# GREAT RIVER ENERGY

## PIONEERS COAL-REFINING TECHNOLOGY

Fire and water. These elemental opposites are combined in coal—especially low-rank coals such as lignite, which is a relatively short geological step removed from peat (partially decayed vegetation). Compared with higher-rank, more "mature" coals, lignite is wet, with a moisture content of 35% or more.

That makes burning lignite and its geologic cousin, subbituminous coal (including the widely used Powder River Basin variety), a challenge for electricity generation. Together, they represent about 47% of the world's coal reserves, and their price is competitive with that of other coals. But the high moisture content presents challenges to the hundreds of power plants around the world using these low-rank coals, lowering generating efficiency and increasing emissions. About one-third of U.S. coal-fired generation—285 units representing about 115 gigawatts—relies on these coals.

High moisture content also is a constant challenge to the thousands of people who run those plants—people like Charlie Bullinger and Mark Ness at Great River Energy (GRE), a not-for-profit power generation cooperative that operates 11 power plants and serves about 1.7 million consumers through 28 distribution co-ops in Minnesota.

"It was a Friday afternoon in 1997. We had all the other brush fires put out for the week and we were thinking long term," said Bullinger, then the engineering leader at GRE's Coal Creek Station in Underwood, North Dakota. "The moisture we were throwing into the boiler, and all the energy we had to spend to raise that water to steam temperature, bothered me. And it had bothered me for a lot of years."

"We ran the numbers and found we had 21% in boiler efficiency losses, and 13% was due to water and hydrogen in the fuel," Ness said. "About 8 of that 13% is due to making water, which is carrying the direct heat of vaporization out the back of your boiler. Our question was, can you get that water out of there?"

## THE STORY IN BRIEF

It began as a Friday afternoon conversation between two plant engineers. Early tests relied on such basic hardware as 55-gallon drums. The combination of utility tenacity, public and private investment, and collaborative support produced a technology that reduces fuel requirements, improves plant efficiency, reduces emissions, and offers potential benefits for carbon-reduction technologies.

### Testing the Concept

Coal drying isn't new, and the benefits are well known. It increases the energy density and hence the value of the coal; it reduces the volumes of coal combusted and flue gas produced, reducing emissions and saving wear and tear on a variety of plant systems; and it improves overall plant efficiency.

"Mark's a really intuitive guy, and together we decided we should see if we had enough residual heat at the plant to drive off a productive increment of the water that comes in with the coal," said Bullinger, now senior principal engineer at Coal Creek Station. "We were driven by a mission, he and I, to prevent having to build larger emissions capture boxes on the back ends of our plants, perhaps by reducing the flue gas volume that goes through the environmental equipment. We knew that nearly 40% of what gets delivered to the boiler on an hourly basis was water that we had to push through the environmental equipment to be treated, just like flue gas."

That conversation provided the kindling for an idea. A conference Bullinger attended in Wiesbaden, Germany, ignited the spark. "There were two things that impressed me—what the Europeans were doing in putting their waste energy to work, and it was much more than we had done on this continent, and how they weren't afraid to integrate the coal yard with the turbine if it offered an advantage," he said.

Both points resonated with Bullinger and Ness in their quest to improve plant efficiency. From his long experience at GRE, and as chairman of EPRI's CoalFleet for Tomorrow® program advisors, Bullinger knew that even a 1% improvement in heat rate—the number of British thermal units (Btus) required to produce a kilowatt-hour of energy—can save an average power plant a million dollars a year or more in fuel costs.

The idea appealed to members of the GRE staff and their counterparts at the nearby Falkirk Mine, which supplies the plant's lignite. A GRE-Falkirk team conducted small-scale tests that showed it is possible to reduce the moisture in lignite by about 6% using low-temperature air.

"We did one test with a barrel—a 55-gallon drum," said Bullinger, now the project leader. "We just ran hot water through a barrel with coal in it and measured how much volume changed with low temperature. Then we did some modeling. We were looking for a show-stopper, something that would show it wouldn't work, and we didn't find any."

Ness said the tests showed the moisture content could be reduced to as low as 10%, but that created new issues. "Your boiler depends on gas flow, which means there are limits to how much you can dry your coal before you affect heat transfer

*Had it not been removed from the coal, the water vapor leaving the DryFining™ system stacks at the Coal Creek Station would have become flue gas and added to the plant emissions.*

performance and lose superheat temperatures. You could spend more money and modify your boiler, but that also gets you into permitting issues."

The next step was installation in 2002 of a 2.5-ton-per-hour (TPH) fluidized-bed dryer, which processed 350 tons of crushed lignite (quarter-inch-sized pieces). Supported in part by the Bismarck, North Dakota–based Lignite Research Council, this pilot project showed the same promise as the earlier lab tests. It also showed the value of refining the lignite, which led to the process name—DryFining™ (drying + refining).

"That's where we learned about segregation, when we found a dense fraction of the coal materials lying in the bottom of this fluidized bed as the coal moved across," Bullinger explained. "We discovered a significant amount of the sulfur and mercury is in there, and two of our patents involve kicking them out." Those unburned particles are returned to the mine, and the refined lignite enters the plant again through the mills and boiler, as it did before. "We intercept it, perform our magic, and then return it to the belt," Bullinger said.

With support from EPRI, GRE applied for and received funding from the U.S. Department of Energy (DOE) through its Clean Coal Power Initiative for the next phase of tests of what now was known as the Lignite Fuel Enhancement System. The $31.5 million project was managed by DOE's National Energy Technology Laboratory (NETL), with Lehigh University, EPRI, and several other companies participating in the support team.

"With the collaborative agreement, the DOE helped share the risk and gave us the courage to go ahead with the project," said Coal Creek Station manager John Weeda, "because when you're developing a new technology, it doesn't come with any sort of guarantee."

## Moving to Full Scale

In the project's first phase, a 115-TPH prototype supplied as much as one-sixth of the coal for the station's 546-megawatt Unit 2. That led to Phase II—a full-scale commercial demonstration featuring four full modules for Unit 2, each capable of processing coal at 135 TPH. And because the prototype had worked so well, GRE's board also approved installing four more modules for Unit 1.

Rick Lancaster, GRE vice president, generation, said that was the second time the team asked the board for more money. "We have a board that believes in putting us through our paces and making sure we know what we're talking about," he said. "Each time, they agreed we were doing the right thing … and even though there were times I wished we only were doing one unit, now that it's all done, it's nice to have the entire plant on the system."

Keeping operational disruptions to a minimum during such a large addition was important to Weeda, and he was not disappointed. "You're constructing a major addition to the plant, in the middle of the plant, with two units that are very important to keep running," he said. "We designed the integration of the facility into the plant, scheduled construction in coordination with our planned outages, and achieved commercial operation without losing a megawatt of production."

Construction was completed in late 2009. A crowd of about 600, including North Dakota governor John Hoeven and North Dakota's congressional delegation, gathered at Coal Creek Station June 3, 2010, for the dedication. There David Saggau, president and chief executive officer

*Great River Energy CEO David Saggau spoke to several hundred guests who came to the facility's dedication in June.*

of GRE, along with other speakers, touted process benefits:

- Lignite moisture reduced from 38.5% to 29%
- Heat content increased from 6,200 to 7,100 Btu per pound
- Fuel input reduced 14% by weight
- Overall power plant efficiency increased by 2% to 4%
- Stack emissions reduced—sulfur dioxide ($SO_2$) by more than 40%, mercury by more than 40%, nitrogen oxides (NOx) by more than 20%, and carbon dioxide ($CO_2$) by 4%
- Wear in the mills and conveying lines reduced

Saggau echoed Weeda's praise for the construction team. "During the two years of construction of DryFining™, the Coal Creek Station was running at full load the entire time," he noted. "Not once, including the day we switched from lignite coal to beneficiated lignite, did the plant miss a beat. It was a very successful transition, and it took every employee at Coal Creek to do that."

"This project is heading to commercialization, which makes this an important occasion," added Dr. Joseph Strakey, chief technology officer at NETL.

## A Technology for the Future

The improvements in plant efficiency and reductions in $CO_2$ emissions are especially important as DOE and the power industry continue developing new carbon capture and storage technologies, which can impose formidable cost and energy penalties. Strakey's colleague, Dr. Sai Gollakota, NETL manager of the Lignite Fuel Enhancement project, said the project exceeded its goals and offers some intriguing additional benefits. The improved operation of the fuel-air flow system allows reduction of nitrogen emissions. DryFining™ can be retrofitted to existing plants and can lower the capital costs of new plants. And Gollakota, as a participant in several current DOE-funded carbon capture and storage (CCS) projects, can see another important role for DryFining™.

*Charlie Bullinger, right, who led the GRE DryFining™ project, was interviewed by Joel Heitcamp of local radio station KFGO-AM during a live broadcast from the project dedication.*

"The advantage of including it in the design of new CCS systems is that it will reduce the downstream $CO_2$ output to the system. Because it increases the plant efficiency, it reduces the carbon emissions and the cost of constructing and operating the $CO_2$ capture and sequestration systems," Gollakota said. "And because you're now dealing with reduced quantities of other pollutants like sulfur and nitrogen, it costs less to clean up flue gases and get the higher concentrations of $CO_2$ needed for capture."

GRE and DOE now are looking to commercialize the technology, which received the Lignite Energy Council's Distinguished Service R&D Award, an EPRI Generation Technology Transfer Award, and the American Council of Engineering Companies of Minnesota's 2007 Engineering Excellence Award. GRE selected the WorleyParsons Group to market DryFining™ to other companies, including about 15 that have signed confidentiality agreements with GRE.

"This project is unique in our experience, because it's such a large project and provides so many benefits to the plant," GRE's Lancaster said. "We're not a research organization. We normally rely on EPRI and DOE for that, and they both provided important support. But we're very proud that a couple of our own engineers had a bright idea, started testing it, and it worked out even better than expected. And that our whole organization got behind it and said, Let's turn this into something real."

"GRE did all the testing and the nuts-and-bolts work. We were involved in a supporting role, looking at alternative designs and evaluating test data," said John Wheeldon, an EPRI advanced generation senior project manager. "We had worked on a number of fluidized-bed projects, and we were able to share the knowledge gained, helping GRE avoid problems others had experienced.

"The GRE team showed a lot of competence and had the courage of their convictions. Their endeavors produced design information that is applicable to subbituminous coal, not just to lignite, and so benefits a wide swath of the industry."

Members of the GRE team are already looking for their next challenge. "Right now, the water we drive off goes up into the air," Bullinger explained. "We're talking to the DOE about another project that would use that water for makeup, so we'd need to take less water from the rivers and streams and wells. It's a significant amount on an annual basis.

"You're never satisfied. You're always looking for ways you can make something better or use it in new ways. You keep having those Friday afternoon conversations about the problems that are bothering you and the things you can do to solve them."

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