Coal Ash 2.0: The Calculus of the Ore Body

Claudio Arato

Introduction

Since 2009, SonoAsh has focused on technology-enabling coal ash beneficiation of both ponded and production coal ash. Coal power faces significant economic headwinds around North America and the world. As coal power fades from the global energy supply, readily available, compliant coal ash will be harder to source in the global construction industry.\(^1\) Technology and process engineering needs to be developed to exploit impounded coal ash as imported ash quantities increase. It is a readily available, strategic resource with broad near- to long-term market opportunities. The alternatives are to ignore environmental risk and pathways to bring modern technology and real world innovation to rural areas that desperately need it for renewal of economic and sociopolitical drivers.

Global thermal coal use is historically limited to generating power. The outdated 20\(^{th}\) century coal power business model is unsustainable in the developing green economy, having lost its social license to continue and due to economic imperatives due to technological progress in renewables and natural gas; there is mounting evidence across the USA and the world that coal simply cannot and will not compete for its vital place in the evolving energy matrix. Market forces are forcing coal power plants to either convert to cheaper natural gas or go offline completely.\(^2,3\)

The industry structure must change to unlock the full value and potential benefits of coal and coal ash byproducts, making coal competitive sufficiently to persist. It is necessary to do to provide the global economic baseline necessary to hedge the financial risk and operational instability with the inevitable transition to renewables over the balance of the 21\(^{st}\) century. This requires a fundamental change in current industry practices and thinking.

The current politics of related coal associations accept the need for innovation in concept but cannot and do not rally enough support in an industry that is desperate for renewal to achieve its publicly stated mutual objectives.\(^4\) This is in part because of lack economic motivation and a silo mentality unable to respond quickly enough to the evolving global energy matrix. Additionally, the missed innovation and technical opportunities applied to the modern oil industry are significantly hampered, where maximum resource components are beneficially and economically recovered and deployed is nowhere near in the discussions for coal and coal products.

SonoAsh believes that data-driven elements of the mining industry are required to evaluate each coal ash impoundment and its constituent components in detail, to establish a predictive approach to maximize value extraction, paving the path where there is significant financial incentive to drive the necessary changes to the global industry structure. The ultimate goal is to change the coal mindset from a single-use, one dimensional resource used only for generating electricity and heat to a multi-product sustainable resource. This is the core strength behind the Closed Loop Coal concept, a vital pathway to developing economic sustainability for the modern world.

Discussion

Impounded coal ash (wet or dry stacked) is typically like a black box. The impoundments are generally managed without detailed understanding of mass transfer, chemical constituents & metals, product
development and water flow patterns, in three dimensions, as a function of time. The current approach within the impoundments remains essentially a containment exercise to limit environmental responsibility and liability outside the boundaries of each impoundment as ecological and legalistic threats present themselves. Scalable process engineering requires the systematic quantification of the feedstock (coal ash) to be successful.

In the age of Big Data, modeling and detailed analytical techniques can provide part of that understanding. Currently, the majority of the industry is only oriented toward legal risk mitigation and not co-product development. This narrow approach offers very few pathways to the robust and necessary suite of solutions offered by the implementation of the Closed Loop Coal.

Meaningful business decisions must be data driven, multivariable & robust. The data set must be statistically valid for the entirety of the impoundment. Simplified assumptions and incomplete data are inadequate starting points for a multi-decade work plan required to complete the maximized value extraction requirement of the coal ash as ore body.

Today, coal ash management is primarily managing legal liabilities and responding reactively to regulation and social license protests, often tinged with very sensitive emotional components. The situation is exacerbated further by declining coal use and increased coal ash variability. What is required is a pragmatic, foundational approach to address coal ash management as a high value, physical asset. Determining the calculus of the ore body includes real-time process engineering combined with long-overdue data driven harvesting methodologies, enhanced chemical data mapping, chemical trace studies and robust technologies.

The SonoAsh approach systematically evaluates the variability of each impoundment as a viable asset. The regulatory, market and technology opportunities together achieve the central objective of 100% ash utility. It maximizes staged market revenues, proactive, long-term water management while simultaneously mitigating real and perceived corporate risk, effectively creating Coal Ash 2.0. Most importantly to the coal power industry, there is no Coal Ash 2.0 without coal to create coal ash.

This is an approach for allowing the creation of new a sustainable coal industry and economic lifeline to the supporting communities. It underwrites enhanced security and innovation for a diverse energy system of 21st century renewable options with the objective function of total pond ash recovery with significant returns on investment.

**Approach**

Any fiscally responsible, data driven technology approach must apply a series of systematic evaluations to develop a robust process toward maximizing the value of coal, and especially, its by-products as a vital aspect of the ultimate objective of closed loop coal. Global social, technological and political drivers are well publicized toward the prediction that thermal coal power as a fuel source will soon disappear. Depending on where you live, that disappearance will occur at different rates. The developing world will see coal used for decades to come and contribute to the energy grid for the foreseeable future. However, the clock is ticking in Europe and North America and we can expect to see 80% of coal power go offline by 2050.

How will the increasing demand for viable coal ash be met for global infrastructure demands? Very clearly, the efficient review of the billions of tonnes of impounded coal ash will need to be revisited. Many such
impoundments have been stabilized and remediated in such a way that they would clearly not be early candidates for the recovery of coal ash. However, it is long documented by the American Coal Ash Association (ACAA) that there is in excess of 1,100 coal ash impounds in North American alone containing billions of tons of waste coal ash. Of those, there are many high risk locations subject to leaking or impoundment rupture or unusually high profile situations that will need to be removed in the near term. Thus presenting the natural opening for an ore body characterization and beneficial use recovery plan to be deployed.

![SonoAsh Path to Closed Loop Coal](image)

**Figure 1: Closed Loop Coal Strategy**

**Process Considerations**

Closed Loop Coal is about maximized efficiency of a natural resource. As illustrated in the above graphic (Figure 1), the burning coal for power is only the first step in a multi-stage process to unlock all of the value while protecting the environment. The key thought to consider is that the ash may well be the product of the highest value and the highest potential for the future.

Total beneficiation of the total ash site as an ore body must answer the following questions, the can be summarized by Table 1 below:
<table>
<thead>
<tr>
<th>Design Component</th>
<th>Past</th>
<th>Present</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash Condition</td>
<td>Dry</td>
<td>Dry</td>
<td>Wet</td>
</tr>
<tr>
<td>Ash Volume Supply</td>
<td>Excess</td>
<td>Imbalance</td>
<td>Shortage</td>
</tr>
<tr>
<td>Technology &amp;</td>
<td>None (Naturally Compliant)</td>
<td>Mature (Thermal, Electrostatic, Chemical)</td>
<td>High (Sonomechanical, Sonochemical)</td>
</tr>
<tr>
<td>Complexity Level</td>
<td>Minor</td>
<td>Partial</td>
<td>Partial; optimizing towards Total</td>
</tr>
<tr>
<td>Solution Level</td>
<td>Single; Filler Material</td>
<td>Single; Filler Material &amp; SCMs</td>
<td>Multiple (Variable Value)</td>
</tr>
<tr>
<td>Product Type</td>
<td>None</td>
<td>Limited Variability</td>
<td>Variable (Broad Integration)</td>
</tr>
<tr>
<td>Industrial Process</td>
<td>None</td>
<td>Collateral Symptom Enhancing Value</td>
<td>Root Cause Analysis (Regional Allowances)</td>
</tr>
<tr>
<td>Focus (Problem)</td>
<td>Static legalistic resolution (limited)</td>
<td>Collateral Symptom Enhancing Value</td>
<td>Material Properties Tuned to Final Product Specifications (LOI, Particle Size, Calcium, Sulphur)</td>
</tr>
<tr>
<td>Product Effect</td>
<td>Product Disposal</td>
<td>LOI (Carbon) Reduction but Quality Static</td>
<td>Material Properties Tuned to Final Product Specifications (LOI, Particle Size, Calcium, Sulphur)</td>
</tr>
</tbody>
</table>

Table 1: Commercial Beneficiation technology Drivers

Fundamental Considerations

A thorough solution requires comprehensive technical solutions beyond mere process and water table modeling techniques currently available to the industry:

1. Is there a process flow sheet intellectually feasible?
2. Is there a process flow sheet economically feasible for integration or standalone (green field) operations?
3. Can the technical risks be mitigated through the utilization of standard technologies and mature unit operations while establishing required innovation, production and efficiency metrics?
4. Is there sufficient innovation to protect the risk and innovation required to proceed?
5. Can processing costs be focused on high value pre-treatment requirements for processing into increasingly segregated processes for increasingly higher value products (i.e. cementitious materials, high performance cement applications, metals, graphite, organic chemicals and materials)?
6. What are the life cycle metrics for all products and baseline differentials from leaving the impoundments, within permitted allowances, versus value creation outcomes to generate a high tech solution for the 21st century?
7. What analytical and process data is required to develop enhanced sophisticated modeling capabilities for the exploitation of the ash source as an ore body, including bulk material specifications and marketing the benefits of previously unable products?
8. There is additional intellectual property to be developed in each of these components.

Any in-depth evaluation and technology commercialization road map outlined in Figure 1 requires the following process design considerations regarding:

1. Full implications of the costs - associated with ash impoundment, storage, including cap in place factors and environmental regulatory requirements.
2. Pre-treatment and material handling options required to extract the available metal components (critical, strategic, REEs). See (3) and (4).
3. Impact quantification for very long-term, stable ash storage comprised of ash generated from variable, high differentiated coal sources, often for decades. This means that more than a single ash source is critical for project sustainability and developing fungible markets for coal ash and its applications, locally and regionally, do not yet exist today. This requires consideration for how best to process the impoundment, from the three dimensional chemistry integrated over time for any ash impoundment (wet or dry), to consider the extraction profile and product slate for commercial application, beginning with a robust process design, a series of demands that industry and its technical service suppliers are ill-suited to provide. The extraction and recovery of vital critical metals such as rare earth elements as well as Yttrium and Scandium from coal ash are vital future components of study.8,9
4. The recovery of maximized product and chemical slate, in varying levels of finished product development (i.e. raw to finished products), to maximize the flexibility of the changing market for chemicals and specialty products and metals as discussed in (2).
5. The process needs to create stable bulk materials from increasingly variable process feedstocks10, which SonoAsh sees as an entry into the market as creating supplementary cementitious materials (SCMs) from one of its fractions while evaluating applications for very high quality construction material applications.
6. A flexible, modular process that preferentially can co-locate to the coal fired power plant or ash impoundment, with additional process elements to valorize products of sufficient quality and quantity to make the effort economically viable, maximizing opportunities to integrate into existing beneficiation technologies and application solutions, as required or available.
7. The possibility of processing other regional ash sources, perhaps in a hub and spoke model needs to be incorporated.

**Conclusion**

If we are to adopt a truly robust, renewable, sustainable and clean energy mandate, the optimization of legacy spent fuels must be incorporated into the industry structure and their
economic value maximized. Understanding the calculus of the ore body ash impoundments presented here allow for a pathway to major renewal for the coal power industry, chemical industries to create the opportunities and vital innovation hub channels for sustainable growth and vital material (i.e. infrastructure and vital metals) independence.

References


About the Author:

Claudio Arato, P.Eng. is the CTO behind all SonoAsh applications, based in Vancouver, Canada. He holds degrees in Chemistry & Chemical Engineering from the University of British Columbia (UBC), is a registered Professional Engineer in BC & Saskatchewan and is an Engineers Canada Fellow.

Claudio is the recipient of honors including the: 2016 Applied Science Dean’s Medal of Distinction, the 2014 Engineers Canada Meritorious Achievement Award and 2018 UBC Alumni Builders Award. He has lead numerous technology teams and authored numerous patents & peer-reviewed papers and is an invited lecturer on innovation, ethics & sustainability. Over 25+ years, Claudio has worked throughout North America, Mexico and in Europe on new technology commercialization in coal power, critical metals extraction & recovery, pulp & paper, nanotechnology, cellulosic ethanol, sweeteners, water & wastewater treatment, contaminated soil remediation & heavy oil upgrading.