Improving Power Plant Carbon Intensity and Emissions with DryFining™: 5+ Years of Commercial Results

David Farnsworth
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What is DryFinning™ fuel enhancement?

- DryFinning™ is a patented technology for utilizing waste heat and mechanical separation for drying and refining low-rank coal
- DryFinning™ can benefit a large portion of US and world coal-fired plants
- DryFinning™ benefits
  - Cost effective
  - Significant reductions in pollutants
  - Improved plant efficiency
  - Lower CO₂ intensity for power
World Coal Consumption Growth

Figure 70. World coal consumption by region, 1980-2040

- Total
- Non-OECD
- OECD

Graph showing the history and projections of world coal consumption by region from 1980 to 2040.
Coal Types and Uses

Low Rank Coals
- Lignite
  - Power generation
  - Domestic industrial including smokeless fuel
- Sub-bituminous
  - Power generation
  - Cement mfg Industrial uses

Hard Coal
- Bituminous
  - Power generation
  - Cement mfg Industrial Uses
  - Thermal (steam coal)
- Anthracite
  - Metallurgical (coking coal)
  - Manufacture of iron ore & steel
  - Domestic industrial including smokeless fuel

Source: http://appscgroup.blogspot.com

CARBON/ENERGY CONTENT
- HIGH

MOISTURE CONTENT
- HIGH

GREAT RIVER ENERGY
Half of World’s Coal is Low Rank

Recoverable Reserves of Lignite and Sub-bituminous Coals
(World Coal Institute, 1998)
Coal Sources and Power Plants
Electricity Generation by Type

United States 2014

- Coal: 39.1%
- Natural Gas: 27.4%
- Nuclear: 19.4%
- Renewables: 12.9%
- Other: 1.2%

Source: US Energy Information Administration
DryFining™ and the Clean Power Plan

- State-by-State CO₂ intensity reductions assume a 6% efficiency improvement on existing coal plants
  - A 6% efficiency (heat rate) improvement is very difficult and expensive to achieve
- DryFining™ utilizes plant waste heat to remove moisture from low-rank coals
  - 2 - 5% heat rate improvement expected
  - Cost effective (reasonable retrofit costs, lowers plant fuel and plant maintenance costs)
- Other environmental benefits
  - Significantly lowers Mercury, SO₂, NOₓ emissions
- Keeps consumer electrical rates affordable while delivering positive environmental results
Heat Rate Improvement Technology Comparison

- Advanced Ultra-Supercritical at 1350F/1400F (732C/760C)
- Ultra-SuperCritical at 1250F/1292F (680C/700C)
- Low-T Fuel Drying
- Ultra-SuperCritical at 1120F/1120F (604C/604C)
- Dual Reheat
- Natural Draft Cooling Tower
- Reduce cooling tower approach temperature
- Low-T Air Pre-heating
- Low-T Feedwater Pre-heating
- Reduce Air Heater Leakage (6% to 1%)

Source: EPRI
Great River Energy

- Generation & Transmission cooperative
- 28 member cooperatives in MN and WI
- Serving 655,000 homes & businesses
- 880 employees
- $1 Billion revenue
- $3.7 billion total assets
- Investment grade debt
- 2,800+ MW of generation
- 4,500+ miles of transmission lines
Coal Creek Station: Units 1 & 2

- 2 x 600 MW natural circulation
- ND’s largest generating station
- Best lignite heat rate in the State
- 64 low NOX burners, SOFA
- Minemouth, ND Lignite
  - 6,200 BTU/lb (14.4 MJ/kg)
  - 38% moisture
- Commissioned 1979, 1981
- Base load, low cost power
- Wet scrubbers, precipitators
- Zero Liquid Discharge Plant
- DryFining™ commercial in 2009
  - Over 33 million tons of coal beneficiated
DryFining™ Fuel Enhancement Process

- Low temperature, atmospheric pressure process
  - No high temperature or high pressure parts
  - No exotic materials
- Uses waste heat from power plant to remove coal moisture
  - No external heat sources are used
- Simple design, few moving parts
  - Equipment is simple and relatively inexpensive to manufacture
Coal Dryers

Feed Stream (Crushed Wet Coal)

Dilution Air

Screw Feeder

Auger

1st Stage

2nd Stage

3rd Stage

1st and 2nd Stage Fluidizing Air

Moist Fluidizing Air & Elutriated Fines

Rejected for Further Cleaning

Product Stream

Dust Collector

Dust Collector Fan

1st Stage Dust Collector

2nd Stage Dust Collector

3rd Stage Fluidizing Air (Cold PA)

1st and 2nd Stage Fluidizing Air (Heated Cold PA)

Screw Feeder

Rejected for Further Cleaning
Coal Creek Station DryFining™ Retrofit

- Engineering and construction from 2006-2009
- Construction performed without additional outage time
- Both units retrofitted simultaneously
DryFining™ for 600 MW (500 TPH)
Dust Collectors for 600 MW
Dust Collector Gallery
Refined Coal Conveyors
Moisture Reduction

Prototype Coal Dryer Performance: March to April, 2006

<table>
<thead>
<tr>
<th>Test Date</th>
<th>Wet Feed</th>
<th>Dried Product</th>
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<tbody>
<tr>
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As Mined

DryFine™

H₂O
Energy Density Improvement

Prototype Coal Dryer Performance: March to April, 2006

<table>
<thead>
<tr>
<th>Energy Density</th>
<th>Coal HHV [%]</th>
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<tr>
<td>Wet Feed</td>
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<tr>
<td>Dried Product</td>
<td>7,000</td>
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<tr>
<td>DryFine™</td>
<td>7,400</td>
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</table>

As Mined
Reduction in Fuel per MW Produced
DryFining™ Performance & Emissions

13% Lower moisture lignite feedstock

Less moisture in flue gas:
- 36°F lower exit gas temperature
- 5.8% lower exit gas volume
- 5.8% lower exit gas velocity
- 9.9% less power for mills
- 17.3% less power for ID fans
- Less erosion & maintenance

43% less SO₂
30% less NOₓ
2.2% less CO₂
35-40% less Hg
2.5% less ash

Higher efficiency throughout

ΔM_coal = -9.5%
6-mill operation

ΔHR_{net} = -3.5%
Δη_B = 3.4%-points

ΔV_{stack,STP} = -5.8%
Lower WFGD bypass

ΔSO₂ = 18%

Greater River Energy
**DryFining™ Net $/Ton Savings**

**Net operational savings per ton of coal**

- **Net Savings**
  - $2.76
- **Fuel Savings**
  - $1.57
- **Reduced Station Service**
  - $0.91
- **Mill Maint**
  - $0.08
- **NH3 savings - NOX**
  - $0.66
- **Lime savings - SO2**
  - $0.32
- **ACI savings - Hg**
  - $0.12
- **$(0.12)**
  - DryFining Parts & Labor
- **$(0.23)**
  - Operators
- **$(0.56)**
  - DryFining power requirements
## Conventional Pollution Controls vs. DryFining™ Technology

<table>
<thead>
<tr>
<th>MILLION $</th>
<th>Conventional Equipment</th>
<th>DryFining Fuel Enhancement</th>
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<tr>
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<td>CAPEX</td>
<td>OPEX</td>
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<tr>
<td>SO₂ Scrubber</td>
<td>$40</td>
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<tr>
<td>NOₓ SNCR</td>
<td>$9</td>
<td>$5</td>
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<tr>
<td>Hg ACI</td>
<td>$5</td>
<td>$1.5</td>
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<td>$54</td>
<td>$11.5</td>
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### Graph

- **YEARS OF OPERATION**
- **$ Millions**
  - 1: -$200
  - 2: -$150
  - 3: -$100
  - 4: -$50
  - 5: $0
  - 6: $50
  - 7: $100
  - 8: $150
  - 9: $200
  - 10: $250

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**GREAT RIVER ENERGY**

25
DryFine™ Coal for More Efficient Plants

- DryFine coal loadout facility added to Coal Creek Station
- DryFine coal shipped 170 miles to new Spiritwood Station (commercial in 2014)
- Spiritwood: one of most efficient combined heat and power plants in nation (low carbon footprint)
DryFining™ and New Coal Plants

- Coal usage for power continues to grow rapidly worldwide, particularly in developing countries
  - Low cost, abundant energy source
- Much of the coal being used for power is low-rank coal
- DryFining™ technology can greatly help lower emissions and carbon dioxide intensity
China uses four times more coal than U.S.

China uses nearly as much coal as the rest of the world combined.

Much of China’s coal is low-rank.
Fuel Drying Can Reduce Capital Cost of New Plants by 5 to 10%

![Graph showing the relationship between higher heating value of coal and relative capital cost of PC plants.]

- Wet Lignite (38.5% moisture) decrease in capital cost ~ 10%
- Dried Lignite (18.5% moisture) decrease in capital cost ~ 5.5%
- Washed Crown 2 (20% moisture)
- Dried Crown 2 (0% moisture)
DryFining™ Technology

Reduces size and cost of new plant components while lowering emissions.
## Estimated U.S. Equipment Cost
2x660 MW (900 TPH with 15 pts H₂O removal)

<table>
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<tr>
<th>Qty</th>
<th>Component</th>
<th>USD</th>
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<tr>
<td>10</td>
<td>DryFinning™ fuel enhancement modules</td>
<td>$25,000,000</td>
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<tr>
<td>10</td>
<td>Fluidizing Air Fans</td>
<td>$2,500,000</td>
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<tr>
<td>10</td>
<td>Dust Collectors</td>
<td>$17,500,000</td>
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<tr>
<td>5</td>
<td>Exhaust fans and stack</td>
<td>$1,250,000</td>
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<tr>
<td>1</td>
<td>External heat exchangers</td>
<td>$15,000,000</td>
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<tr>
<td>1</td>
<td>Instrumentation &amp; Controls</td>
<td>$2,000,000</td>
</tr>
<tr>
<td>4</td>
<td>Air Jig</td>
<td>$1,600,000</td>
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Total: $65,000,000
POWER Engineering “Best Coal Fired Project”

- Over 33 million tons of DryFine coal since late 2009
- 9 US Patents
DryFining™ can help states meet their energy and environmental goals

- Retains reliable base-load generation sources
- Reduces carbon footprint and emissions of regulated pollutants
- Helps keep consumer electrical rates affordable

DryFining™ can help the world meet rising energy needs while minimizing emissions
Thank you

Sandra Broekema  
Manager, Business Development  
sbroekema@GREnergy.com  
(612) 280-8689

David Farnsworth  
Manager, North Dakota Power Generation & Engineering  
dfarnsworth@GREnergy.com  
(701) 219-9744