DryFining™
FUEL ENHANCEMENT PROCESS

Improving Power Plant Efficiency and Power Generation

August 8th, 2013

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Coal Creek Station

- Coal Creek Units #1 and #2…
  - 2 X 600 MW Natural Circulation
  - Tangentially Fired, Dual Furnace
  - 8 X 8 burners, plus SOFA
  - Eight Pulverizers per Unit
  - Mine Mouth, ND Lignite
    - 6,200 BTU/lb (14.4 MJ/kg)
    - 38% moisture
  - Commissioned 1979, 1981
  - Base Loaded
  - Wet FGD's, No SCR's
  - Closed Loop Cooling

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Efficiency Improvements: GRE

- Turbine blades
- Cooling Towers
- Simulator
- Ventilation
- Variable packing

- Coal Drying/beneficiation

- Fans
- Controls
- Leak detection
- Compressed air

- 605,771 tons

- 4%, 400,000 tons

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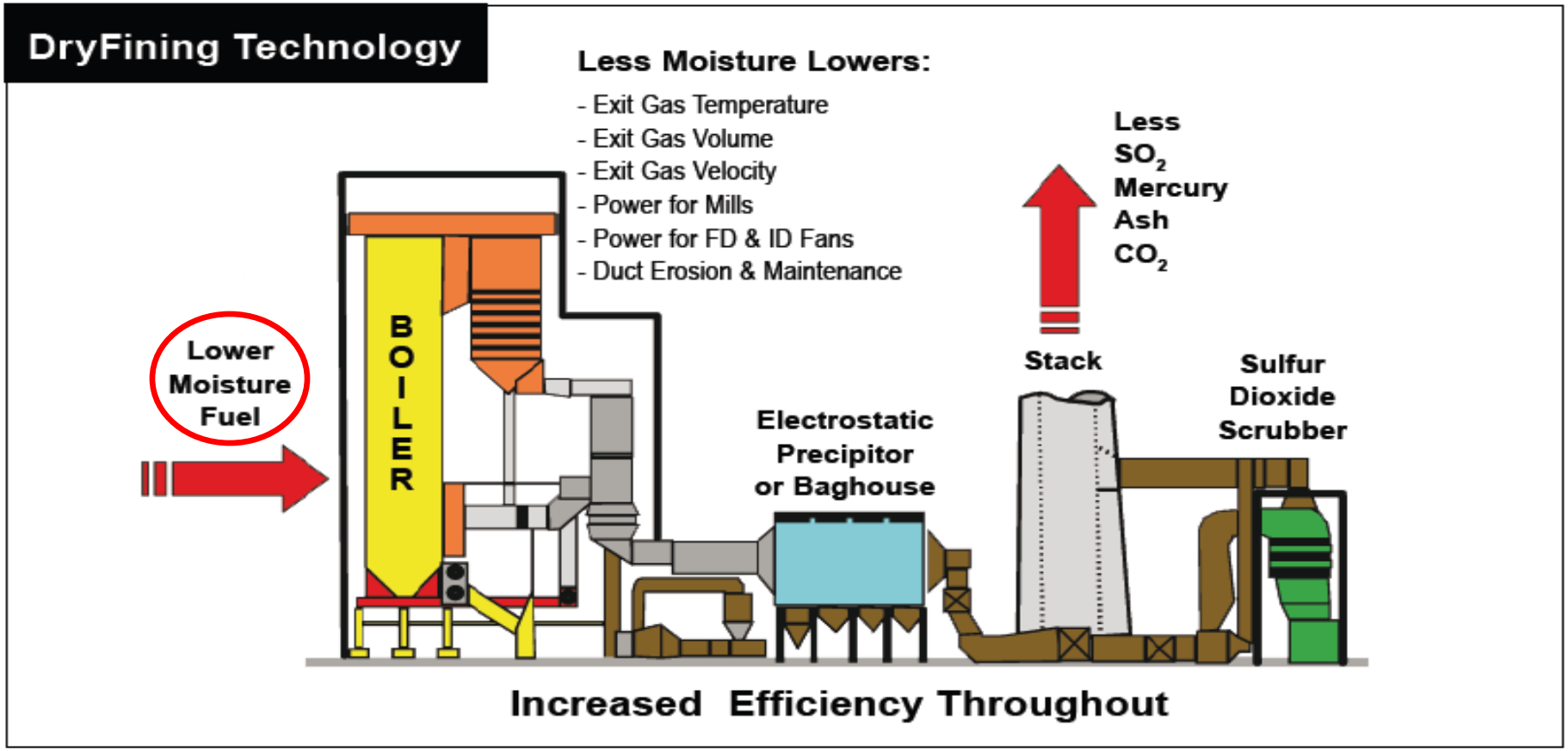
Problem Statement:

- Plant performance is based on 6,800 BTU/lb (15.8 MJ/kg) fuel (with normal margins), but delivered fuel HHV has rarely exceeded 6,200 BTU/lb (14.4 MJ/kg)
- As a result….
  - Lost Boiler And Cycle Efficiency
    - **9% Higher Coal Flow Rate Than Design**
    - **20 MW Of Station Service Power**
    - **20% Higher Flue Gas Flow Rate Than Design**
    - **High Exit Gas Temperature**
  - Lost Spare Mill Capability
  - Increased Operating And Maintenance Costs
  - **Flue Gas Flow Limited Scrubbers!**

DryFining™ Process



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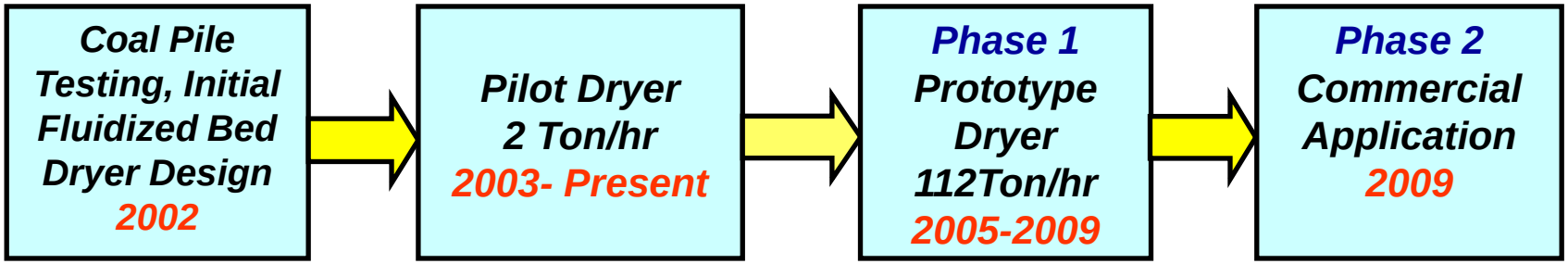
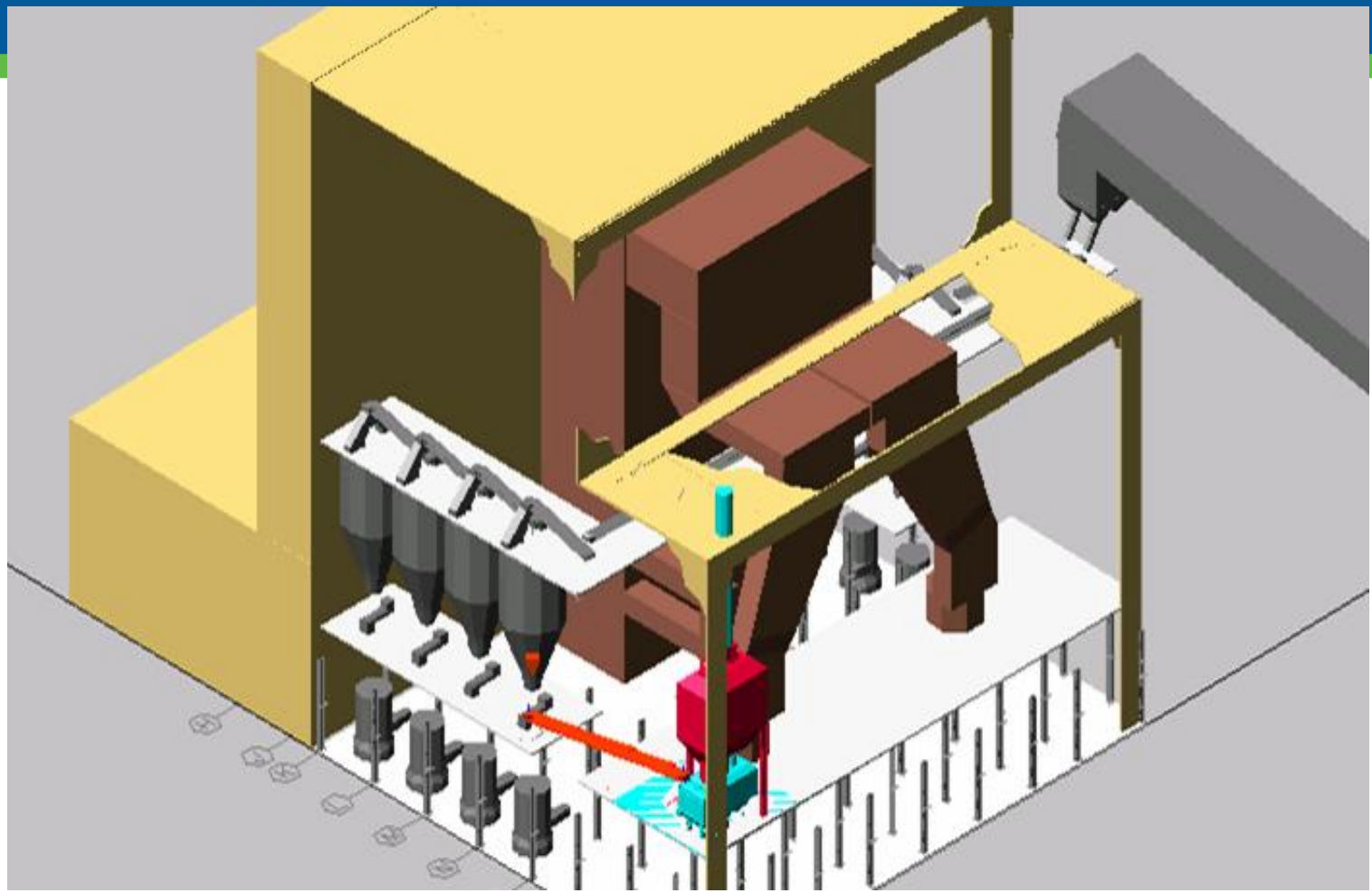
Solution

- Objective….
  - Restore lost performance by removing moisture in the incoming fuel stream just prior to bunkering
- How….
  - Employ waste heat to reduce moisture content of the lignite conveyed to the bunkers
- Approach….
  - Demonstrate and Select Basic Drying Process Concept
  - Develop “Proof Of Concept” Pilot Plant
  - Develop Dryer Design And Predictive Performance Modeling
  - Prototype Full Scale Dryer Design
  - Integrate Full Scale Commercial Demonstration Into Existing Plant Project



2 Ton/Hr Pilot Coal Drying

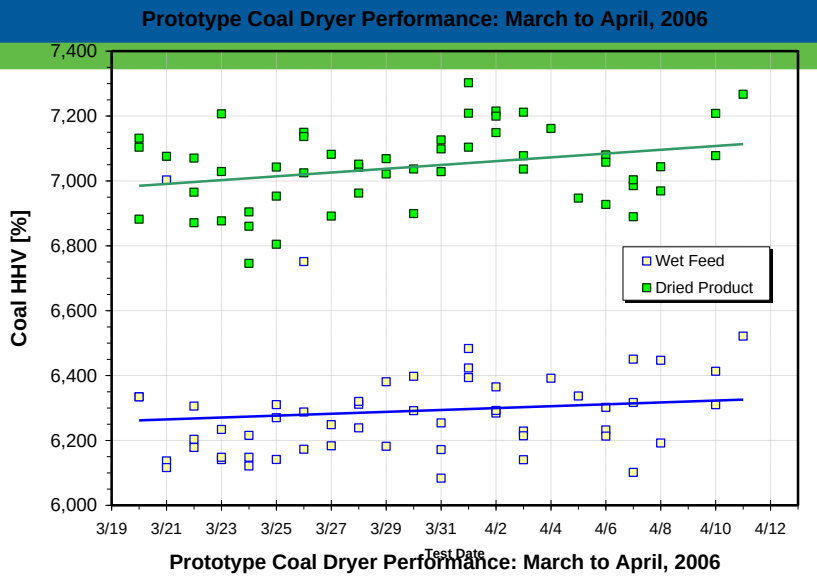
Prototype Dryer: Unit 2 East

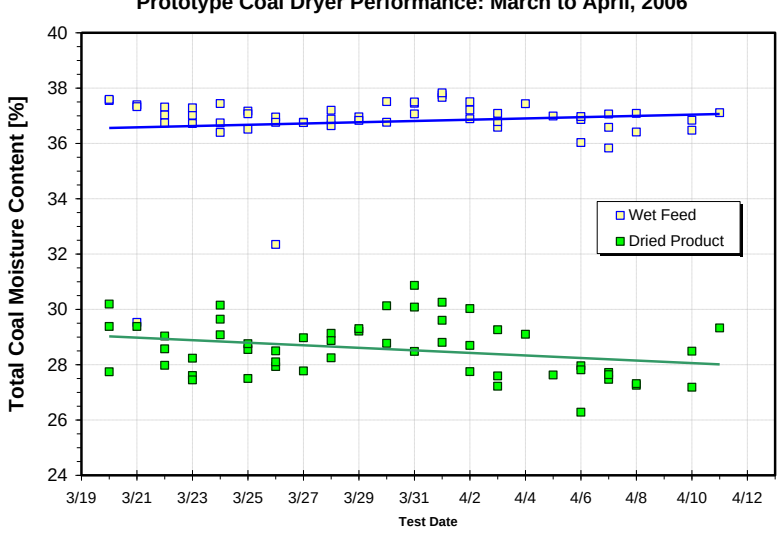


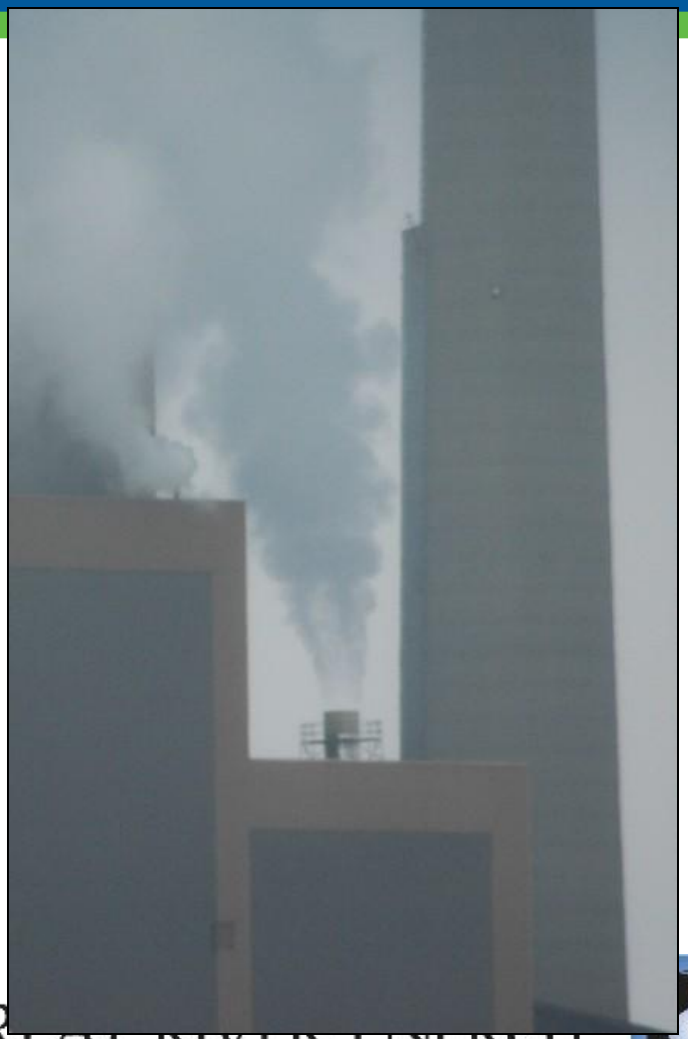
Prototype Coal Dryer

- Maximum capacity - **112.5 tons/hr**
- Removed approx. ¼ of coal moisture.
  - Dried lignite from **38.5%** to **29.5%** moisture
  - Improved HHV from **6,200** BTU/lb (14.4 MJ/kg) to **7,045** BTU/lb (16.4 MJ/kg)
- Fully automated operation, integrated into the plant control system.
- Nine patent applications on dryer design and control filed by GRE (six awarded).

Coal Drying Testing







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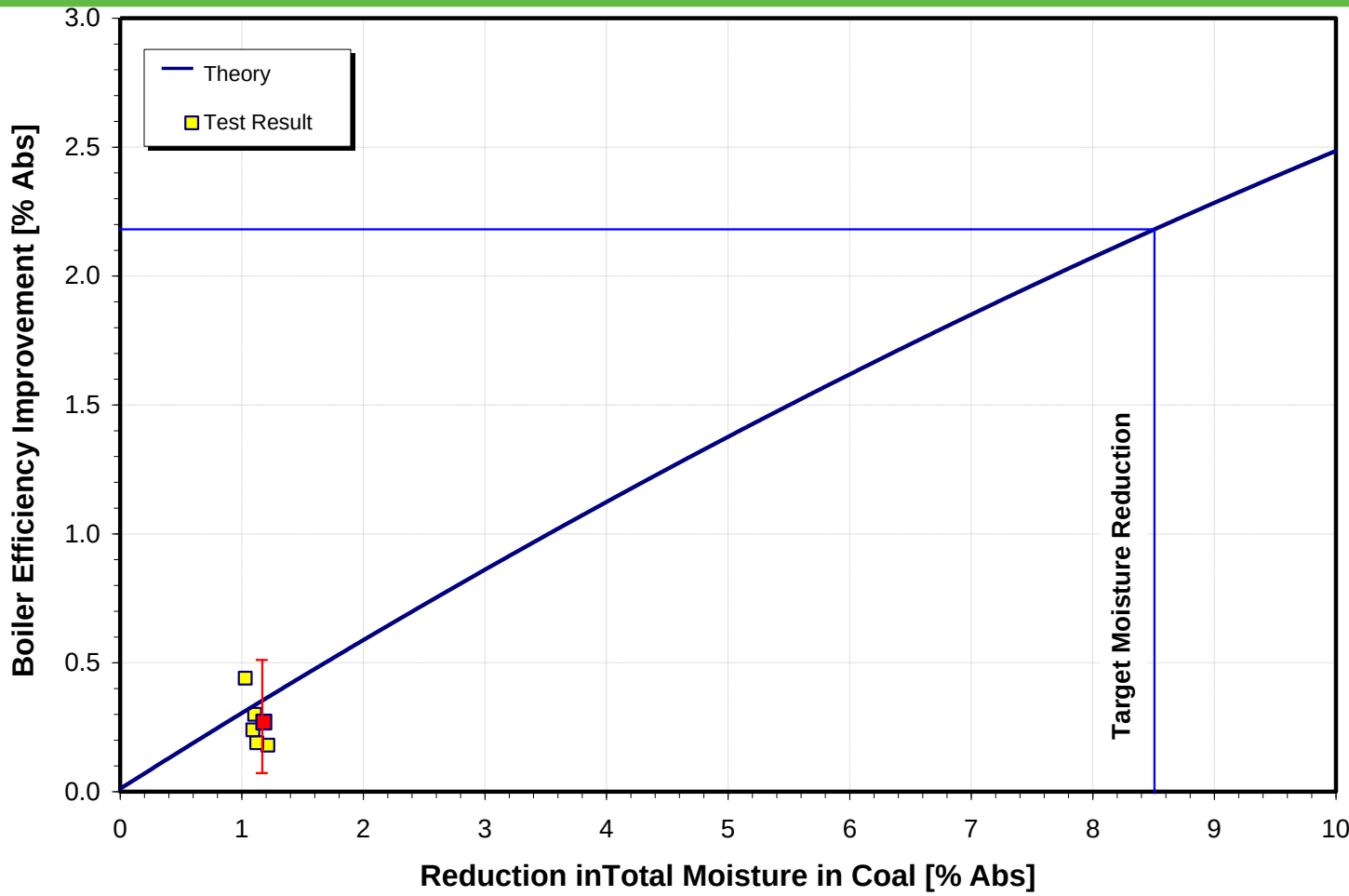
Boiler Efficiency Improvement



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Unit #2 “Complete” April ‘08

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December 2009

DryFining Results

- **25% less H_2O** - dry lignite from 38 to 29% moisture, improving HHV from 6,100 to 6,800 BTU/lb
- **54% less SO_2** - Segregation of ash minerals, plus improved collection efficiency
- **40% less Hg** - Segregation of ash minerals, plus improved collection efficiency
- **32% less NO_X**- Reduced volumetric release rate, improved fineness and air & fuel distribution to furnace
- **4% less CO_2** - 4% improved cycle efficiency

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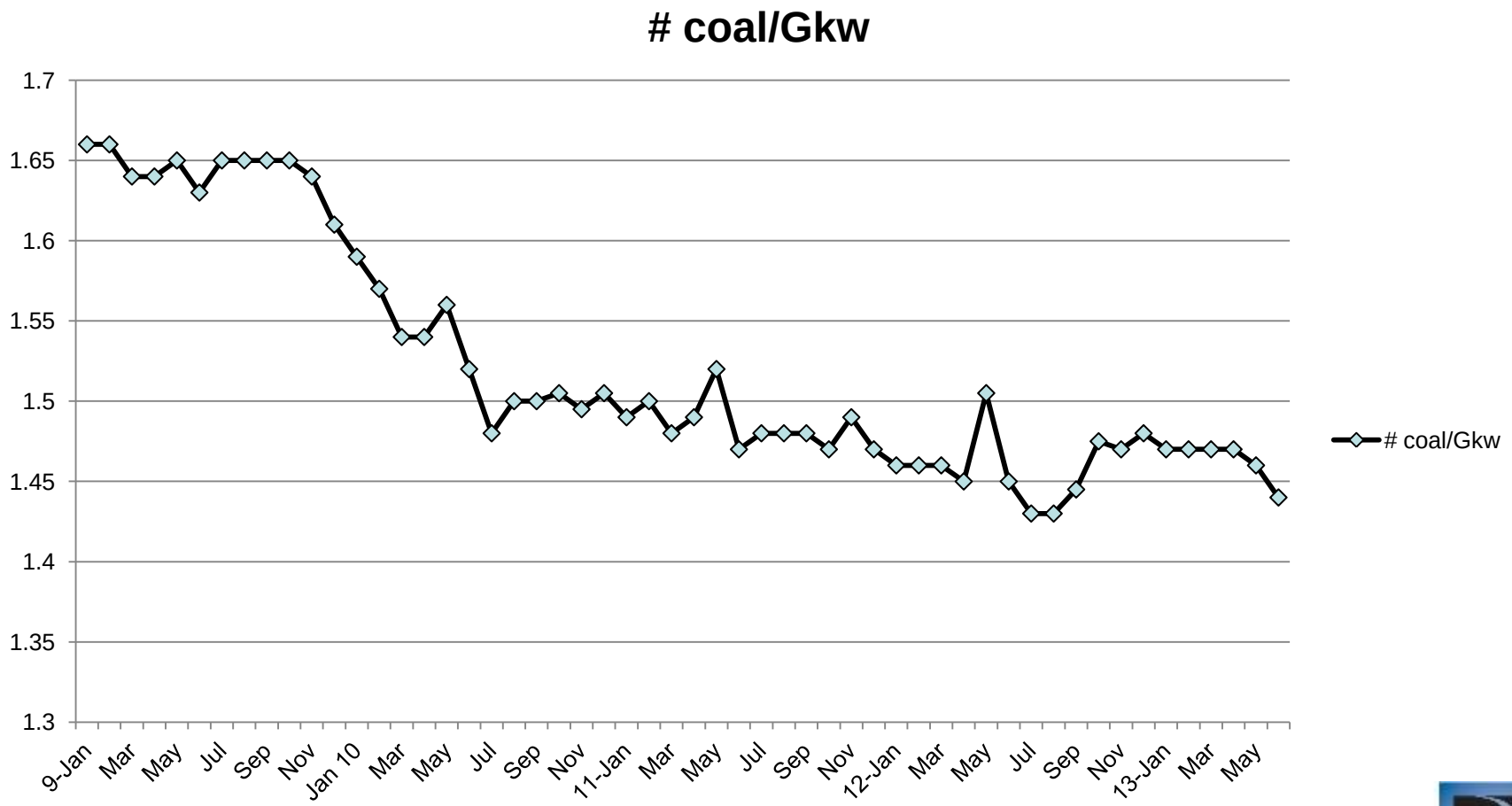
2009 to July 2013



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System Performance Impacts:

- **Observed:**
  - Each unit now operates with N-1 pulverizers in service
  - Total station service reduced
  - Boiler thermal efficiency increased by 3.7% (on HHV basis)
- **Expected:**
  - Further reductions in NO_x as the furnace is retuned to benefit from increased SOFA capacity and improved fuel distribution
  - Substantially reduced routine pulverizer, boiler, & AQCS maintenance costs

So, In General…

- **Coal Drying as needed**
  - On demand drying, no protracted storage limits nor risk of spontaneous combustion
- **Moisture reduction**
  - Lower fuel throughput
  - Boiler efficiency & net heat rate improvement
  - Station service reduction
  - Flue gas volume reduction
- **Emissions effects**
  - Pre-combustion segregation of Sulfur, Mercury, Iron
  - NO_x reduction from fuel distribution improvement and volumetric release reduction
  - CO_2 reduction equivalent to net heat rate improvement

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