The History of CCR Beneficial Use and its Future using Stored CCR as the Main Source: A Strategy to Properly Profile Stored Products

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Abstract:

Many of the large and complex CCR sites will be required to either remove or cap in place CCR and are currently in design phase for closure or alternate remediation applications. This requirement is in conjunction with the shuttering of coal fired units. The reductions of coal fired generation affects the construction industry and FHWA which uses CCR as a performance enhancing product. With reduction in pozzolan availability from generating facilities, alternatives must be considered. A key component to fill the void is to reclaim and beneficiate stored CCR in impoundments and dry fills. This paper presents and discusses the proper and specific approach to rigorously evaluate utility and nonutility CCR sites to effectively determine product characteristics and beneficiation requirements the product will need for specific markets. It is also important and beneficial to the client to create comprehensive market studies within the geographic range of these source locations. With the requirements of impoundment closures, the clients and technical advisor can determine specific closure strategies can enhance future reclamation strategy and QC procedures during product deposition provides a roadmap of stored materials for future reclamation and can enhance stored product quality.

This paper will present the application of effective and concise site product evaluation, market survey and on some specific sites the utilization of closure strategy to effectively place and track future product with real time correlation CCR testing data to enhance market materials.

Approach/Activities.

The example projects cover medium to large scale impoundments and dry fills and provides comprehensive dashboards providing all key parameters for beneficial use opportunity. Closure strategy which can not only provide a value-added closure approach but enhance future reuse applications with clear QC testing through out placement and roadmaps of where all product and deposition dates are known.

Traditional CCR Production and Handling

Pulverized coal combustion generating plants were the main power generation source within in the United States for a good part of the last 100 years with some 50-55% of U. S. power generation in the mid 2000’s with facilities operating across the US. The

production operations varied in boiler size and produced either a Class C or Class F ash depending on fuel source. The “quality” of the CCR or pozzolans also varied by facility due to factors such as coal BTU – ash content, pulveriser operations, combustion efficiency, and load capacity. In general, the operations would handle the by – products by sluicing to impoundments (some 735) where products would settle and remain in state with occasional commingled products (bottom ash, FGD, etc.) within the storage facilities or place in dry landfill units.
Around the 70’s the use of CCR, specifically fly ash became a value-added product for use in concrete and specifically for performance criteria to mitigate specific deleterious reactions in concrete life cycles. These beneficial uses required more power plants to convert to dry handling systems for fly ash marketing purposes. As testing and research for CCR grew new uses of fly ash, bottom ash and gypsum became commodities for the utility and independent business entities. The use of fly ash in concrete is a general spec material for DOT work along with almost all ready-mix producers around the country due to performance criteria and specification requirements.

However, since the promulgation of the EPA CCR Rule implemented in 2015, many coals fired plants have begun to shut down or retire and this trend has also been accelerated due to the abundance of less expensive natural gas. Many facilities have retired pulverized coal units or converted to natural gas units which produce fewer emissions and are more cost effective to operate with PC generation producing about 30% of electricity currently, See Fig 1 and more retirements of PC units by 2035 see Fig. 2.

So, what does this mean for the performance and durability for concrete the DOT’s and other industry users of CCR with the continued decline and eminent shut down of live CCR production? The demand and utilization have stayed strong and is projected to do so but product supply will continue to diminish.

Figure 1:

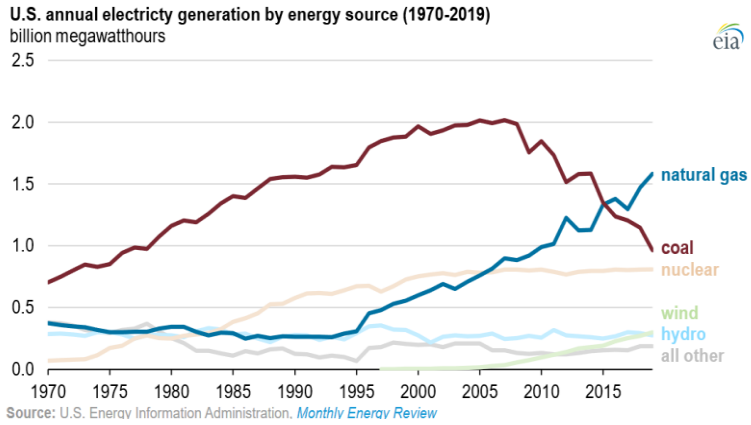
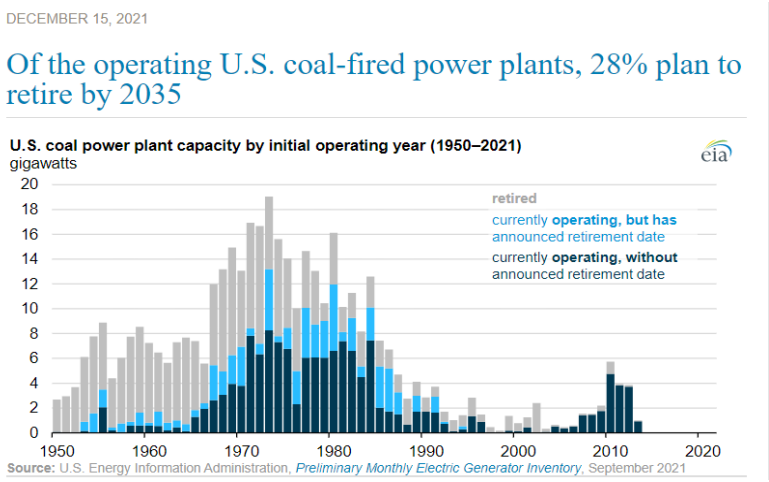


Figure 2:



I have worked with many utility clients across the US and even outside the US to provide scientific and technical support to meet the EPA and State CCR rules and develop strategy to close and mange CCR impoundments and landfills alike. Within this strategy, having CCR subject matter expertise to properly evaluate each owner's landfill or impoundment, regardless of size to accurately determine volume of product, product types, quality and recommend beneficiation needs is important and SMEs for BU are not that common. A second phase based on the materials characterization will be an in-depth market survey and study that not only evaluates ready-mix utilization capacity but all non-traditional use as well if requested.

A Strategy and Solution

Due to the retirement of facilities and conversion to gas, the availability of pozzolans will continue to diminish as well as force use of lower quality materials. However, there are ~ 1.5 billion tons of stored pozzolans and CCR materials than can be reclaimed and beneficiated to meet specification for each product utilization.

Many of these quality improvement or beneficiation technologies have been available but with ample production of CCR, economics mitigated widespread utilization. Typical systems reduce carbon contents by chemical, thermal, electrostatic and in some case particle manipulation by classification. Particle size (Fineness, C430) can be readily reduced by crushing, simple screening methods, air classification and even selectively pulling hoppers in the PC facility. While several systems are in use, we will not specifically notate each company and technology in this paper to maintain neutrality and courtesy to each entity. However, as your consultant I can certainly determine the BAT for your stored products and long-term beneficiation needs and marketing strategy.

With the EPA CCR rule, many utilities find that product management would be greatly enhanced by properly using the product in value added uses and reduction of virgin material utilization which drives sustainability and ultimately reduce environmental impact risk. Lastly, this is a significant public relations advantage to proactively utilize the products as opposed to managing and monitoring for 30 years or more.

So how do we and the utility get there? Simply develop a strategy and approach to evaluate each impoundment or landfill and produce a high value comprehensive report which will provide all fundamental aspects of products and beneficiation needs. The following activities are a typical approach for a stored material location.

Stored CCR Evaluation Procedure: Fig 1. <u>Example</u> dashboard (not CCR)

Standard Project Site Summary Approach

A standard Phase 1 site study will encompass a desktop evaluation and laboratory testing program of existing samples to (a) organize and summarize existing information with respect to beneficial use potential, (b) identify and test available existing samples for beneficial use laboratory characterization, and (c) to identify data gaps in the existing available information and samples on hand following the previous closure engineering evaluations.

Following completion of the proposed Phase 1 desktop data analysis and geotechnical and beneficial use laboratory testing of available existing samples, a summary of the Phase 1 results of the analysis in the form of a client preferred dashboard summary. Fig. 1 (is an example dashboard format) and in addition, a PowerPoint summary of the study findings; a summary memo documenting the methodologies, sources, and findings; and high-level bullet points for consideration beneficial use and how to optimize closure phasing with respect to beneficial use opportunity.

If the Phase 1 efforts identify gaps in the resource potential information, a targeted supplemental field sampling and laboratory testing protocol for CCRs (to be executed as a client option Phase 2 supplemental study) based on the recommendations and findings of the initial phase of the study to provide an updated full assessment of beneficial use potential. Additionally, if the beneficial use evaluations show promise for

short or mid term commercial application, we will evaluate the potential benefits of completing a supporting market study, and a study to incorporate beneficial use into the planned closure construction activities in the short term.

TYPICAL SCOPE

The initial step will use the available geotechnical information, deposition history, closure drawings, recent topographic information if available and other information available from any closure engineering plans in the development of the beneficial use resource dashboard. Additionally, the evaluator should request that the client provide any available coal source (determines ash content and type), boiler history, ash generation volume and quality data available from any market use from the plant's history over the course of the operating facility, any data from the ash ponds or landfill operations that could help inform and be useful in evaluating the beneficial use resource potential of the CCR materials.

With this information, a beneficial use quality study will be developed to determine the potential for and feasibility of beneficial use of stored CCRs. During this study, data gaps may be identified and recommendations for further testing and bore sample investigations to fill the gaps will be provided.

The key or recommended dashboard components are listed below and is an example of a thorough review of an active facility with stored CCR.

Key components of the CCR Dashboard:

1) *Storage site layout, topography, and estimated volume*
   a) GIS- bore sample program
   b) Sample depth and sample type locations (characteristic identifiers)
2) *CCR characteristics*
   a) Loss on Ignition (LOI) C311
   b) Fineness, C430
   c) Moisture content, C311
   d) Specific gravity
   e) Oxide Content
   f) C109 SAI performance 7, 28 day and sulfate testing as required*
   g) Mercury (Hg) content
   h) Split Sieve and LOI @ each screen size retained content
   i) REE (Rare Earth Elements)
   j) Leachate testing: use dependent
3) *CCR Classification*
4) *Beneficiation needs and suggested approach BAT*
5) *High Level market use discussion based on product characteristics*
6) *Suggested in-depth market study based on product testing*

The evaluator will complete material characterization testing on a representative group of samples selected from stored samples or borings (bore sample layout) previously collected at the ash pond or landfill. If a second phase is needed and executed to fill

the data gaps, we will provide a combination of field sampling (drilling as required) of CCRs and select laboratory testing of those samples to allow for a full baseline assessment of beneficial use potential for the ash pond or landfill at the client's option. A specific dashboard summarizing the CCR beneficial use resources for the ash pond or landfill at the PC Plant will be developed as well. The dashboard will summarize the ash quality and quantity along with other important physical and chemical characteristics. It will also present the most practical beneficial use options for the stored CCR, based on this information.

Phase 1: Desktop Study, Testing of Available Samples, & Data Gap Identification

Phase 1 will consist of a desktop study to determine the potential for and feasibility of beneficial use of stored CCRs based on the available existing facility information from the generating facility. The study will make use of available information to summarize the quantity and location of different CCR materials (types, quality, etc.) within the storage unit (ash pond or landfill) and the CCR suitability for beneficial reuse (based on production sales history or testing information). The study will also highlight any existing data gaps in material characterization, material quality (e.g., LOI, fineness, moisture content, etc.), and quantity, and recommendations for potential supplemental targeted investigations and testing to fill any identified data gaps.

The Phase 1 study should target the following goals:

- Report on the available estimated limits and quantity of CCR in the storage unit.
- Gather available data on the characteristics of the CCR deposit including data obtained during the development of the required CCR unit closure strategy.
- Perform beneficial use material quality testing on previously collected samples as necessary or available and review of current CCR analysis if available through current or previous sales.
- If data gaps are found, a deliverable of this phase will be to recommend targeted investigations and testing of those newly collected samples to fill gaps to be executed in Phase 2, executed at the client's option.
- Generate project deliverables: an informative dashboard, summary memo, summary PowerPoint.

In addition to the summary dashboard, a well-prepared PowerPoint summary of the study findings to facilitate discussion of the results with the utility; a summary memo documenting the methodologies, sources, and key findings from the market study; and high-level bullet points to consider in the CCR facility closure strategy with respect to future beneficial use. Based on the initial data analysis and representative sample testing will provide the necessary data sets in the dashboard to determine beneficiation needs and can assist with assessments of best available technology in future phase work. A follow up meeting with utility client stakeholders to discuss the summary data memo, recommendations, and the summary document will be initiated.

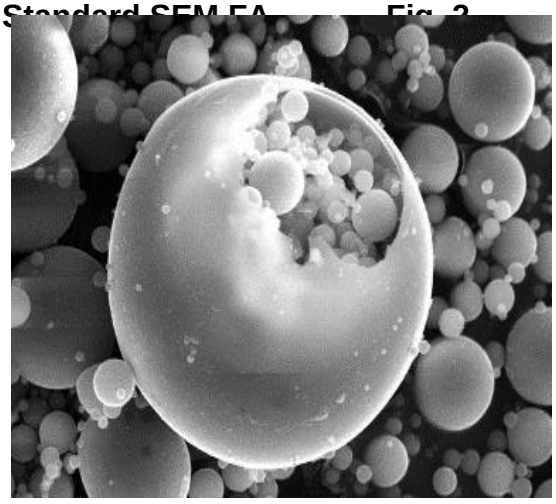
CCR Beneficial Use Characterization Testing of Existing Available Samples and Further Sample Bore Sample Collection

Specific and proper material quality testing on previously collected samples as available will be performed. A representative set of samples will be tested for basic characteristics as outlined in **Table 1** below.

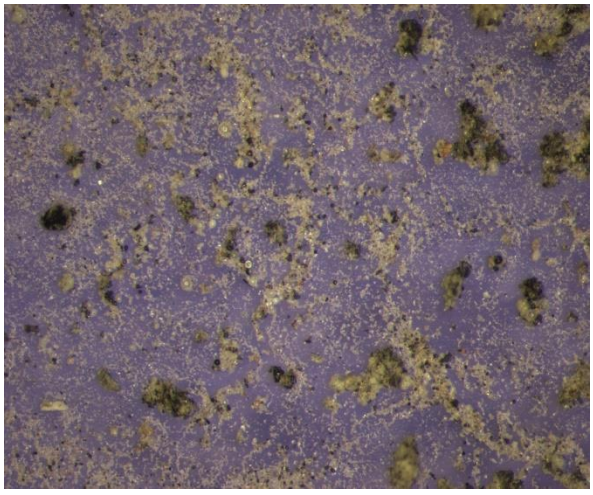
Table 1: Basic Characterization- Standard C618 Req. (representative sample set)

Required Tests	Recommended Test Procedure
Moisture Content	ASTM C311
Loss on Ignition (LOI)	ASTM C311, or LECO Carbon Analyzer
Fineness	ASTM C430, Amount Retained on #325 Screen
Specific Gravity	ASTM C188, and or Helium Pycnometer
Bulk Chemistry- oxide content	X-ray Fluorescence (XRF)

Standard SEM FA Fig. 2



Class F Pond Ash – 400X Fig. 3



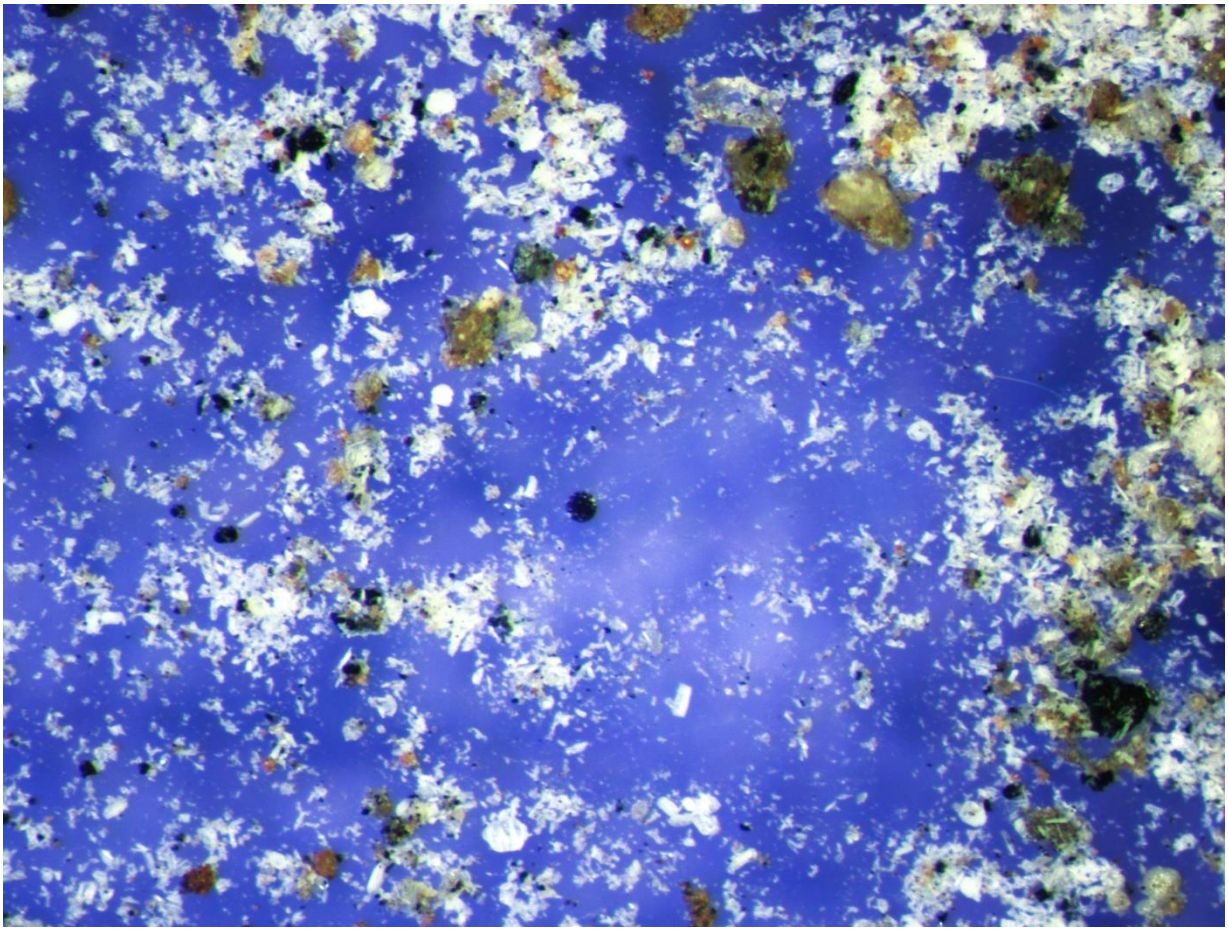


Fig. 4

Class C Ash with Gypsum – Dry Storage 400X

A smaller subset of the available samples (~25% of samples tested for basic characteristics) will then be subject to more in depth testing as outlined in table 2.

Table 2: In Depth Characterization (~25% of Sample Set)

Available Tests	Notes
Particle size fractioning over #80, #100, #200 sieves.	Modified ASTM C136
LOI on Sieved Fractions +80, 80-100, 100-200, and -200.	ASTM C311, or LECO Carbon Analyzer Determine carbon and PSD fraction analysis
Combine representative samples to make a bulk representative sample for each CCR impoundment or landfill.	Run all tests in table 1 above on the bulk composite sample
Coal Fly Ash and Raw or Calcined Natural Pozzolans for use in Concrete: ASTM C618	ASTM C311: Strength Activity Index with Portland Cement C109; Water Requirement; Mortar Air Entrainment; Effectiveness of Fly Ash in Controlling Alkali-Silica Reactions

Table 3 will be conducted on lab-prepared bulk samples, representative of individual stored CCR on site. This data analysis will provide the needed information for specific non-traditional beneficial uses outside of standard ready-mix quality performance.

Table 3: Additional (Bulk Samples)

Optional Tests	Notes
Mercury Content (bulk sample)	Cement production industry has Hg limits as it affects air emissions at the kiln.
Encapsulation and Leaching Analysis (bulk sample)	Some beneficial use applications may require this kind of testing. LEAF 1315
Rare Earth Elements	Supplies indication of potential rare earth element processing / harvesting. DOD has strong interest source evaluations

Beneficial Resource Dashboard Preparation

Dashboards supply a means to present a concise site-specific summary of CCR materials and their potential for beneficial use. The dashboards can supply a wide variety of information, such as:

- historic and current reuse strategy,
- operational throughputs and volumes over time,
- closure plans regarding CCRs at the site, and

- a range of market study drivers.

Depending on the project site and physical characteristics a specific sampling strategy and specific equipment selection will be deployed to obtain representative samples safely and properly for each site.

Suggested equipment and sampling techniques include the following:

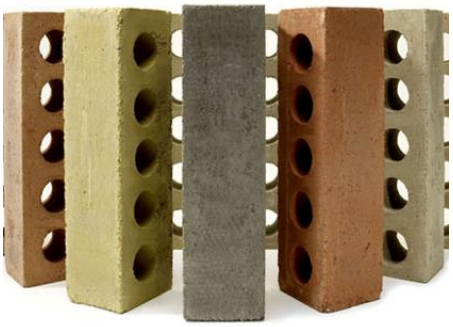
1. **Stacked or compacted land storage**
    a. Hand augers and other sample devices
    b. Truck or ATV mounted auger systems
    c. Yellow iron- track and wheel mounted excavation
2. **Soft or moisture laden storage areas: small loads and LGP**
    a. Tripod augers
    b. Tracked loader
    c. Amphibious platforms and amphibious excavators
3. **Open water – typical impoundments**
    a. Kayaks and canoe platforms
    b. John boats and small skiffs
    c. Large platform vessels and deck barges: platform supports

As noted, the most important activity is to prepare for safe and efficient sampling assessments.

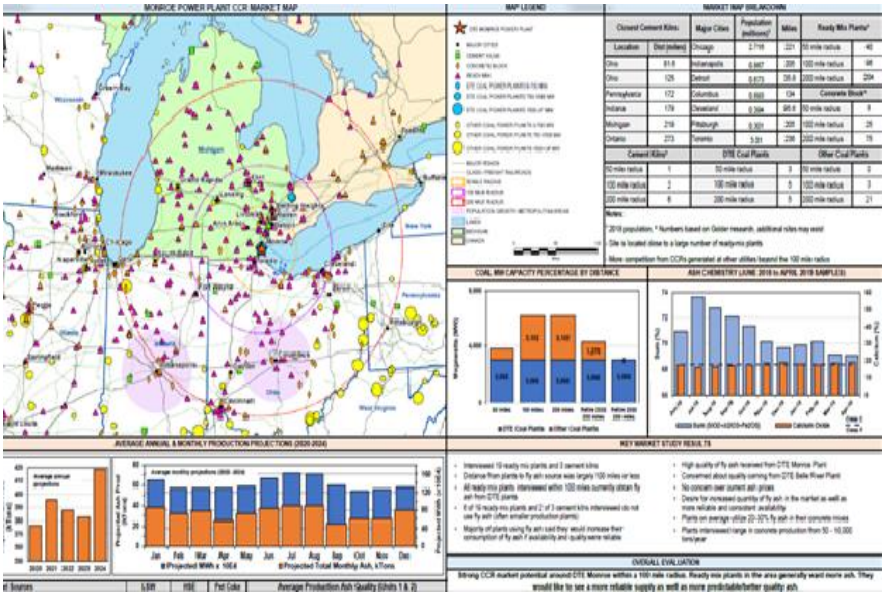
MARKET STUDY

In addition to the initial Phase I and Phase II site assessments and bore sample collection, an in-depth market study will focus on traditional beneficial use markets (concrete, DOT) and nontraditional markets (raw feed source, sub-base, structural fill, flowable fill, mine reclamation, brick-CMU etc.) and specialty market uses (carpet backing, roofing shingle, plastics, zeolites, paint fillers etc.). The analytical data will define specific market survey analysis for long term beneficial use options.
Some of the non-traditional use options are seen in the figures below.
Figure A, B, C, D: Non-Traditional Applications

a. Plastics
b. Brick-CMU
c. Flowable Fill – CLSM
d. Gypsum: Wallboard and Agricultural Applications



The market survey will include key factors and indicators represented in the example Figure 5 and will be specific to product quality, quantity and clients' preferences based on initial quality and quantity assessments. The following diagrams provide examples of market studies that cover all key parameters needed to effectively market by-products.



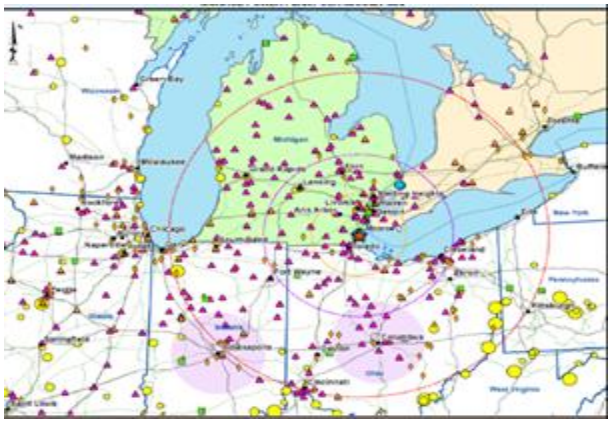
Market Study Dashboard

- Market Map
- Market Map Breakdown
- Site Annual & Monthly Production Projections
- Site Process Information
- DTE and Competitor Coal MW Capacity Outlook (through 2030)
- Ash Quality (production)
- Market Research Summary
- Overall Beneficial Use Evaluation

MARKET MAP BREAKDOWN

Closest Cement Kilns		Major Cities	Population (thousands)[1]	Miles	Ready Mix Plants*	
Location	Dist. (miles)	Montgomery	352.00	157	50 mile radius	27
Florida	3.5	New Orleans	390.85	196	100 mile radius	63
Florida	10	Tallahassee	191.28	197	200 mile radius	119
Alabama	52	Tuscaloosa	103.01	221	Precast Concrete	
Alabama	55	Birmingham	207.23	250	50 mile radius	1
Florida	52	Atlanta	524.10	317	100 mile radius	7
Mississippi	111	Jacksonville	929.65	358	200 mile radius	21
Cement Kilns*		Shingle/Carpet Manufactures			Other Coal Power Plants	
50 mile radius	1	50 mile radius		0	50 mile radius	0
100 mile radius	5	100 mile radius		2	100 mile radius	3
200 mile radius	9	200 mile radius		5	200 mile radius	4

Notes:
[1] 2020 population, * Numbers based on Golder research, additional sites may exist
- Three cement kilns located within 60 mile radius
- Site is located close to a large number of ready-mix plants



*__Source Credit:__ *Golder Associates, Electric Power Research Institute (EPRI), University of Kentucky: Client market survey example format*. Circa 2018

Figure 5: Market Dashboard Examples

Each site is unique and in will require the assessments to determine best market capacity which will also include required BAT for quality improvement. These systems and requirements may include:

- **Carbon reduction or mitigation**: Chemical, Electrostatic, Thermal, Particle Manipulation, Flotation
- **Percent Retained on #325**: Screening, Air Classification, Hopper Selection-Reduction, Particle Manipulation (crushing)

The long-term goal of the client will drive the specific market targets, geography and if a quality improvement technology system (which can be a significant investment) will be installed. I have experience with and will evaluate specific systems needed for the best long-term strategy. This is predicated on the initial volume and quality of stored pozzolans.

CLOSURE STRATEGY AND BENEFICIAL USE QC

The utility and closure engineering firm should also incorporate a strategic plan for deposition and quality control sampling during the closure design phase. The initial phase one and two protocols define the quality, quantity and beneficiation needs of the product in-situ, however if the closure programs require a consolidation, clean close or hybrid approach the long-term beneficial use option will be greatly benefited by designing a QC program and storage map of moved products. Ultimately if the closure protocol can coincide with a BU strategy and beneficiation systems can be designed into the closure planning and permitting requirements.

CONCLUSION-SUMMARY

The history of CCR beneficial use is significant and has been critical to improved performance and durability concrete systems for the last 5 decades. However, the dynamics are changing for quality material access and long-term sustainability of high-performance concrete. The availability of the estimated 1.5 billion tons of stored CCR material is now a key resource to continue to meet industry supply needs. While many of these beneficiation systems were evaluated, researched, and created 20 plus years ago, now the cost to produce quality improved CCR is becoming more a value-added solution with a positive return on investment. The first and most important aspect developing markets and installing quality improvement technology is to thoroughly evaluate supply and quality of the stored products. As an SME in coal combustion production and characteristics this unique expertise, ability to evaluate and provide all required information, develop market studies will help the client make critical decision that will affect the utility, environment, rate payers and construction industry for the foreseeable future.