Coal Ash 2.0: Foundation of the Value-Creation Model of Total Ash Pond Closure

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Over the last 50 years, production coal ash, in various global markets has successfully transitioned from a "resisted use" product to a "specified component" in cement mixtures to be used in infrastructure projects. The next 50 years will require an extension of that effort. It will necessitate the specification of coal ash to include the use of post-production coal ash from the vast reserves stored in impounded coal ash sites around the world. To initiate this transition, a new approach is needed to create a fungible market for this 21st century material.

Global View: Looming Shortage of Compliant Coal Ash and the Next 50 years

In all major markets, coal is being displaced in favor of lower-cost and reduced carbon emissions-intensive fuels. The UK and an increasing number of EU member states will eliminate coal by 2025 (see Figure 3), and Canada is mandated to follow by 20301. It is further evident that the USA will continue to see accelerated, ahead-of-schedule coal plant retirements. Even in emerging markets such as China, India, and other Asian countries, coal use for energy is reaching a plateau, which will be seen as a percentage decline as renewable power sources are brought online over the time horizon. All these factors are compounding a worldwide supply shortage of compliant production coal ash.

Going, going, gone

Figure 1. European countries phasing out coal power plants, 2015–2027. SOURCE: Bloomberg New Energy Finance.

In the United States, given the planned end of life closures, and the addition of the accelerated closures will have an identical outcome, over a longer timeline. In 2009, there were 530 coal fired power plants in operation; at present there are approximately 263 currently in operation as of this writing. Reviewing the data of planned closures by 2030, SonoAsh predicts a further reduction to between 150 – 160 operating power plants, which will be reduced to 100 by 2040 and likely 50-60 by 2050. If there is no change to technology or energy/environmental policy, the path the industry is on will lead to the conclusion that in the next 50 years there will be no coal fired power plants and thus no production coal
ash. All coal ash material requirements will need to be served by an estimated 2 billion tons in various forms and stages of storage.

Accessing this stored reserve material will require a technology shift to support the new ASTM standard (C618). Collectively, the industry will need to embrace the concept of impounded coal ash as a viable ingredient when engineered to a certain specification with the potential to be a primary active cementitious ingredient.

Additionally, many jurisdictions around the world are implementing some version of carbon pricing, either through a tax or cap-and-trade system. Carbon policies focused on coal power generation and the cement industry require a reduction of carbon emissions. The impact of these policies on power generation is reducing the use of coal as a fuel. The result impacts cement producers and requires process adjustments and new cement formulas.

**Impounded Coal Ash Is Key to Inevitable Shortages**

Resource optimization means understanding our building history. What is old becomes new again. As with the formulas developed during the Roman Empire circa 312 BC to 500 AD (see Figure 4)—which used volcanic ash as a natural pozzolan in the construction of some of its most durable structures—new formulas will need to be considered in the search for a low-carbon reality for 21st century infrastructure buildout and revitalization.

**2000 years and counting**

Figure 2: The Pantheon in Rome is an example of Roman concrete construction built in 113–125 AD.

SOURCE: Jean-Christophe BENOIST, CC BY 2.5, https://commons.wikimedia.org/w/index.php?curid=2532901

John Ward, Chairman of the American Coal Ash Association’s Government Relations Committee, stated: "However...if you want to invent the machine/pixie dust that eliminates performance variability among
ash types and sources, that would be a true breakthrough—enabling the CCP world to shift from a series of local markets to a single fungible commodity market."

The authors agree completely with this statement; it is the key to unlocking the 21st century opportunity. The SonoAsh approach enables a consistent product to be manufactured from an inconsistent supply for a complete product matrix solution.

Applying this new thinking together with the appropriate innovative technology converts coal ash impoundments to resource-rich above ground ore bodies. The opportunity paradigm in this new reality is the additional high-value product matrix available in coal ash impoundments. This product matrix includes engineered pozzolanic material (high-performance cement), cenospheres, silica flour, rare earth elements, strategic metals, carbon offsets, and proppants.

The coal power industry and related associations have made excellent progress in quantifying and mitigating the perception of risk associated with production coal ash as a high-quality pozzolanic material. This can be seen in the dramatic rise in the use of production coal ash in North America, as the product application utilization rate has nearly doubled over the last decade to nearly 45% even while the share of coal in the global energy mix has declined.

The decline in coal use has reduced the volumes of reliable, uniform high-quality production coal ash available to the concrete and construction industries, as measured by consistent loss on ignition (LOI) and impurities (such as sulfur, chlorides and nuisance heavy metals). Key cement parameters, like workability and ASTM C-618 (EN 450)-grade material particle size, are often assumed to be consistent in the marketplace but are not. Both LOI and particle size of production coal ash have highly empirical correlations with one another relating to high-performance and LEED-eligible applications, where reuse has significant value-add upside. Ensuring both workability and uniform particle size will be essential to making reclaimed coal ash a fungible market material in the 21st century marketplace and useful for future cement applications.

A Case Study: The United Kingdom and the end of Coal Power

Nowhere is the problem of coal ash more acute than in the United Kingdom. The UK's situation represents the ‘canary in the coal mine’ for the industry structure around the world.

The UK leads the global charge toward zero-coal power generation, with plans to close all remaining coal plants by 2025 (see Figure 1). To put this action in context, as recently as 2012, the UK generated more than 6 million tons of fly ash. In 2018, that figure dropped to roughly 1.6 million tons\(^1\) following further reductions in the use of coal. These trends foreshadow a new era in the domestic cement markets.
Coal - Turned off

Figure 3. Historical and projected UK electricity generation by fuel type, 2008–2025 (TWh).
SOURCE: 2008–2016 actuals from BEIS (the UK Department of Business, Energy & Industrial Strategy) 2018 forecast

The historic supply of readily available, and compliant production coal ash will end with the production of coal power generation. For the UK the timing could not be worse. The complication of Brexit is causing cost uncertainty on materials historically imported from Europe. As a result, the domestic building products industry is now faced with a significant problem: Where will it source new EN 450 (European ASTM C-618 equivalent) compliant materials?

The 2nd end of coal
The answer to the supply question will be realized in the country’s vast supplies of post-production ash. Both impounded and landfilled coal ash. The United Kingdom Quality Ash Association (UKQAA) has been studying this issue since 2014. The UKQAA has stated that the country's stockpiled ash, estimated at 50 million tons, should be designated as future “pozzolanic” reserves. However, this sort of initiative will require multi-level government support. In the meantime, the UK will have to continue to import its coal ash from Europe. While that might be a solution for the short term, Europe is also moving away from coal as a fuel. Therefore, whatever relief the industry can gain through those imports will only delay the inevitable.

Discussion

The coal ash supply challenges facing the United Kingdom have been particularly interesting to SonoAsh. SonoAsh has developed a sustainable, modular, and patented solution to beneficiate production and impounded coal ash. The technology enables variable coal ash streams to be manufactured into consistent products designed to meet regional and individual customer specifications.

The patented SonoAsh process is effective on a broad range of input material properties to produce a uniformed product with respect to LOI, particle size, geochemistry and processing implications. The resulting engineered coal ash material meets and exceeds the ASTM C-618 (AASHTO M295 (USA) and the EN 450 (EU)) requirements for high value ordinary portland cement (OPC) displacement. The process creates <1% LOI from variable coal ash sources at more than 15% LOI at definable particle size specifications to meet customer demands, typically 25-100 µm.

The SonoAsh outcome represents the above market opportunities, producing a scalable, regional, and economical OPC supplement with minimized greenhouse gas (GHG) emissions. This creates economic relevance from a risk mitigation and marketing perspective even where GHG/carbon discussions are unmeasured, untaxed, or not currently recognized. This is significant for a global market demanding major infrastructure expansion with challenging high-performance cement applications.

The Data Driven Decision Model: The Calculus of the Ore Body

However, the technology process is only half of the solution. Understanding the physical properties of each coal ash impoundment (wet or dry) is paramount to making optimal decisions. The limited data used for environmental monitoring of ash and impoundments is useless for predictive process modeling of the ore body. The new approach is to develop a 3D model of the ore body and determine the “calculus of the ore body”. The new data generated from this approach allows for a more complete understanding of what can be extracted from the ore body as it ages, impacting geochemistry and particle polarity. The decision model produced creates a de-risked mine plan to work out the asset with an optimized economic outcome.
SonoAsh Model Case Study

Ore Body Model:  
- 25+ million tones  
- 6-15% LOI  
- 100 µm to 10 cm mean particle size  
- Ca 12-20%  
- S > 5 - 7%  
- Not Class C or F or ‘EN 450 compliant’ or ‘ASTM C-618 compliant’

Production Input:  
- 400,000 – 500,000 tons annual process facility

Revenue Model Matrix:  
- Low Carbon Cement material  
- Cenospheres  
- Silica Flour  
- Rare Earth Elements (REE)  
- Proppants (Fracking Sand Material)

Additional Benefits:  
- Social License  
- Generational Employment – 120 FTE/yr over 50 years (6,000-person years)  
- Reduction of Environmental Liability  
- 20+ million tons CO₂ offset  
- TBD – International Transferrable Mitigating Outcomes (ITMO)

Production Output:  
- 400,000 – 500,000 tons  
- Sub-1% LOI  
- 25 – 75 micron depending of specification required mean particle size  
- Calcium (Ca) 10 %  
- Sulfur (S) < 5 %  
- Engineered to end use requirement

Total Project Potential:  
- $1 billion to $2 billion over the life of the project

A new Multi-Billion Dollar Industry is in the making

As noted above, a new industry structure is required. The demand for the products that can be produced from beneficiated coal ash will be measured in the billions of dollars over the next 50 years.

As the market conditions evolve, some of the existing industry players will survive and some will not. The opportunity exists therefore for both existing players and new entrants to seize the opportunity to realize increased margins that attend technological breakthrough.

As a proforma example the following chart shows representative and prospective value that will come from a single 25 million ton ore body. The indicative value shown in the following is to a degree a function of the product mix and the regional value creation but in total over the economic life of the ore body, not discounted for present value, a total measured in the billions of dollars of value creation.
By adopting a product matrix approach, allows for maximum revenue generation, with minimum non-revenue generating material produced.

For a 25 million ton (Mt) processed over 50 years

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity (Mt)</th>
<th>Market Value ($/t)</th>
<th>Current Value (Potential)</th>
<th>Future Value (Potential)</th>
</tr>
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<tbody>
<tr>
<td>Cement Material</td>
<td>10-15</td>
<td>$60 - $100</td>
<td>$600,000,000</td>
<td>$1,500,000,000</td>
</tr>
<tr>
<td>Cenospheres</td>
<td>0.03-1</td>
<td>$1200 - $1500</td>
<td>$35,000,000</td>
<td>$1,500,000,000</td>
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<tr>
<td>Silica Flour</td>
<td>3-10</td>
<td>$80 - $100</td>
<td>$240,000,000</td>
<td>$1,000,000,000</td>
</tr>
<tr>
<td>REE</td>
<td>0.005-0.5</td>
<td>$20 - $1000</td>
<td>$10,000,000</td>
<td>$500,000,000</td>
</tr>
<tr>
<td>Proppants</td>
<td>5-25</td>
<td>$60 - $80</td>
<td>$300,000,000</td>
<td>$2,000,000,000</td>
</tr>
<tr>
<td>Carbon Equivalent</td>
<td>20-22</td>
<td>$20 - $50</td>
<td>$400,000,000</td>
<td>$1,100,000,000</td>
</tr>
<tr>
<td>ITMO</td>
<td>25</td>
<td>$0 - $40</td>
<td>$0</td>
<td>$1,000,000,000</td>
</tr>
</tbody>
</table>

Total Approx. $1.5 billion $ 2-3 billion

The business model enabled by the SonoAsh approach aligns well with the closed loop, limited environmental footprint, circular economy which will define the modern and future marketplace and outline required industry structure changes required to survive. By first determining all revenue potentials available from a given ash reserve, and then designing a closed loop process to extract the maximum economic benefit, including financial, social, and environmental contribution to the total.

Each of these dimensions matter depending on the location geography and demographics. It is important to understand the optimum economic value benefit is the balance of maximizing financial benefit, social and environmental contributions.

**Conclusion:**

Governmental legislation, energy policy and environmental policy are impacting the historic industry structure, with multiple impacts effecting the electric power generation, coal mining industry, infrastructure material, rural community sustainability and the both local and global environment. By taking a complete value, data driven approach (considering the economic, social license, stranded asset, and environmental impacts) a new business model and rational for the utilization of coal ash can be realized.

Coal ash is not waste, it is a valuable resource and a multi-billion dollar opportunity.
The federal government of Canada announced on Dec. 12, 2018, that traditional coal-fired electric generation plans will be phased out by 2030 regulations were published on Dec. 12 in the Canada Gazette, Part II.


Bruce Sifton, P. Eng., is the President and Founder of SonoAsh Engineered Materials Ltd., based in Vancouver, B.C. He has a proven track record in creating value around diverse opportunities such as urban mining from electronic waste, carbon-based nanochemistry in power and metal applications, basalt fiber composites for military applications, and specialty paints and coatings. Bruce holds a BSc. (Chemistry) and Master of Engineering (Chemical) from the University of New Brunswick. He is a registered Professional Engineer in British Columbia and Saskatchewan.