byproduct per unit of manufactured product.

The foundry industry, like iron and steel, has been subject to intense global competition from China and other countries, which has led to the closing of many facilities over the past 10 years. This, however, could lead to consolidation in the industry, with each plant generating larger quantities of sands.

According to FIRST, there has not been a sharp rise in demand for foundry sands, mainly because of issues associated with the prevalence of small foundries in the industry. Some generators and end users have attempted to address this issue by consolidating small batches of foundry sand from many generators into a single large batch for shipment to a cement kiln or other large-quantity user. However, brokers are limited by shipping fees, so they need to be careful about locating centrally to foundries, but also strategically to reuse opportunities.

3.7.2 Beneficial Reuse Drivers and Barriers in Foundries

Table 3-17 lists foundry byproducts selected for analysis in this paper, along with the rationale for their selection. As discussed in Section 3.8.1, demand for foundry sands has grown, but the current rate (approximately 28 percent) leaves much room for improvement. The sections below discuss this and other barriers to reuse of foundry sands in other manufacturing industries, in addition to addressing the drivers that have led to the cross-sector beneficial reuse of foundry sands and that may encourage further cross-sector beneficial reuse. Foundries do not appear to use any byproducts from other industries that meet the selection criteria for this paper.

Table 3-17: Byproducts from Metal Casting – Foundries (NAICS: 3315) Selected for Analysis

Byproducts	Reuse	Rationale for Inclusion
Foundry Sands	• Geotechnical applications such as road bases, structural fills, embankments, general fills and landfills • Manufactured products such as flowable fill and concrete products • Manufactured soils and other agricultural applications[275] • Fine aggregate for asphalt paving[276] • Road base/subbase • Soil blending/manufactured topsoil/potting soil/compost • Alternative daily cover for landfill • Hydraulic barrier in landfill final cover • Rock wool[277] • Raw material for Portland cement production[278] • Fill on construction sites	• Produced in quantities significant enough for beneficial reuse: approximately 9.4 MMT of waste foundry sand are generated annually in the U.S. • Potential for more reuse to occur: only about 28 percent currently reused outside of foundries • Can be reused in sectors of interest and in other sectors for nonfuel purposes
BYPRODUCTS FROM OTHER SECTORS USED IN FOUNDRIES		
Byproducts reused by foundries do not meet criteria for selection.		

3.7.2.1 Foundry Sands

Economic/Market Drivers and Barriers

In addition to the overarching economic/market drivers and barriers discussed in Section 3.1, several drivers and barriers specifically affect beneficial reuse of foundry sands.

Geographic distribution of foundries creates some challenges for beneficial reuse in the Gulf Coast states. Of the 2,513 foundries in the U.S., most are concentrated in the Eastern and Midwestern U.S. However, only 10 percent are in the Gulf Coast states, which could result in lower quantities to be reused in Gulf Coast industries.[279] However, almost half of the Gulf Coast state foundries (117 of 236) are located in Texas, possibly providing opportunities for consolidating and reusing foundry sands. In fact, approximately 70,000 tons of foundry sand are produced in Texas annually.[280] Also, there are fewer foundries in Alabama (57), but they tend to be some of the largest foundries in the industry, which is why Alabama is a top 10 foundry state by production.

Disposal and transportation costs also play into the cross-sector beneficial reuse picture for foundry sands. As discussed in Section 3.1, low tipping fees can encourage disposal and higher tipping fees could lead to less disposal and potentially more beneficial reuse. Hauling costs and tipping fees for disposal of foundry sand tend to be low, with a national average of about $32.61 per ton.[281] Without the incentive to save money on tipping fees, generators may be more likely to opt for disposal, rather than incur time and cost trying to connect with end users of the sand. Transportation costs can be a significant barrier to cross-sector beneficial reuse, considering the weight of foundry sands. An EPA review of case studies found that 25 to 50 miles is the maximum distance generators or end users are willing to transport foundry sands for beneficial reuse.[282]

Foundry sands must be screened prior to beneficial reuse to remove metal scraps, or may need to be crushed to an appropriate size for reuse. A recent EPA study found that foundry sand processing costs range, on average, from $5 to $10 per ton.[283]

Research into beneficial reuse of byproducts can open avenues for reuses and reduce uncertainty for potential end users. Universities and DOTs have performed numerous studies on the physical, chemical, and engineering properties of foundry sand and its suitability for reuse in highways, flowable fill, embankments, and other reuses. A collaborative research effort between EPA and USDA will soon yield a study on foundry sand use in soil amendments. The study is expected to be published in Summer 2008.

Finally, collaborations between industry organizations such as FIRST and AFS and government organizations, such as EPA's Resource Conservation Challenge (RCC) and Sector Strategies have resulted in initiatives to educate generators and users of foundry sands about markets and possibilities for reuse. In addition, AFS offers a web-based mapping program to help metal casters find their closest end users in cement, asphalt, or ready-mix concrete production.[284]

Foundry Sand in Home Construction

Eureka Foundry, a family-owned iron foundry in Tennessee, began making its foundry sand available to local contractors and haulers for beneficial reuse projects in 1996. Eureka samples and tests the sand every two to three years to comply with Tennessee regulations governing the use of foundry sand as structural fill.

Eureka removes the sand from the casting process and screens it to separate sand for beneficial reuse from the sand that can continue to be used in the foundry's casting process. Eureka does not charge contractors for the sand, but transportation arrangements are generally made on a project-by-project basis in order to ensure that the beneficial use of the sand is not cost-prohibitive to any potential end users.

Contractors generally use Eureka's foundry sand as foundation fill for individual home construction projects within an hour's drive of the foundry. The sand is typically placed within cinder block walls and capped with concrete. Contractors complete approximately four to five projects, of varying sizes, per year with Eureka's sand. These uses amount to a total of about 200 to 300 tons, about one-third of Eureka's byproduct foundry sand.

A more detailed white paper on economic incentives for foundry sand will be published by EPA, Office of Solid Waste in spring 2008. In the paper, EPA uses economic models to attempt to quantify the benefits of foundry sand beneficial reuse accounting for life-cycle costs of manufacturing.

Regulatory/Programmatic Drivers and Barriers

As described in Section 2, Alabama has a detailed regulatory program for foundry sands. This type of program can help encourage beneficial reuse, because it reduces the uncertainty associated with potential liability from beneficial reuse. Each foundry is required to maintain proper documentation and recordkeeping.

In Texas, TCEQ also has a specific beneficial reuse program addressing foundry sands. In the state, non-regulated hazardous wastes require notification to the state upon beneficial reuse, while recycling of regulated hazardous wastes require both permits and notification. TCEQ maintains a database of beneficial use notifications, which includes the quantity of byproducts beneficially reused, the identity of the offsite receiver, and information on the beneficial reuse.[285]

On the federal level, EPA's Sector Strategies Program is working to drive beneficial reuse of foundry sand and has produced the *State Toolkit for Developing Beneficial Reuse Programs for Foundry Sands*, which gives states a step-wise process to develop programs that encourage beneficial reuse of foundry sands while protecting human health and environment. As described in the *Toolkit*, some states approve reuse of foundry sands on a case-by-case basis, which can involve a time intensive and costly process for generators or end users to prove their sands meet requirements for beneficial reuse.

Environmental Effects

According to FIRST, most sands come from ferrous foundries and are "green sands," which are considered nonhazardous in most cases. Therefore, the sands can be reused for a variety of reuses without impacts to human health and environment. A recent OSW draft report suggests beneficial reuse of foundry sands can have significant energy savings and, therefore, emissions reductions, over extraction of virgin sand:

- Substitution of all spent foundry sand for virgin sand would result in an extrapolated 1.2 billion mega joules of avoided energy consumption, which would equal approximately $34 M per year in saved energy costs based on 2006 energy prices.

- The report also suggests that substitution of virgin sand with 10 million tons of foundry sand in road base would result in 170.8 million gallons of water savings.[286]

Despite these findings, some still hold perceptions that foundry sands are environmentally hazardous. To address this perception, EPA's Office of Solid Waste (OSW) is collaborating with USDA to undertake a multi-year evaluation of the environmental and ecological effects of foundry sands in soil. The five-year project, entitled "Benefits and Risks of Using Waste Foundry Sand for Agricultural and Horticultural Applications" (expected to be published in Summer 2008) will:

- Focus on identifying and quantifying potentially hazardous organics and trace metals in waste sands from ferrous and non-ferrous foundries.

- Conduct studies to determine the movement potential of any organics and/or trace metals of environmental concern identified.

- Investigate blending waste sands with organic amendments as a method of mitigating hazardous constituents.

- Investigate whether waste foundry sands present a risk to commonly used biological indicators, including soil micro-organisms, earthworms, and plants.

- Assess the suitability of using waste foundry sands in horticultural and agricultural settings.[287]

3.8 Oil and Gas Extraction (NAICS 211111, 211112, 212111, 213112)

As part of oil and gas drilling process, operators must handle the large volumes of rock fragments that are carried to the surface in the drilling fluid as well as the drilling muds that flow through the drilling pipe.[288] These muds, which are water or oil-based fluids with additives, close the reservoir to prevent contaminant flows and eliminate cuttings. They also stabilize the well bore, offer lubrication and counteract formation pressure.[289] Though oil-based fluids—coated in both oil and mud—cannot be discharged to surface waters, they are often reused in the drilling of other wells because associated base material is relatively expensive.[290]

During the oil and gas production phase, gas is first separated, and then the sand, silt, water, and other additives used to facilitate extraction are removed. In addition, oil-water emulsions are broken down during the production phase. The process that separates the leftover fluids and solids creates layers of sand, mostly oil-free water, emulsion, and a relatively small amount of pure oil. The loose sediment and water are removed by using vibrating shaker screens, while the emulsions are broken apart by exposure to high heat or chemicals.[291] The resulting oil is approximately 98 percent pure, a level appropriate for storing or sending to a refinery for further processing.[292] As the oil is stored, however, the heavy hydrocarbons, clay, sand, and mineral scale previously suspended in the liquids begin to settle, creating a layer of sludge, known as "tank bottoms" or "basic sediment and water," along the bottom of the tank.

3.8.1 Beneficial Reuse Traits and Trends in Oil and Gas Extraction

The American Petroleum Institute (API) reports an upswing in extraction activities: an estimated 37,261 oil wells, natural gas wells, and dry holes were completed in the first three quarters of 2006, which is the highest number in 21 years.[293] Although the 2004 U.S. Census reports numerous oil and gas extraction facilities in the Gulf Coast region, these raw data reflect neither the supply of nor the demand for beneficial reuse of byproducts within the industry.[294] The amount of extraction activity taking place provides a better predictor of the quantity of drill cuttings and nonhazardous tank bottoms potentially available for beneficial reuse.

On-site beneficial reuse occurs frequently during oil and gas extraction activities; however, such reuse activities are not within the scope of this paper. EPA estimates that roughly 10 percent of total drilling waste volumes, including both liquids and solids, are reused or recycled into construction and infrastructure projects as levee fill and road-base material.[295] Nonetheless, demand for drill cuttings and nonhazardous tank bottoms for use in other manufacturing sectors is not as strong. This weak demand could be due to the small amounts of tank bottoms that tend to be generated and/or extensive transportation costs and liability concerns.

Drilling Waste Reuse in Texas

U.S. Liquids of Louisiana (USLL) recently has begun converting exploration and production waste into road-base material and levee fill in South Texas. As part of USLL's recycling process, waste is purified and mixed with other feedstock to create the road-base materials. With legislative support from the Texas Department of Transportation and the Texas Railroad Commission, USLL produces the recycled materials without assuming operator liability for exploration and production waste. USLL anticipates serving a growing market in the Gulf Coast region interested in purchasing road materials that not only are environmentally advanced, but also possess a higher compressive strength for less price than similar road construction substances.[1]

3.8.2 Beneficial Reuse Drivers and Barriers in Oil and Gas Extraction

Table 3-18 lists oil and gas extraction byproducts selected for analysis in this paper, along with the rationale for each byproduct's selection. As discussed in Section 3.9.1, beneficial reuse of drill cuttings and nonhazardous tank bottoms in other manufacturing sectors has not been widespread. The following sections discuss barriers that are contributing to lack of cross-sector beneficial reuse, including liability concerns and limited quantities of byproducts. The discussion also focuses on efforts to lower these barriers to reuse. In general, the oil and gas sector does not appear to rely upon byproducts from other industries in their extraction processes.

Table 3-18: Byproducts from Oil and Gas Extraction (NAICS: 211111, 211112, 213111, 213112) Selected for Analysis

Byproducts	Reuse	Rationale for inclusion
Drill Cuttings	• Roadbed construction • Dike stabilization[296] • Substrate for restoring coastal wetlands[297] • Fill material • Daily cover material at landfills • Aggregate or filler in concrete, brick, or block manufacturing • Road pavements • Bitumen • Asphalt • Cement manufacture • Use as fuel at UK power plants[298] Does not meet definition of beneficial reuse for this paper: • Landfarming/landspreading, which seems to be a land disposal method rather than reuse • Drilling muds are reconditioned and used in drilling of other wells • Plugging and abandonment of other wells • Reuse within drilling operations for roads, construction of drilling pads, and other drilling infrastructure[299 300]	• Produced in quantities significant enough for beneficial reuse: for offshore drilling, EPA estimated in a Technical Amendment that on the order of 500 to 2,000 barrels of drill cuttings are generated per well drilled in the Gulf of Mexico (density of drill cuttings is on the order of 700-1,000 lbs per barrel)[301,302] • Potential for more reuse: in 2000, only about 10 percent of total drilling waste quantity was being reused [303] • Can be reused in a sector of interest and across other sectors for nonfuel purposes [304,305]
Nonhazardous Tank Bottoms (sediments and water)	• Used in refineries as feedstock for coking[306] • Dust palliative on low-volume public roads • Fuel in cement kilns or aggregate kilns[307]	• Although quantities may not be large (tank cleanings occur a few times a year or several years apart), co-location of many refineries and exploration operations may facilitate reuse. • Can be reused in two sectors of interest.
Byproducts from Other Sectors Used in Oil and Gas Extraction		
Oil and Gas Extraction industry does not appear to reuse byproducts from other sectors.		

3.8.2.1 Drill Cuttings

Economic/Market Drivers and Barriers

The physical condition of drill cuttings can dictate beneficial reuse options. Before drill cuttings can be beneficially reused, it is necessary to ensure that the salinity as well as the hydrocarbon moisture and clay content of the cuttings are suitable for the intended reuse of the material. Even after separation from other byproducts, cuttings are still coated with mud and therefore difficult to use for construction. Treatment options can mitigate these barriers, along with the possibility of combining the cuttings with fly ash, cement, or other materials to facilitate handling.[308]

Industry sources cite location, quantity, and cost as the most important criteria for potential end users in deciding whether to purchase drill cuttings. For example, due to high transportation costs, prospective clients for roadbase material want the reused product to be located in close proximity to the feedstock repository. Likewise, the end user needs to have a sustainable amount of the reused product on hand, and the cost for such material must be attractive compared to other similar options already available.[309]

If connections can be made between generators and end users, the market for beneficial reuse of drill cuttings can expand. Historically, road base products used by the South Texas Department of Transportation (DOT) have been imported from as far away as Central Texas and Southern Mexico, indicating viable demand for such products and a potential market for beneficial reuse of drill cuttings.

Other potential barriers arise when: the end user of the reuse product needs larger volumes than the recycler currently can provide; the end user needs more exact engineering product design details than the recycler can offer; and recyclers lack the necessary experience or equipment to produce a correctly engineered recycled item.[310]

Regulatory/Programmatic Drivers and Barriers

At the federal level, drill cuttings are typically exempt from Resource Conservation and Recovery Act (RCRA) hazardous waste regulations and can therefore be beneficially reused.[311] Despite the RCRA exemption, and even though DOE has funded several projects to test the feasibility of reusing cuttings to restore Louisiana's damaged wetlands, neither EPA nor the U.S. Army Corps of Engineers (USACE) would issue a permit to field demonstrate the use of cuttings for wetland restoration.[312]

Some states are addressing the liability concerns that can inhibit beneficial reuse of drill cuttings. In December 2006, the Railroad Commission of Texas (RRC) revised Texas Administrative Code Title 16, Part 1, Chapter 4, Subchapter B to specify that "a recyclable product is not a waste…" The rule was proposed and written to address concerns held by potential end users on liability associated with reuse.[313] When "recyclable product" is no longer classified as a waste, but instead becomes a commercial product after complying with the environmental and engineering expectations set by the local governing board, then operators benefit from greatly reduced liability because responsibility for the product shifts to the recycler. The "recyclable product," however, would convert into waste if it were disposed of or abandoned instead of following the prescribed recycling process.[314]

Environmental Effects

Drill cuttings have been used for road spreading in the past, which can have deleterious environmental impacts due to their hydrocarbon content. Such impacts have raised significant concerns and, as a result, road spreading applications involving drill cuttings are prohibited by many regulatory agencies.

3.8.2.2 Nonhazardous Tank Bottoms

Economic/Market Drivers and Barriers

Offsite beneficial reuse of nonhazardous tank bottoms requires a suitable quantity and quality of the byproduct. Research indicates that tank cleaning takes place occasionally and does not create large amounts of byproduct, though co-location with extraction and refining operations can facilitate beneficial reuse by shortening transportation distances and time requirements. Petroleum refining operations use the byproduct as alternative fuel for their coking operations. Sludges can only be recovered for use as feedstock if the sludges have a high percentage of recoverable hydrocarbons and no hazardous components in hazardous amounts.[315]

Regulatory/Programmatic Drivers and Barriers

Nonhazardous tank bottoms are typically exempt from RCRA hazardous waste regulations and, thus, can be beneficially reused.[316]

Environmental Effects

Obtaining beneficially reusable materials from tank bottoms can ensure that tanks and drums are thoroughly cleaned before being reused or stored, lessening the chance of environmental contamination due to drum deterioration and leakage.

3.9 Petroleum Refining (NAICS 32411)

The purpose of the petroleum refining process is to separate distinct organic compounds from the crude oil, creating more valuable compounds out of less valuable ones.[317] Petroleum refining typically begins by removing salt content from the crude feedstock and then continues with distillation and further refining process such as cracking and treating.

In the first phase of the process, salt, clay, and various other components are removed by mixing water into the crude. In the distillation stage, the crude is heated to allow various fractions in the oil to be recovered. The refining phase targets particular fractions by subjecting them to thermal treatment and other catalysts.

Each stage of the refining process creates waste: removing salt produces significant wastewaters and sludges affected with petroleum, while distillation and refining generate spent heavy-metal catalysts, spent caustics, and spent desiccant clays. Afterwards, tank cleaning and wastewater treatment create more sludges from primary or second treatments.[318]

Oily wastes generated during the refining process can be recycled by returning them to the crude or processing them in a coker. Spent caustics, acids, and catalysts may be reused by a regeneration process or by retrieving their valuable metal components. For example, 'cat cracking' catalyst has been recycled into alumina in cement manufacturing, and sulfidic caustics may be recycled off-site in the paper industry or as feedstock for producing sulfuric acid.[319]

3.9.1 Beneficial Reuse Traits and Trends in Petroleum Refining

In 2004, more than 100 petroleum refineries were operating in the Gulf Coast states (approximately 2/3 of the total U.S. population), with the majority located in Texas and Louisiana, as shown in Table 3-19.

Table 3-19: Number of Petroleum Refineries in Gulf Coast States as Characterized by U.S. Census 2004 County Business Patterns[320]

State	Petroleum Refineries (NAICS 32411)
Alabama	6
Florida	6
Louisiana	30
Mississippi	8
Texas	61
Total	**111**

Reuse of byproducts from petroleum refineries in other sectors carries liability concerns. However, there does exist a low, but slowly growing, level of interest in reusing sulfidic caustics. In fact, some individual firms have shown interest and have developed processes for beneficial reuse. Because sulfidic caustics are likely to be reused within a refinery, ample supply should be available for beneficial reuse. By 2010, the petroleum industry intends to cut total amount of finally disposed waste by 67 percent in comparison to 1990 levels.[321]

3.9.2 Beneficial Drivers and Barriers in Petroleum Refining

Table 3-20 lists petroleum refining byproducts selected for analysis in this paper, along with the rationale for their selection. As mentioned in Section 3.10.1, manufacturing industries are exhibiting a slight, but growing level of interest in reusing sulfidic caustics. The following discussions present drivers that are leading to this beneficial reuse and barriers that present challenges to increasing the level of cross-sector beneficial reuse. The petroleum refining industry also uses nonhazardous tank bottoms as an alternative fuel for coking operations, as discussed in Section 3.9.

Table 3-20: Byproducts from Petroleum Refining (NAICS: 32411) Selected for Analysis[322]		
Byproducts	**Reuse**	**Rationale for Inclusion**
Sulfidic Caustics	• A bleach for pulp in paper manufacturing facilities • Feedstock for manufacturing sulfuric acid[323] • Merichem's proprietary manufacturing process in Houston, Texas, uses sulfidic caustic as a substitute for other commercially available chemical products[324] (Substitution for other commercially available products is considered a non-waste by EPA) • Some specialty chemical companies will buy spent caustic streams from refiners to recover the phenol value[325]	• At least one firm is reusing sulfidic caustics in manufacturing process; therefore, it is likely these byproducts are produced in quantities significant enough for beneficial reuse • Potential for more reuse to occur outside the refinery; sulfidic caustic has the least potential for reuse within a refinery[326], but there is legitimate potential for more reuse across sectors • Reuse potential across two sectors of interest for nonfuel uses
BYPRODUCTS FROM OTHER SECTORS USED IN PETROLEUM REFINING		
Nonhazardous Tank Bottoms (from oil and gas exploration; see Section 3.9.2)	• As feedstock for coking operations[327]	See Oil and Gas for rationale

3.9.2.1 Sulfidic Caustics

Economic/Market Drivers and Barriers

Phenolic compounds can be recovered from caustics and used as inputs into manufacturing processes. However, the cost effectiveness of recovering phenolic compounds for beneficial reuse depends on proximity of the recovery facilities to the refinery.[328] Such beneficial reuse may be less expensive than treatment and discharge to a wastewater treatment plant.

Regulatory/Programmatic Drivers and Barriers

EPA excludes from the Resource Conservation and Recovery Act (RCRA) hazardous waste regulations spent caustics generated by petroleum refineries when they are reused as a feedstock in the manufacture of certain commercial chemical products.[329] This exclusion can lower barriers to beneficial reuse by reducing compliance costs.

Environmental Effects

By taking materials out of the wastewater discharge stream, beneficial reuse of spent caustics reduces strain on wastewater treatment facilities.

4.0 Discussion and Findings

Chapter 4.0 Findings

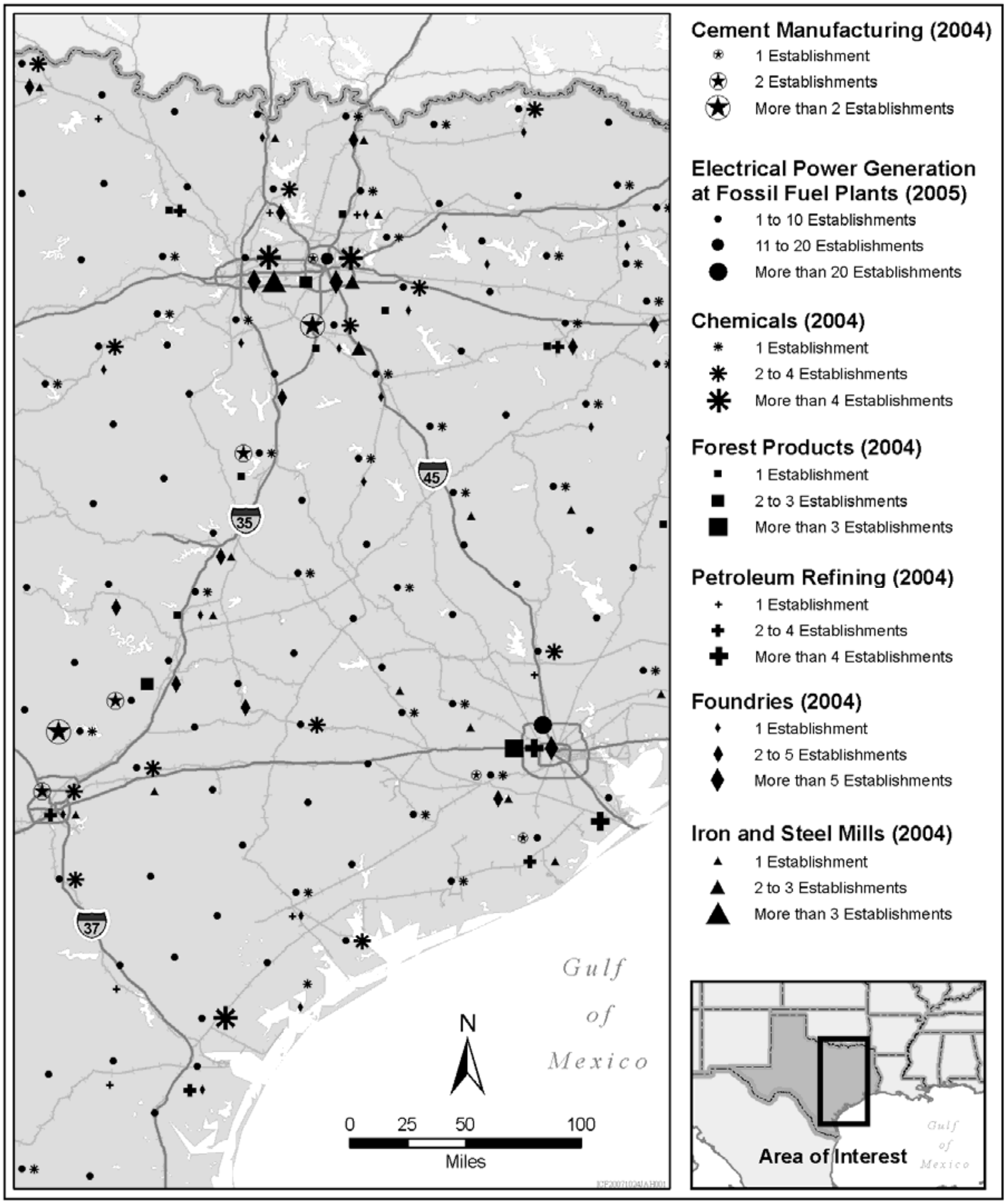
Our research and analysis reveals themes in the drivers and barriers affecting cross-sector beneficial reuse of byproduct materials. As illustrated in the sector specific discussions in Section 3, we found that the themes ran across all three categories: economic/market drivers and barriers; regulatory/programmatic drivers and barriers; and environmental effects. These findings may be useful in informing future EPA research efforts, policy and/or voluntary initiatives, as well as outreach efforts to potential stakeholders interested in beneficial reuse of byproduct materials (e.g., industry, federal and state governments, regulatory agencies, industry groups).

4.1 Economic/Market Drivers and Barriers

Several economic/market drivers and barriers affect most of the industrial sectors examined in this paper. Each of these drivers and barriers can shape the supply and demand for beneficial reuse of byproducts.

1. Geographic Distribution. The distance between byproduct generators and potential end users, access to transportation corridors (highway, rail), and associated transportation costs affect beneficial reuse across all of the sectors analyzed for this paper. Plotting the locations of industrial sectors in a region of interest is an initial step to identifying potential flows between byproduct generators and end users and addressing the challenge of geographic distribution. Figure 4-1 illustrates such as exercise, presenting the locations of seven industrial sectors in a region within Texas. Plotting facility locations on a map that includes road and railroad corridors may readily illustrate potential beneficial reuse pathways. For example, the numerous establishments from several sectors and ease of access to transportation at the convergence of I-35 and I-45 indicate potential opportunities for byproduct pathways. Organizations interested in material exchanges might also look at the area along the southern part of I-45, in which there is a cluster of two to three forest products establishments, two to five foundries, more than 20 electric power generation facilities, and two cement manufacturing facilities, all within 25 miles of one another.

Figure 4-1: Geographic Distribution and Density of Establishments in Seven Industry Sectors as Characterized by US Census 2004 County Business Patterns



2. Relative Convenience and Lower Cost of Landfilling. The easiest and cheapest means of a facility ridding itself of most byproducts is a landfill. Unless a material has a market value such that an end user is willing to pay top dollar for it (e.g., scrap metal or petroleum coke), incentives must be in place for beneficial reuse. Otherwise, a generator is more likely to dispose of byproducts in the closest landfill, which is most likely more convenient than arranging and transporting for beneficial reuse.

In addition, tipping fees charged for waste disposal tend to be relatively low, especially in the southeastern states, which may make landfilling a less expensive option when compared to the effort of locating an end user and transporting or arranging for transport of byproducts for reuse. Tipping fees vary significantly from one location to another. Tipping fees for both municipal solid waste (MSW) and construction and demolition (C&D) waste in the southeastern U.S. were among the lowest in the country in 2005, at an average of $33.43 per ton, as compared to the average of $67 per ton in the northeast.[330] Nationally, these average tipping fees have risen steadily each year and are expected to continue to rise. As tipping fees increase and become expensive enough for generators to consider alternatives to disposal, beneficial reuse may become a more desirable option.

Land for landfills is relatively cheap and plentiful in the Gulf Coast. Without scarcity of land leading to restrictions on landfill disposal (and therefore encouraging beneficial reuse), economic incentives may be more important, and possibly more effective, in encouraging reuse. For example, a tax break for companies engaging in documented beneficial reuse may steer more facilities to that option.

Some localities have taken specific actions to create disincentives to landfill disposal. Vancouver, British Columbia, Canada, banned gypsum wallboard in landfills, because the material's breakdown creates hydrogen sulfide gas, a human health hazard. This type of active governmental decision creates a strong barrier to landfill disposal and a strong driver to get byproducts into the hands of potential end users.

3. Inconsistent Quantities and Composition of Byproducts. Beneficial reuse projects often require a minimum quantity of byproduct and a specific composition and consistency to make reuse in a manufacturing process feasible. Numerous small- to medium-sized facilities comprise most of the sectors, making accumulation of significant amounts of byproduct challenging. This characterization is also illustrated by the size of the clusters displayed in Figure 4-1. Thus, even though industries are generating reusable byproducts, volumes from one or even a few facilities may be insufficient for beneficial reuse in certain manufacturing processes. In addition, if the end user is paying for byproduct transport, transportation of one large shipment can be much more cost effective than transportation of multiple small shipments.

The prevalence of small generators may also contribute to inconsistent physical and chemical compositions of byproducts. Although consolidation and blending of byproducts could address these barriers, establishing a network to accomplish this can be a daunting task. In addition, some states prohibit mixing of byproducts from different facilities, thereby inhibiting the collection of threshold quantities of byproduct needed for input into manufacturing processes.

This “inconsistent quantities and composition” barrier could be addressed through federal and/or state regulatory frameworks relating to storage, transportation, and/or mixing of waste products. Depending on byproduct materials and regulations in place, storage of a material may be a viable option for a generator until a sufficient quantity is produced to make transportation of the material economically feasible. In addition, consolidator firms may address this barrier by picking up byproducts from small volume generators, accumulating shipments until a ”critical mass” is gathered, and then transporting the material to an end user. To make transportation and consolidation effective, other organizations, facilities, and/or governments addressing the “inconsistent quantities” barrier might also think in terms of facility clusters (see the “Geographic Distribution” barrier discussion).

4. Awareness and Marketing. Lack of awareness of the connections between generators and potential end users creates another barrier to beneficial reuse, even where the markets for reuse exist. Whether generators are unaware that potential end users exist nearby or end users are unaware that byproducts can be used in their manufacturing process, matching up these entities can be a challenging process. The lack of connections can also lead to generators incurring costs to find end users or third parties who will broker their byproducts to potential end users. Several industry trade associations and beneficial reuse organizations have led awareness and marketing efforts to address this barrier, and state programs, such as Texas’ RENEW, are making connections between generators and end users to increase beneficial reuse. Some local government entities in Europe are addressing this issue by coordinating the exchange of materials, ensuring quality of materials, and examining the economic costs and benefits of beneficial reuse.

5. Standards and Specifications. Some states and industries have developed standards to address the beneficial reuse of byproducts in manufacturing, engineering, and construction. For example, several state departments of transportation (DOTs) have instituted specific engineering standards for reuse of foundry sands and coal combustion products (CCP) in road base, asphalt, and embankments. For other industries, however, states or organizations have only distributed very generalized information on beneficial reuse of industrial byproducts. In addition, specifications that are in place are not always effective. For instance, the beneficial reuse of asphalt shingles in pavement has the potential to keep the shingles out of landfills. However, some specifications, such as those in Texas that require separation of manufacturer and post-consumer asphalt waste, may contain provisions that are difficult, costly, or time-consuming to meet. Specifications that are carefully crafted may enable beneficial reuse by taking away uncertainty associated with engineering properties, while still providing some flexibility in consolidation and reuse options.

A 2003 meeting held by EPA’s National Center for Environmental Innovation (NCEI) found the potential for liability creates increased costs with beneficial reuse.[331] Published manufacturing specifications for input of byproducts may diminish the uncertainty of liability and production issues associated with bringing a byproduct into the manufacturing process, thereby lowering barriers to beneficial reuse. However, specifications must be relevant and attainable to help drive beneficial reuse.

6. Core Competency. Core competency is a business concept describing "an area of specialized expertise that is the result of harmonizing complex streams of technology and work activity."[332] Beneficial reuse is not a core competency for many manufacturing sectors, which creates challenges in overcoming perceived notions of the time and cost involved to beneficially reuse materials. A key barrier to beneficial reuse is overcoming the hesitancy of firms to investigate reuse opportunities based on a lack of information about the reuse process and its potential benefits to the firm. Due to this lack of information, some industries may not understand the value to production (or the upfront costs in terms of staff expertise and research necessary) that can make beneficial reuse a viable alternative to standard treatment and disposal practices. The cement sector is an example of one industry that has made beneficial reuse part of its core competency, meeting and even exceeding industry goals for beneficial reuse.

If industries and stakeholders approach the concept of beneficial reuse by "thinking with the end in mind," they may shift away from the a waste management chain that consists of waste generation, followed by waste treatment, followed by waste disposal. Although some manufacturing processes cannot be modified to incorporate collection of byproducts, many firms can facilitate more beneficial reuse by analyzing their processes and their waste streams, assessing potential end users, and modifying "end-of-pipe" processes to collect and convey the byproducts to end users. As shown by the Dow Byproduct Synergy project, this can be a collaborative effort between industries and governments. Finally, where industries and firms can be shown quantifiable evidence of the benefits of beneficial reuse, they may be more willing to consider modifying their core competencies to include beneficial reuse.

4.2 Regulatory/Programmatic Drivers and Barriers

We found that state government regulations and non-regulatory programs (described in Section 2) typically have a significant effect on the beneficial reuse of industrial byproducts. State regulations in Gulf States vary in their complexity, levels of allowable beneficial reuses, and even required processes for state approval of beneficial reuse. Inconsistent state regulations and approval processes on beneficial reuse can inhibit cross-sector reuse across state lines when generators and end-users must be compliant with two or more sets of regulatory requirements. We found that materials are more likely to be safely reused when state regulations and non-regulatory programs encourage industry to initiate reuse activities while also ensuring adequate protection of human health and the environment.

1. State Regulations Specific to Beneficial Reuse. Although regulations may be seen by some as a barrier to beneficial reuse because they outline restrictions on beneficial reuse activities, regulations also provide generators and end users with a predictable process. The steps outlined in regulations, such as those in Louisiana, may provide generators and end users with assurance that, by following the requirements, they will be able to lawfully reuse industrial byproducts. Therefore, regulations may reduce the regulatory uncertainty generators and end users face when deciding whether or not to reuse certain byproducts. A lack of regulatory limitations on reuse activities, such as in Alabama and Florida, may lower barriers to beneficial reuse because generators and end users will not incur costs associated with obtaining approval from the state. However, as discussed in Section 2.0, some review and approval processes, such as Florida's case-by-case reviews, might result in some limitations on reuse requirements, despite the lack of regulations.

2. State Regulations Specific to Beneficial Reuse of Certain Materials. Some states have beneficial reuse regulations that pertain to specific byproducts, either in lieu of or in addition to the state's general beneficial reuse regulations. These regulations governing reuse of specific materials may provide generators and end users with a predictable process and reassure them that, by following the requirements, they will be allowed to lawfully reuse specific industrial byproducts. For example, Alabama's beneficial reuse regulations for foundry sand regulations give generators and end users of that material certainty about their regulatory requirements when initiating reuse.

3. Exemptions for Beneficial Reuse Activities Proven to be Safe. Providing exemptions for specific beneficial reuse activities may lower barriers to beneficial reuse. For example, Louisiana has specific regulations for the pulp and paper industry, which include pre-approved reuse activities, including use as ingredients, raw materials, or feedstocks in industrial processes to make products; use as effective substitutes for commercial products; and land application reuses. By lifting the application requirement for pulp and paper byproducts in specific reuses, Louisiana is removing a barrier to reuse. Mississippi's regulations allow generators or end users to pursue beneficial reuse activities that are "Standing Uses" without applying to the state for approval and exempts generators or end users who pursue a Standing Use from the annual reporting requirement.

4. Exemptions for Byproducts that are Effective Substitutes for Raw Materials. By exempting from regulation those byproducts that are effective substitutes for raw materials, some states reduce a generator's or end user's costs for compliance with solid waste transport and disposal requirements. With lower costs, a generator or end user may be more inclined to participate in beneficial reuse activities. For example, in Louisiana, pulp and paper byproducts that are used as raw materials in an industrial process or as effective substitutes for commercial products are exempted from generator, transporter, or permitting requirements under Louisiana's solid waste regulations.

5. State Agency Specifications and Standards. As with specifications published by standards organizations and supported by trade associations, those published by state agencies can also lower barriers to reuse. In Texas, the state DOT established specifications that specifically call or allow for the use of recycled materials in road and transportation construction.[333] By providing the public with this information, the state DOT is helping generators and end users identify suitable materials for construction reuse activities.

6. Investment in Outreach, Education, and Marketing Programs. Outreach efforts educate generators and end users about beneficial reuse opportunities and may serve as a catalyst to encourage beneficial reuse activities. To encourage reuse, TCEQ provides various guidance documents regarding beneficial reuse of byproducts on their website. In addition to the outreach materials, TCEQ sponsors the RENEW program, which is a marketing channel for generators and end users. RENEW helps generators of various byproducts connect with potential end users, which is a driver for reuse.

7. Government Resources. Encompassing both economic/market and regulatory/programmatic issues are the resources available for governments to run beneficial reuse programs. Median income levels in the Gulf Coast states are lower than in many other areas of the country, which limits the tax revenue available for state and local agencies to run environmental programs. In fact, Alabama ranks last out of all 50 states for the amount of money available and spent on environmental issues.[334] Although government agencies may not be able to dedicate resources to providing information and insight into beneficial reuse, some industry organizations have stepped in to fill this need, devoting time and resources to research and education on beneficial reuse opportunities.

8. Sampling and Testing Requirements. Material sampling and testing requirements are often necessary to protect human health and the environment. However, requirements that are not clearly defined may create barriers to beneficial reuse. For instance, Louisiana's regulations do not specify the constituents to test for, the constituent concentration thresholds, or the testing method to be used. Such a lack of specificity can cause uncertainty on the part of generators or end users, who may perceive beneficial reuse activities as too risky in terms of liability and enforcement. If a generator characterizes its waste in one way, identifying certain constituents, and the LA DEQ disagrees with the generator's approach to the analysis, the generator may need to re-run the analysis. These uncertainties discourage reuse because of the time and cost to gain approval.

9. Approval Process. When states incorporate an approval process into their regulations and beneficial reuse programs, the states gain greater oversight of beneficial reuse. However, generators and end users may view multiple layers of approvals as a barrier to reuse, because the additional approvals may increase the costs of and time needed to initiate beneficial reuse activities. For example, in Louisiana, for nearly all beneficial reuse activities, a generator or end user must submit an application to the LA DEQ and receive the agency's approval. For byproducts from the pulp and paper industry, in certain cases industry also needs approval for the reuse activities from the LA Department of Agriculture and Forestry. In Mississippi, for byproducts that fall within Categories II-IV, a generator or end user must submit an application to the MS DEQ and receive the agency's approval. In addition to the MS DEQ's approval, for byproducts that will be used in engineered construction or other civil engineering uses (Category II), a PE licensed in Mississippi must certify that the byproduct is suitable for the proposed construction or civil engineering use. Generators and end users may view these multiple layers of certification and approvals as a barrier to reuse because of the added costs and time.

10. Permit Requirements. In some cases, generators or end users of byproducts face additional costs associated with obtaining permit modifications. These costs may serve as a disincentive to initiating beneficial reuse of the byproducts. For example, in Louisiana, before removing the materials from the landfill or surface impoundment, a generator or end user must obtain a Solid Waste Permit Minor Modification. However, once the byproducts are removed from the facility, they are no longer subject to generator, transporter, or permitting requirements under Louisiana's solid waste regulations.

4.3 Environmental Effects

As shown in the sector discussions, there are significant positive environmental outcomes and the potential for some negative outcomes as well. The positive outcomes are compelling. First, and probably foremost, the use of secondary materials obviates the need to harvest virgin materials for the same use. In cases where the extracting the virgin material is very damaging, such as most mining activities, the benefits are significant. However, not all harvesting or extraction has the same level of environmental damage, so this benefit varies from material to material.

In some cases, the by-product is also prepared in a less environmentally damaging manner than the virgin material. For example, using fly ash in concrete reduces the need for Portland Cement production, which generates relatively high greenhouse gas emissions.[335] Also, in many situations, the generators and end users are located closer to each other than they are to the virgin materials. The shorter transportation requirements lead to reduced air emissions, energy consumption, and other environmental impacts from transportation. There are also specific benefits for many materials, such as decreased water use, filtering capability, or ability to use the material in cooler weather. In almost every case, the beneficial reuse diverts byproducts from landfill disposal, conserving land for other purposes.

All of these factors together usually results in massive environmental gains. For example, energy savings associated with the use of fly ash and FGD gypsum totals approximately 167 billion megajoules of energy (or approximately $4.7 billion in 2007 energy prices). Based on the average monthly consumption of residential electricity customers, this is enough energy to power over 4 million homes for an entire year. Avoided water use totals approximately 121 billion liters or approximately $76.9 million in 2007 water prices). This is roughly equivalent to the annual water consumption of 61,000 Americans.[336]

Another example is also from a recent EPA economic report on foundry sand. Beneficial reuse of foundry sand has significant impacts that include energy savings and water use reductions associated with avoided extraction of virgin sands. Total energy savings are approximately 224 million megajoules of energy (or approximately $6.2 million in 2006 energy prices), and 36 million gallons of water (or approximately $88,000 in 2006 energy prices). Other key impacts include greenhouse gas (CO2) emissions reductions of approximately 18,000 megagrams, particulate matter emissions of approximately 267,000 kilograms and reductions in RCRA hazardous waste generation of nearly 289,000 kilograms.[337]

Negative environmental effects can run the gamut from benign to significant environmental effects if mismanaged. However, in every case a carefully designed state program that is protective, but also simple for the regulated community to navigate, can mitigate potential environmental damages. The risks (which are usually far less than the benefits) tend to vary not only with the nature of the material, but also with the use. Bound applications, such as use of a material in cement or asphalt, generally require far less scrutiny than unbound applications, such as road bases, embankments, and soil amendments. However, we also found that a relatively benign material that is reused in an unbound application can be as safe (or more safe depending on the nature of the virgin materials) as use in bound applications. It is important to evaluate not only the material and its use, but the background levels in the soils where it will be used. In some cases, state programs have established requirements that are equal to or higher than the background levels that already exist. In those cases, it may be appropriate to allow the permit-seeker to make an alternative demonstration to the state authority.

End Notes

[1] U.S. EPA's website reports that the U.S. annually generates 7.6 billion tons of industrial solid waste (http://www.epa.gov/industrialwaste/) and that in 2003, the country generated more than 236 million tons of municipal solid waste (http://www.epa.gov/garbage/facts.htm).

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[5] Richard Tedder, Florida Department of Environmental Protection. Solid Waste Section. Personal Communication with Liz Gormsen, ICF International. 16 October 2007.

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[7] Mike Lindner. Texas Council on Environmental Quality. Personal Communication with Liz Gormsen, ICF International on 17 October 2007.

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[15] Portland Cement Association, 2007 Report on Sustainable Manufacturing, http://www.cement.org/smreport07/sec_page3_2.htm (obtained on October 19, 2007)

[16] Portland Cement Association, 2007 Report on Sustainable Manufacturing, http://www.cement.org/smreport07/sec_page1_3_C.htm (accessed on October 19, 2007)

[17] United States Geological Survey. Minerals Yearbook, Cement: 1999, 2000, 2001, 2002, 2003, 2004, 2005 http://minerals.usgs.gov/minerals/pubs/commodity/cement/ (accessed on October 19, 2007)

[18] Portland Cement Association. www.cement.org/smreport07/images/graphs_maps/GR_CKDUSES_S.jpg

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[20] Portland Cement Association, 2007 Report on Sustainable Manufacturing, http://www.cement.org/smreport07/fly_ash_raw_materials.htm (accessed on October 19, 2007)

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[29] U.S. Geological Survey. Minerals Yearbook, Cement: 1999, 2000, 2001, 2002, 2003, 2004, 2005. http://minerals.usgs.gov/minerals/pubs/commodity/cement/

[30] http://minerals.usgs.gov/minerals/pubs/commodity/iron_&_steel_slag/790401.pdf

[31] Scrap tires are outside the scope of this study because scrap tires are a "post-consumer" waste and not an industrial process byproduct. Approximately 400,000 metric tons of scrap tires were used as alternative fuel in cement kilns in 2003, 2004, and 2005.

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[40] http://www.cement.org/smreport06/sec_page3_2.htm

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[43] http://www.cement.org/smreport06/sec_page3_2.htm

[44] http://www.hatch.ca/Sustainable_Development/Projects/cemstar_process.htm

[45] http://findarticles.com/p/articles/mi_m0NSX/is_1_49/ai_112905707 *Patented grinding technology offers new ready-mix options: Portland cement substitute yields economic, environmental, and durability benefits – Innovations* Concrete Construction, January 2004 by Tom Klemens

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