

SONIC REACTOR TECHNOLOGY FOR COAL ASH BENEFICIATION AND RARE EARTH ELEMENT RECOVERY

By Claudio Arato

Historically, coal for power generation has been viewed as a single-use fuel source. As a result, the industry structure that has been built around coal power over the last century is a one-dimensional, low-cost fuel for electricity, and all by-products are coincidental.

However, times are changing. The opportunity for coal to become viewed as a strategic resource now exists. SonoAsh has worked steadily since 2009 to create a new, twenty-first century narrative for coal. That narrative includes proprietary technology and environmental liability considerations to change the view of coal as a single-use resource for generating electricity and heat. Instead, this model will move the coal industry from single-use to a multi-use sustainable resource.

Coal power is a safe, abundant, and low-cost fuel source in an increasingly variable, renewable fuel world. But more can and needs to be done to ensure coal remains a valuable fuel source in the twenty-first century. That is why the downstream by-product of burnt coal is so important. SonoAsh is working with coal utilities in North America to unlock the potential economic and environmental value of beneficiating coal ash. Since securing its patents in the North America, SonoAsh has worked diligently with the American Coal Ash Association (ACAA), selected utilities, and ash partners to explore higher value coal ash beneficiation opportunities beyond current risk mitigation; that is, dewatering and storage of ash in long term impoundments.

But perhaps more impactful to the bottom line, and only made possible by the SonoAsh technology, is SonoAsh's second patent, validating the separation and unique carbon encapsulation of commodity metals, strategic metals and rare earth elements.

ABOVE-GROUND MINING AND RARE EARTH ELEMENT (REE) RECOVERY

It is well-documented that coal ash presents a unique ore body, characterized by the number of metals present and their corresponding concentrations when compared to conventional mining. Typical assays demonstrate many of the 17 Rare Earth Elements (REEs) are present in various Appalachian and Powder River Basin coal seams.

SonoAsh research and granted international and U.S. patent families validate wet, low-frequency sonic fracturing and separation of the carbon from the coal ash (refer to Fig. 1) creating a stable, non-leaching metal encapsulation for subsequent traditional mine process techniques to recover selected commodity metals, strategic metals, and REEs as available.

According to the Canadian Institute of Mining, Metallurgy and Petroleum (CIM), rare earth elements are required for a range of special electronic, magnetic, optical, and catalytic applications.

Interestingly, REEs are not all that rare. But finding them in concentrations where they can be economically mined and processed presents a considerable challenge. SonoAsh process solves this problem by concentrating the metals to levels associated with conventional mine economics.

In addition, some rare earth elements are more valuable than others. The U.S. Department of Energy listed five particular elements of critical importance to clean energy and subject to supply risk in the next 10 years. Two more are listed as near-critical (Fig. 2).

The five critical elements—yttrium, neodymium, dysprosium, europium, and terbium—and the two near-critical, lithium and tellurium, are present in coal ash.

The SonoAsh process establishes a viable mining application with the ability to also harvest the low-carbon, uniform particle size ash for standard ash marketing, a balance that makes the integrated process truly “closed loop.”

The process assumes a standard impoundment where the ash can be extracted wet in a 30% slurry before processing through the SonoAsh technology. The U.S. Environmental Protection Agency has established in its Effluent Limitation Guidelines (ELGs) about the imperative for pollutants commonly in fly ash such as mercury, arsenic, or hexavalent chromium not be discharged. A key feature of the SonoAsh process is to be able to use and reuse this water repeatedly with only a modest water treatment component for process blowdown.

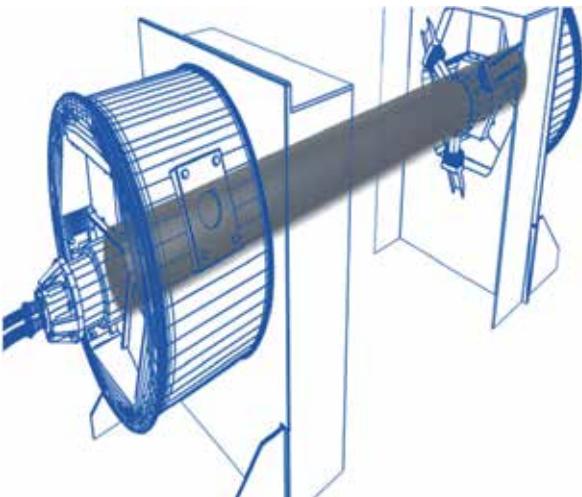


Fig. 1: Cross section and actual field application of SonoAsh sonic reactor

Figure 3 shows the integration of the SonoAsh process. By installing SonoAsh facilities where variable ash is recovered, 75% of the fraction produced is a uniform, high-quality, beneficiated ash that allows for the industry to address concerns of variable and insufficient quantities of saleable ash in North American markets. The high-carbon fraction collects and accumulates the metals.

OPTIMIZING THE VALUE OF COAL

Stepping back, it is clear that the coal power utility industry structure needs to evolve. At the recent Copenhagen and Paris climate change conferences, countries from around the world are looking to adopt new climate change strategies. Traditional coal power applications are under broad retreat as jurisdictions move towards natural gas, along with alternative and renewable fuels such as wind, solar, geothermal, biomass, and nuclear.

Since 2009, SonoAsh has focused on its technical ash beneficiation and mining development program. The objective is to ensure coal, properly processed after burning, provides multiple benefits, not constrained by legacy perspectives that view it only as a single-use fuel source.

The potential for a multi-use coal business model recognizing value throughout the coal life cycle holds significant upside for multiple stakeholders.

By adopting a process that includes both an innovative approach to the historic reality of the cementitious properties in coal ash and above-ground mining coal ash for commodity metals, strategic metals and REEs will generate new revenue opportunities, variable carbon accounting, and other benefits. These opportunities become available to the utility with SonoAsh facilities and will be able to create meaningful rates of return (IRR) >30% without carbon accounting (for example, carbon taxes being introduced in Canada).

Coal power generation should be viewed as a part of a twenty-first century energy economy. It will underwrite societal demand for renewable fuels with the SonoAsh above-ground, non-traditional mining process to recover commodity metals,

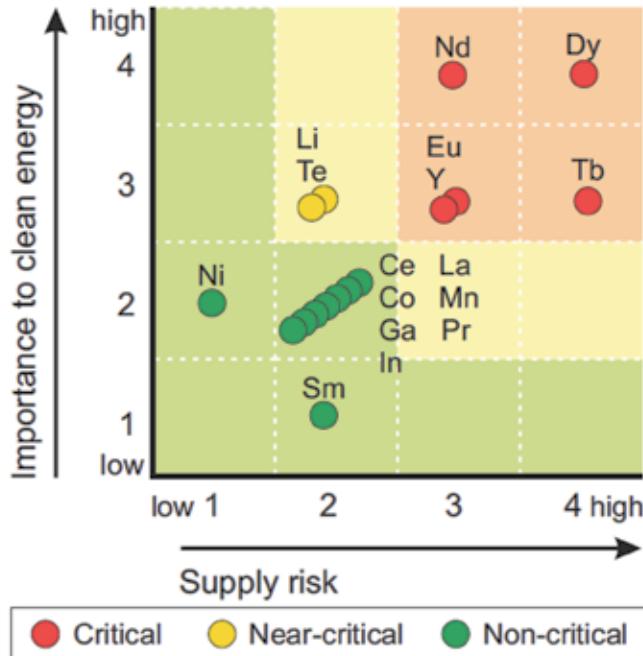


Fig. 2: U.S. Department of Energy criticality matrix of 16 elements for 2015-2025, based on importance to clean energy and supply risk. Modified from U.S. Department of Energy (2011)

strategic metals, and REEs and in turn allow for a new narrative for coal to be written. SonoAsh has received support from ACAA members as well as government and power generation officials throughout North America in establishing its new path to retaining meaningful coal viability.

DRAIN THE POND AND IMPACT THE BOTTOM LINE

In North Carolina, Duke Energy has been mandated to find beneficial uses for the millions of tons of material in three coal ash impoundments. These impoundments hold significant value when viewed through the SonoAsh process.

The perspective that impoundments are unrecognized assets instead of perceived corporate and environmental liabilities is

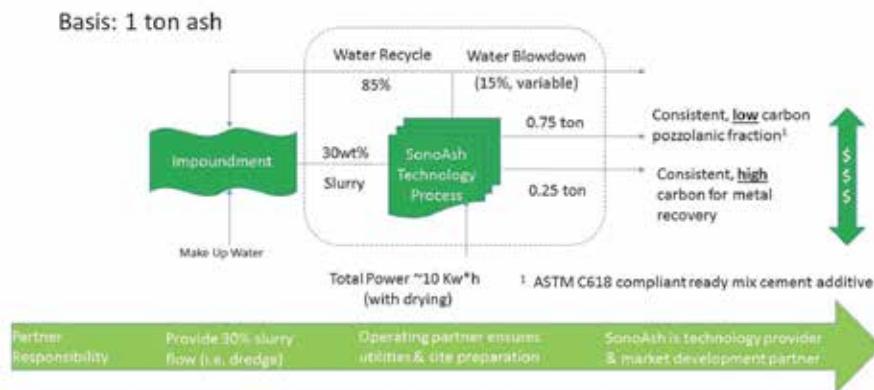


Fig. 3: SonoAsh process schematic

critical to the twenty-first century above-ground mining paradigm shift. In 2015 at the World of Coal Ash conference in Nashville, TN, Lucinda Tolhurst presented her research pointing out that not only are REEs present in these impoundments, the values of the elements range anywhere from \$4500/ton of coal ash to \$46,000/ton.

Recovery rates would certainly be less than 100%. However, assuming the recovery rates and processing costs amount to a worst-case scenario of 10% of the total available revenue value of commodity metals, strategic metals and REEs for even a nominal metal revenue value of \$500 per ton still makes the potential new revenue streams a viable business.

The comparative technological differences between the current incumbent technologies have entrenched the idea that only dry ash beneficiation technologies like carbon burnout and electrostatic processes are viable, beyond the baseline dig and dump options. The SonoAsh process challenges these assumptions.

The SonoAsh patented process allows for “tunable” manufactured ash specifications from different ash sources. By removing mercury and ammonia to below detectable levels, the process creates a mean particle size specification tailored to market specifications while creating the opportunities for the recovery of strategic metals. The SonoAsh process also reduces liabilities and offers significant value that far outweighs the value of the manufactured beneficiated ash.

Over time, impoundments are sustainably drained and liabilities reduced while generating new revenue streams that allow for new project financing opportunities to be developed around ash impoundments, by monetizing the risk and realizing the new metal and traditional pozzolanic value.

SUMMARY

SonoAsh is a new answer for the twenty-first century coal industry. The thought that burning coal, not just for its historic power generation, but to concentrate and recover the metals is a major path forward and provides for a sustainable future and business model. SonoAsh should be considered the first step of a closed-loop, economically and socially viable method of unconventional mining, where the significant financial basis

driving current industry metrics of power generation and clean building material production are secondary benefits.

Social perception, comprehensive environmental liability reduction, and GHG credit opportunities are low hanging fruit for stabilizing the industry's footing and value, creating immediate benefit for coal power generators and utilities in addition to the above high value revenue streams that will follow.

The coal industry needs a new narrative. A new perspective on the starting point

moves coal from a single-use power source from the past to a strategic and socially important component in tomorrow's technologies and diverse energy infrastructure.

ABOUT SONOASH

Based in Vancouver, BC, Canada, SonoAsh is an engineering technology company leveraging its patented and industry validated processes to create a high-value ore source for above-ground mining and highly cementitious green building materials from variable quality coal ash.

In addition to the technology, patents, and know-how, the SonoAsh principals are professional chemical and mechanical engineers with nearly 100 years of combined industrial, management, and strategy experience.

Using supplied field ash from two major North American coal power utilities, the results of this work produced a strong intellectual property (IP) portfolio of patents granted around the application and core technology through 2015. ♦

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