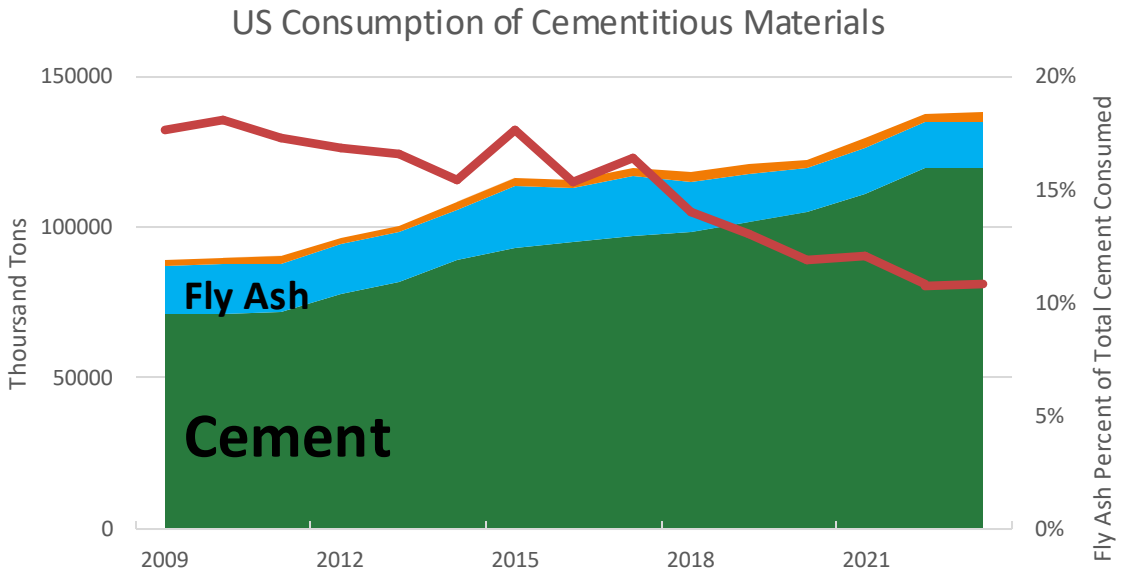
Harvesting and Beneficiating Ash: Advancing from Idea to Commercial

Benjamin Gallagher, Program Leader
bgallagher@epri.com

ANCOLD Tailings Dam Operators Forum
September 23, 2024

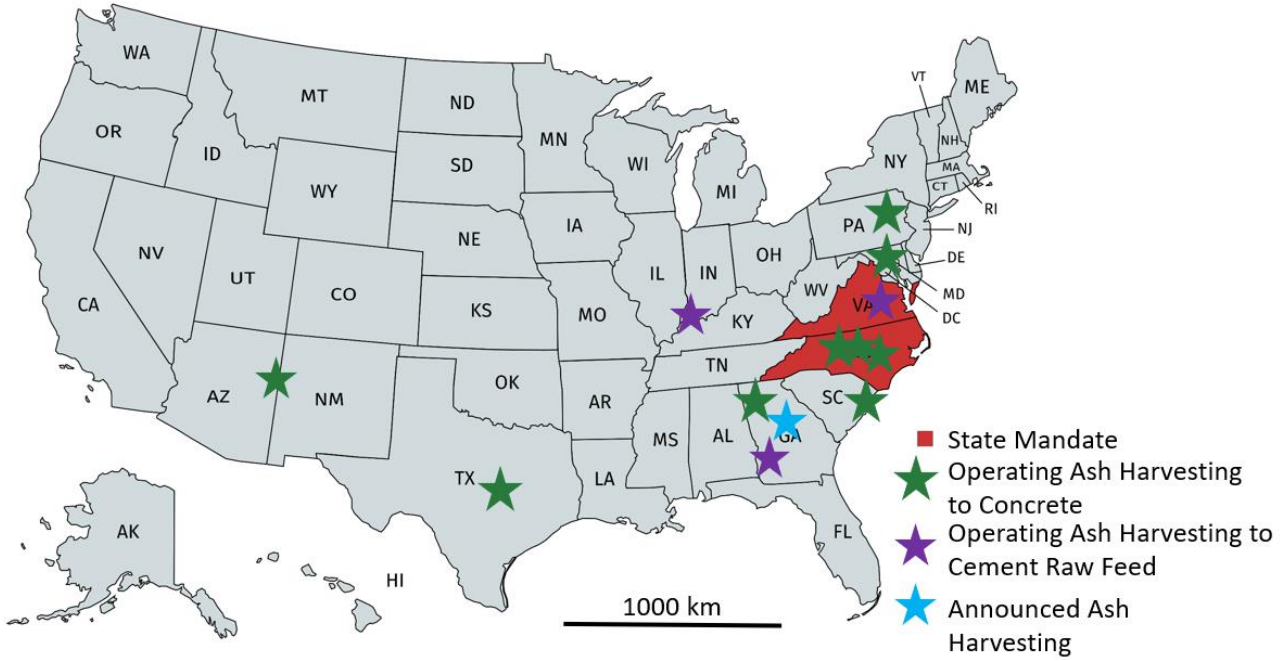
US Motivations for Harvesting Ash For Beneficial Use

- **Energy Transition Reduces CCP Production**
  - Cement a use is steadily growing



- US fly ash production down 42%
  - Increase cement use increases GHG emissions
  - EPRI [3002024165] Harvested Ash in Concrete LCA
- US FGD gypsum production down by 38%
  - Net reliance on imports doubled

- **2 States Mandated Harvesting and BU**



- **2B tons USA stockpile**
  - ~4M tons per year harvesting capacity

US utility approaches to new harvesting projects

Competitive

- ~Request for Proposal
- Increased transparency from economic bids
  - Open-ended RFPs make complex bid comparisons
- Best suited to established markets and established technologies

Collaborative

- ~Request for Qualifications
- Doesn't result in direct economic comparison with competing alternatives
- Better suited to uncertain uses
  - Easier to incorporate new technology or novel markets

Example from Dominion Energy Virginia USA:

- 2018 Summary; Full Report
- 2022 Progress Report; Proposals
- Poffenberger 2024 Ponded Ash Beneficial Use Investigation and Bid Solicitation

Example from Duke Energy North Carolina USA:

- EPRI Phase 1 Report
- EPRI 3002009569 Technologies for Coal Combustion Product Management
- Oberlink 2017 Coal Ash Use Study for Duke E.

What is the objective of harvesting?

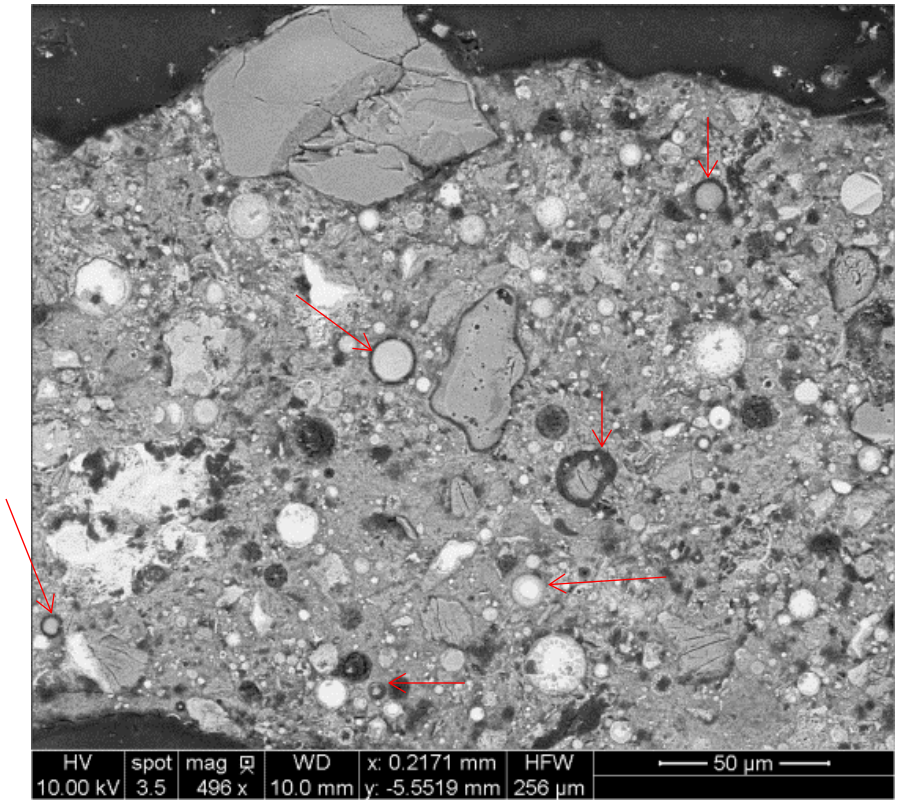
What is beneficial use?

Hallmarks from US regulations:

- Provides a functional benefit
- Substitutes for virgin material
- Meets applicable standards
- Not used in excess quantities

Range of Ash Beneficial Uses:

- Cement, Concrete, and Block
- Alternative Cement Concrete
- Synthetic Aggregates
- Polymer and Metal Fillers
- Metal/Rare Earth Element Ore
- Engineered Materials (Proppants, Zeolites)



Distinctions between uses:

- Bound (Encapsulated)
  - Example: Fly Ash in Concrete
- Unbound (Unencapsulated)
  - Structural Fill for Roadway Embankment

Key Elements In Developing New Harvesting

Market Evaluation	Resource Evaluation	Technology Selection	Permitting/Regulatory Review
• Use Specifications • Finished Product Safety	• Field Sampling • Lab Testing • Data Interpretation	• Tech. Development • Tech. Scale-Up	• Environmental Protection • Worker Safety

Market Evaluation

Primary Market

- Bulk of Deposit Materials
- Demand
  - Growth
- Pricing
  - Alternative materials
- Transportation
  - Truck, Rail, Barge
  - Existing Plant Infrastructure
- Seasonality
  - Storage

Alternative Markets

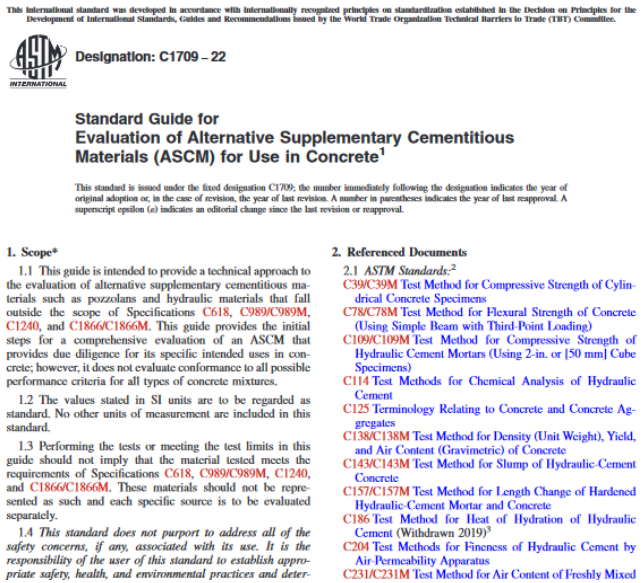
- Excess materials
  - Off season uses
- Off-spec materials
  - Bottom ash
- Smal volume, high value uses

- Resources:
  - Commercial Market Research
  - Independent Research Organizations

Use Specifications

- Construction materials rely on voluntary specifications
  - Utilities may be able to participate
- Concrete often has dated specifications
  - Anticipate changing specifications
- Hidden Aspects of Specifications
  - Material description is underappreciated
    - Specification limits only valid for described materials
  - New or different test methods may be needed to enter market

- Example of systematic development of new concrete product: ASTM C1709-22
  - Stage I — Characterization of the Material
  - Stage II — Determination of Suitable Fineness
  - Stage III — Testing to Specification
  - Stage IV — Concrete Performance Tests
  - Stage V — Field Trials and Long-Term Performance



This International standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: C1709 – 22

Standard Guide for Evaluation of Alternative Supplementary Cementitious Materials (ASCM) for Use in Concrete[1]

This standard is issued under the fixed designation C1709; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This guide is intended to provide a technical approach to the evaluation of alternative supplementary cementitious materials such as pozzolans and hydraulic materials that fall outside the scope of Specifications C618, C989/C989M, C1240, and C1866/C1866M. This guide provides the initial steps for a comprehensive evaluation of an ASCM that provides due diligence for its specific intended uses in concrete; however, it does not evaluate conformance to all possible performance criteria for all types of concrete mixtures.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 Performing the tests or meeting the test limits in this guide should not imply that the material tested meets the requirements of Specifications C618, C989/C989M, C1240, and C1866/C1866M. These materials should not be represented as such and each specific source is to be evaluated separately.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and deter-*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C78/C78M Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)

C109/C109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50 mm] Cube Specimens)

C114 Test Methods for Chemical Analysis of Hydraulic Cement

C125 Terminology Relating to Concrete and Concrete Aggregates

C138/C138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C143/C143M Test Method for Slump of Hydraulic-Cement Concrete

C157/C157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

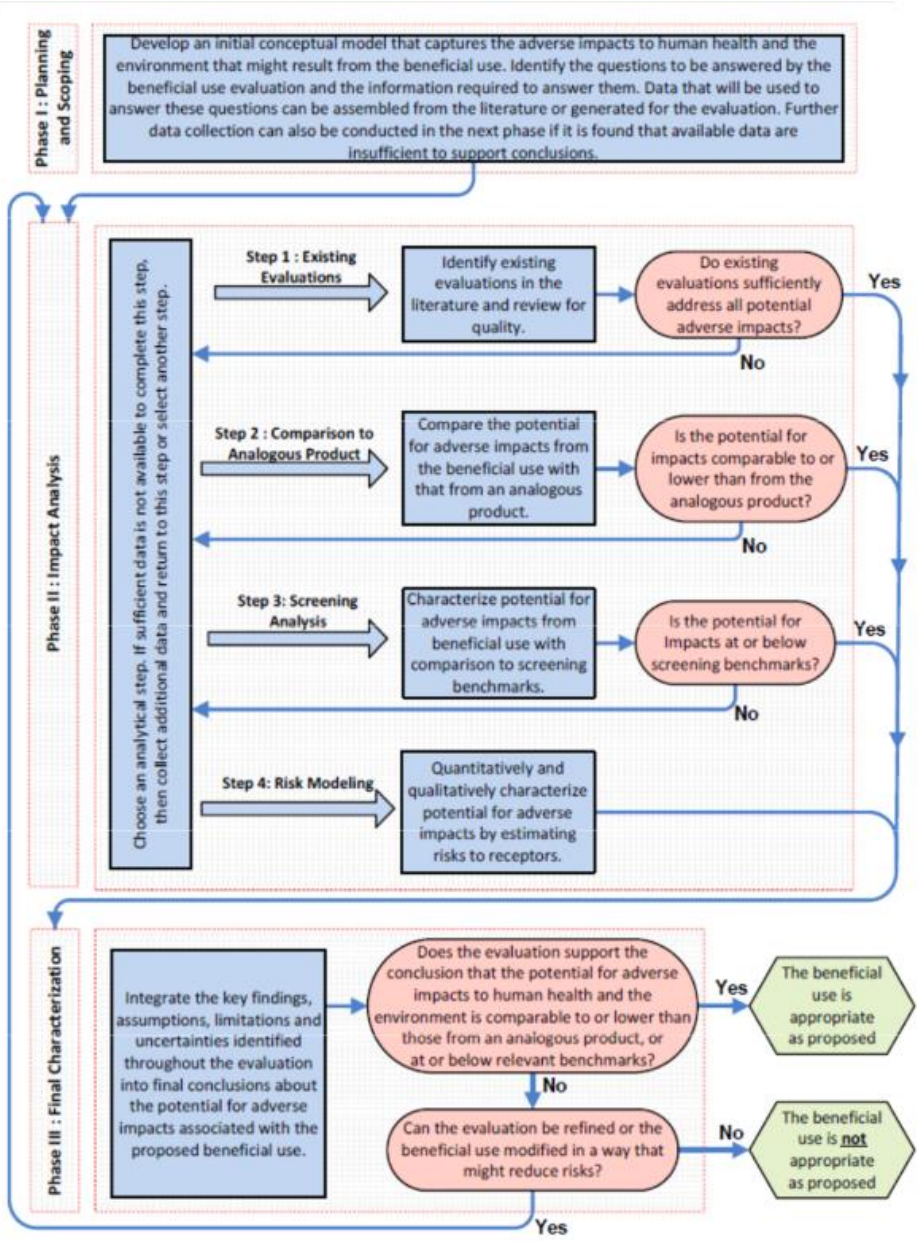
C186 Test Method for Heat of Hydration of Hydraulic Cement (Withdrawn 2019)[3]

C204 Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus

C231/C231M Test Method for Air Content of Freshly Mixed

Specs apply to finished products but don't predict beneficiation

Finished Product Safety



- Secondary materials / wastes often attract safety and environmental concern
  - Significant pressure for quick results
  - Intuitive belief these questions can be answered by simply sending a sample to lab - *Often Incorrect*
- USEPA published method and compendium for assessing beneficial uses and compendium of reference values:
  - Method and Compendium
- EPA 2014 review of ash in concrete and gypsum in wallboard relied on 100s of references
  - A final conclusion requires appreciable intermediate work, including full scale uses
  - Environmental regulator support is often critical

Resource Evaluation

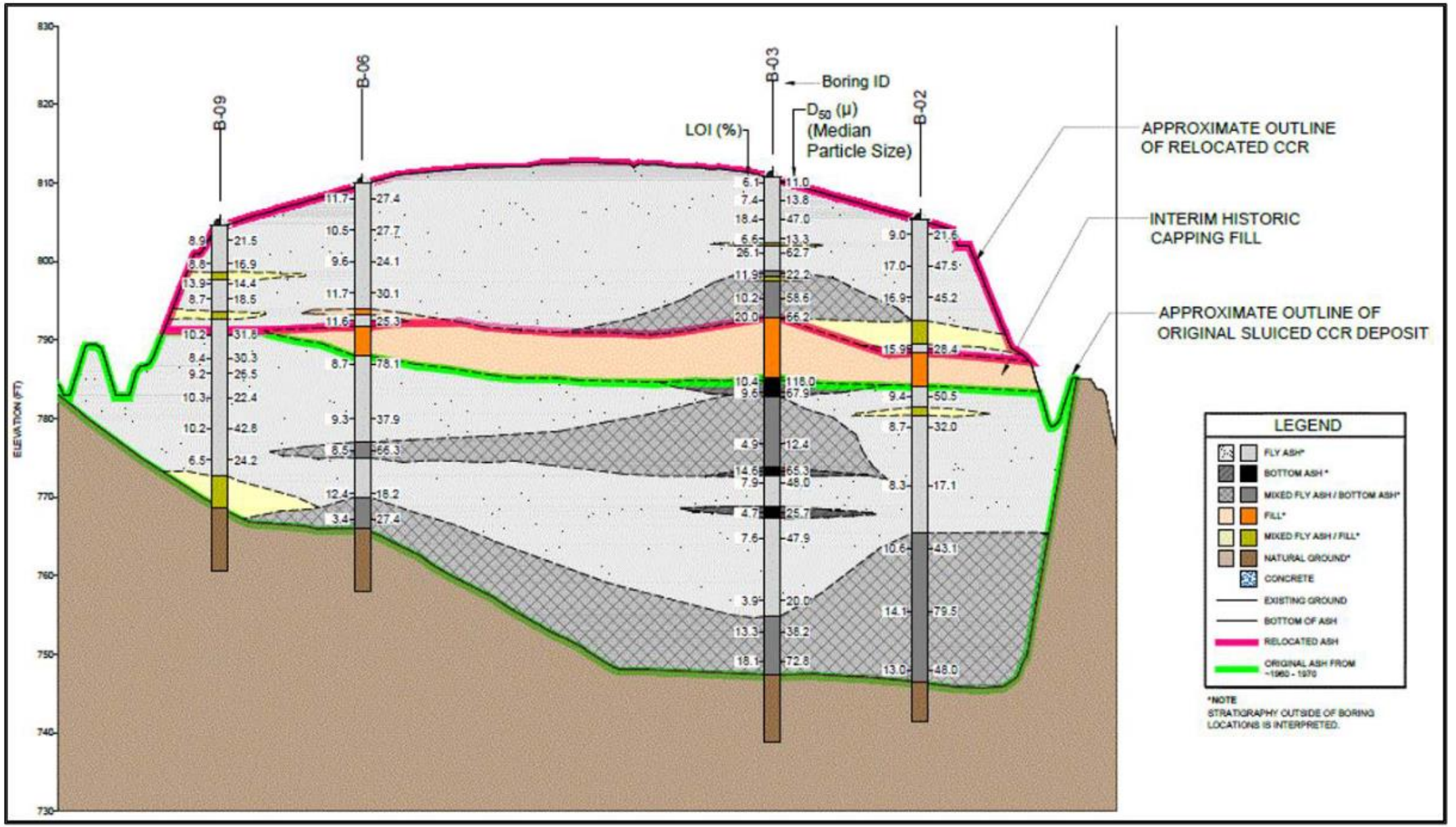
- Wide range of technologies for investigation
- Variably of ash deposits seems to be under appreciated
  - Impacts of excess sulfur, clay on beneficiation not predicted
  - More investigation may not be the solution
- Use specifications are often used as a checklist for lab testing
  - Additional tests may be needed to support beneficiation technology selection and process development
- What sources may contribute to variability?
  - Substances like clay in sluice water?
  - Co-disposed wastes?

Resources:

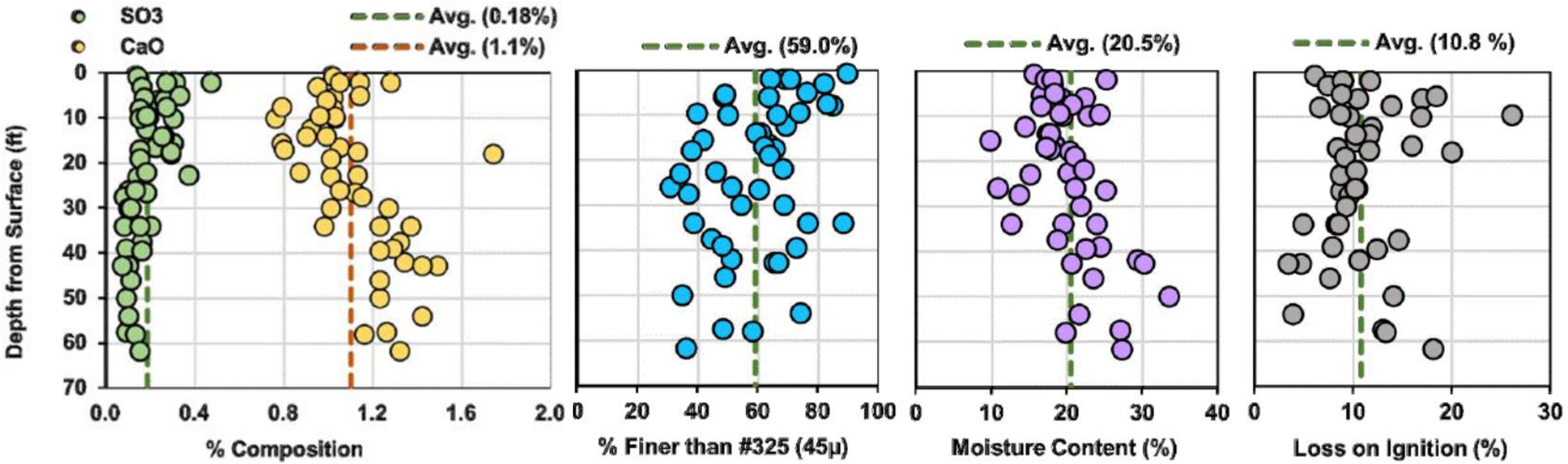
- EPRI 3002013740 Guidance for Sampling and Mapping of Coal Combustion Products in Ponds and Landfills for Beneficial Use Applications
- EPRI 3002016509 Laboratory Assessment of Fly Ash Harvested from Ponds and Landfills for Use in Concrete
- ASTM E3355-23 Standard Guide for Characterization of Coal Combustion Products (CCPs) in Storage Area(s) for Beneficial Use
- Gorman 2024 Coal Combustion Residual Characterization for Beneficial Use

No Consensus on Necessary Level of Investigation

Resource Characterization



Resource Characterization



Technology Selection

- What deficiencies need addressed?
  - Excess moisture, high LOI, poor fineness, excess sulfur are common issues
- How will the material be excavated and processed?
  - Dry processing is most common today but wet processes are promising
- What is the desired throughput?
- Which technologies are commercially available?
  - Have they been applied to fly ash?
    - Pilot testing is often needed to address both technology and stockpile questions
  - Novel technologies will have a longer path to commercial
- How will feedstock variability be accommodated?
  - Blending feed, process adjustment, alternative markets may help

Novel Technology Development and Scale Up

Ideas most often begin at lab scale

- 5 to 25 kg samples are common
  - ~1/1,000,000,000 of full scale
- Lots can go wrong between field and lab
- Sampling and testing bias rampant:
  - accessible deposits free of non-ash
  - few samples due to sampling cost and effort
  - undocumented lab handling before experiment
  - lack of rigor in experiments
  - poor sampling of experiment outputs
  - lack of test methods and poor method selection
  - vested interest in positive outcome
- Many inventors lack experience with ash or beneficial use applications
  - Existing publications should be reviewed

Scale Up

- Systematic scale-up based on process engineering principals
  - What is the objective of each pilot test?
- Limit the integration of pilot processes
- Instrumentation is undervalued
  - Very easy to rely on grab sampling during pilot
  - Independent, automated measurements of key parameters helps detect blunders and diagnose process.
- Consider how full-scale operation will be controlled

Novel Technologies Require Systematic Scale-up

Environmental Considerations for Harvesting

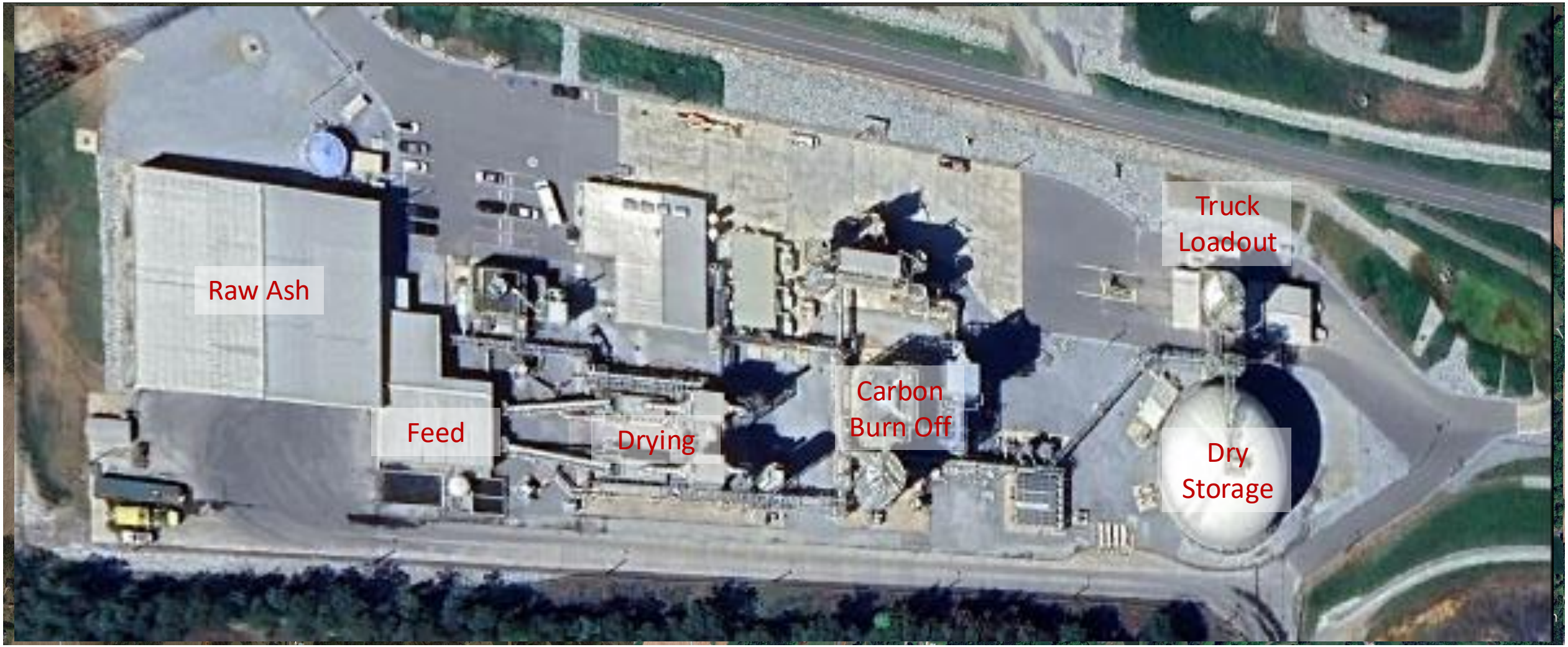
Key Considerations:

- Progressive Removal / Instant Closure
- Wastewater Treatment
- Dust Control
- Groundwater Impacts
  - Changing redox conditions
  - Exposure of fresh surfaces

Resources:

- EPRI 3002013741 Environmental Considerations for Coal Combustion Product Harvesting from Landfills and Surface Impoundments
- ASTM E3183-24 Standard Guide for Harvesting Coal Combustion Products Stored in Active and Inactive Storage Areas for Beneficial Use

Example: Thermal Beneficiation Plant for Concrete Use



Dry fly ash for concrete: 300,000 tons per year

Key Technical Challenges in Harvesting

- Variability of deposit and presence of unexpected materials
  - Often existing, off-the-shelf data on ash quality is limited
    - Sometimes knowledge of deposit is overestimated
  - Field screening of composition and properties in infancy
- Lack of beneficiation technologies
  - No commercial technologies for ash/sulfur separation
    - EPRI 2022 Technologies to Recover High-purity Fly Ash or Gypsum from Mixed CCPs
- Difficult dewatering
  - Dryer feed limitations underestimated
  - Mechanical dewatering for fly ash unproven
    - Although: Keat 2024 Design and Commissioning of Coal Ash Filter Plant
- Lack of standard guidance for handling wet/moist ash

TOGETHER…SHAPING THE FUTURE OF ENERGY®

www.epri.com