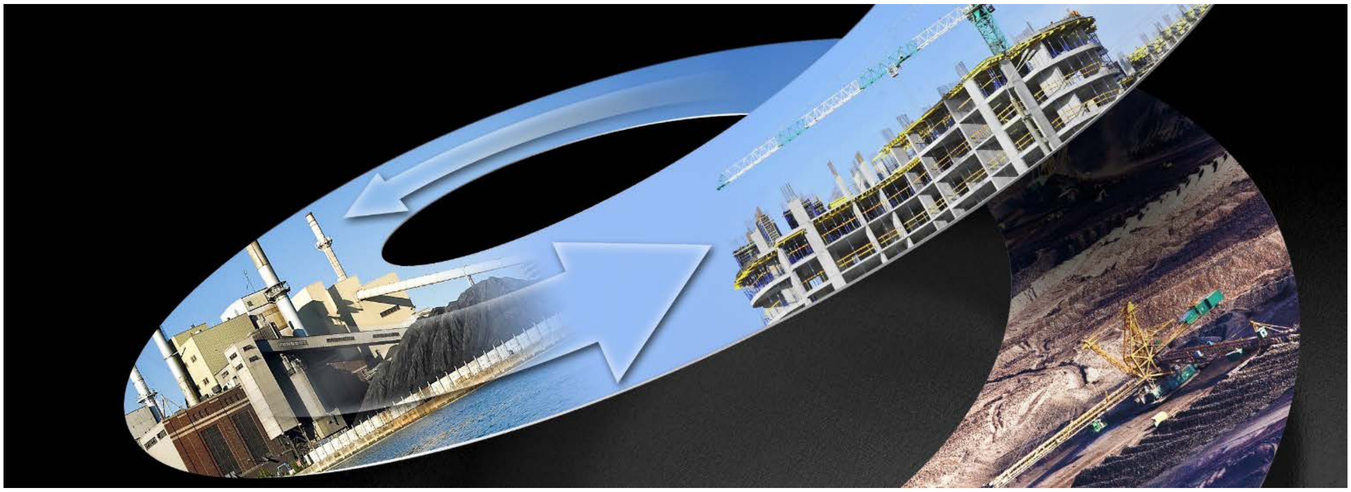
A Second Life



EPRI Investigates Innovative Uses for Coal Ash

By Chris Warren

In 2012, Duke Energy retired the 382-megawatt, coal-fired H.F. Lee Plant in Wayne County, North Carolina, ending six decades of service. The plant began commercial operation shortly after World War II to help meet the state's growing energy demand in the 1950s and 1960s.

In December 2016, the utility launched a new chapter in the plant's history, announcing its intention to recycle most of the 6 million tons of coal ash stored on-site for use in concrete. Duke Energy also is investing in "beneficiation" technologies for processing the ash because it contains too much carbon for concrete production.

Coal ash is used in about half of the concrete produced in the United States. It increases the material's workability, long-term strength, and durability while reducing permeability. Making concrete with recycled ash also reduces mining and transportation of materials used to make Portland cement (a basic ingredient in concrete). For every ton of coal ash that replaces Portland cement in concrete, about one ton of greenhouse gas emissions is avoided. Nationwide, other beneficial uses for large volumes of ash include cement production and structural fill in embankments, roads, and other construction.

Decision Confirmed by EPRI Research

Collaborative research by EPRI, the University of Kentucky Center for Applied Research, and Golder Associates helped inform Duke Energy's efforts to ramp up ash recycling. The research, mandated by the North Carolina Coal Ash Management Act of 2014, examined three areas:

- The drivers and dynamics of established markets for coal ash in North Carolina and surrounding states, including concrete and cement manufacturing
- State of the technologies for processing ash to make it suitable for use in these markets
- Innovative coal ash uses and products still in the research stage, or with little or no market in the United States

Duke Energy had investigated these issues and wanted third-party, independent researchers to assess markets, evaluate beneficiation technologies, and identify economically viable products and uses. "I wanted to know if EPRI would find anything we hadn't found," said Tim Smart, Duke Energy's Senior Byproducts Manager.

A coal ash pond.

While focused on Duke Energy, the research is instructive for other utilities considering appropriate uses and markets for coal ash.

"It's tempting to assume that a utility can beneficially use all of its ash in local markets," said EPRI Senior Technical Executive Ken Ladwig. "But it's not that simple."

Indeed, the research revealed that the best use of ash depends on many factors, including regional supply and demand for ash, ash quality, public perception, regulatory drivers, and cost of ash processing, transportation, and incorporation into new products.

In North Carolina, supply is not a constraint for Duke Energy because it is the main fly ash producer. EPRI found that the most common beneficial use of coal ash in North Carolina, as elsewhere in the United States, is as an ingredient in ready-mixed concrete, with demand concentrated in Raleigh, Charlotte, and other areas with significant construction. For Duke Energy, the key to optimal use is to match centers of concrete-quality fly ash with current and future market centers.

EPRI, Duke Energy, and academic organizations point to the societal benefits of coal ash use, including reduced greenhouse gas emissions, water and energy use, ash storage and disposal, and land use for mining natural resources used in Portland cement.

Improving Ash Quality

For use in ready-mixed concrete, fly ash must have a certain composition and consistency to meet technical specifications. Fly ash with a high concentration of unburned carbon can reduce concrete's resistance to freezing and thawing. Beneficiation technologies can improve the quality of both recently produced fly ash (known as *production ash*) and ash stored in ponds for years.

EPRI evaluated commercially available beneficiation technologies and identified those Duke Energy facilities best positioned to deploy them cost-effectively.

For production ash, quality control can help optimize ash use. Operators can separate ash streams with low unburned carbon content (usually produced when the plant's load is constant) and high carbon content (produced when load is increasing or decreasing). Other carbon-reduction processes include thermal technologies, which employ combustion to burn the residual carbon, and electrostatic separation, which takes advantage of different electrical properties of the ash and carbon particles.

Most fly ash is stored in ponds, typically along with bottom ash and sometimes with by-products of power plant scrubbers. Such mixed ash composition can make processing more challenging and costly.

A key takeaway: Economically viable beneficiation typically combines a large ash supply (production or stored) and nearby markets that can use a consistent supply for many years. The EPRI analysis used these and other factors to assess the potential for beneficiation of Duke Energy's production and stored ash in North Carolina.

Beyond Ready-Mixed Concrete

With respect to potential new uses for coal ash, researchers investigated emerging technologies requiring significant R&D, commercially available technologies with limited markets such as foamed concrete, and mature technologies such as geopolymer concrete, alternative cements, and asphalts.

"Geopolymer concrete, for example, can potentially use large volumes of ash and develop a high-value product, particularly in pre-cast applications, but it may not be economically viable in areas already dominated by ready-mixed concrete," said Ladwig.

EPRI concluded that there are many technically viable uses for fly ash, but most face either niche applications or market constraints that limit their use. "This part of the research reaffirmed that the big marketplace out there is still ready-mixed concrete," said Duke Energy's Smart. "EPRI did not see any silver bullets on the horizon that could use significant amounts of ash."

EPRI continues to research potential products, with a focus on applications for lower-quality ash, such as that recovered from ponds and landfills and unsuitable for concrete without beneficiation. Ladwig will create a database to track emerging products and conduct market and technical research on those most promising.

Mining Ash for Metals

One potential use involves extracting rare earth elements from coal ash. These metals are used in diverse technologies, including DVDs, cell phones, and fluorescent lights. The U.S. Department of Energy (DOE) has pointed to the importance of reliable, affordable supplies of rare earth elements, particularly for use in electronics, defense equipment, and clean energy technologies such as wind turbines, photovoltaic thin films, and electric vehicles. This was highlighted in 2010 when China, the world's largest producer of the elements, scaled back production dramatically, causing prices to spike as much as tenfold.

Following the market disruption, DOE ramped up R&D on extracting rare earth elements from coal and coal ash, and EPRI is supporting these efforts by facilitating collection of samples from utilities.

"DOE wants to examine ash and coal samples from around the country to determine which ones contain the most rare earth elements," said Ladwig, who is leading this research at EPRI. "We are helping DOE with that analysis through our industry relationships."

The results will be compiled in a database that researchers and companies can use to develop technologies for extracting rare earth elements from coal ash. DOE also is funding research on extraction methods and technologies, and small demonstrations are underway.

Acid is often used in research to extract rare earth elements from coal ash, but this approach may result in large quantities of waste. "With acid leaching, we are removing less than 0.1 percent of the material," said Ladwig. "That leaves 99.9 percent for use or disposal. Research needs to address what to do with the remaining solids and liquids and how to make extraction economically viable."

EPRI is reviewing other commercially available technologies that could be used to remove rare earth elements from coal ash. "We're evaluating claims that companies make about the effectiveness and economic viability of their technologies," said Ben Colgrove, EPRI senior manager of labs and corporate safety, who is helping Ladwig manage the research.

Whether these technologies make economic sense will depend largely on global production of rare earth elements. If production is slow and prices high, extracting rare earth elements from coal and coal ash could be economically viable and help insulate countries and industries from price swings.

Extracting rare earth elements aligns the electric power industry with the nation's technology and security interests. "It could help the U.S. have a strategic domestic supply of the critical rare earth elements which are vital for the economy," said Colgrove.

Key EPRI Technical Experts

Ken Ladwig, Ben Colgrove