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Recovery of Water from the Drying of North Dakota Lignite

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NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

Northern Great Plains Water Consortium (NGPWC)

- NGPWC goal:
  - Assess, develop, and demonstrate technologies and methodologies that minimize water use and reduce the impact of water discharges from a range of energy technologies
- A partnership between the EERC, the U.S. Department of Energy (DOE), and key stakeholders:
  - Energy producers (oil, gas, and electrical)
  - Industries
  - Municipalities
  - Other entities interested in the energy water nexus

NGPWC Project

- Evaluate recovery of water from the drying of low-rank coals
  - 48% of the world's coal supply is low rank.
    - Great River Energy's (GRE's) lignite fuel enhancement (LFE) is a lignite-drying system.
      - Reduction of moisture leads to:
        - » Higher-Btu fuel.
        - » Increase in energy production efficiency.
        - » Less emissions.

Water Recovery from Low-Rank Coals Phase 1 Project

- Hypothesis: Recovering 30% of the moisture removed from 20,000 tpd of lignite could produce 200,000 gpd of high-quality water that may be suitable for boiler or cooling tower makeup, thus reducing freshwater demand for power generation.

Photo source: Ness and Bullinger, 2009.

Water Recovery from Drying of Low-Rank Coals

- Water is recovered by cooling the LFE exhaust and condensing the water.
- Phase 1 project objectives:
  - Determine the market value of the water recovered
  - Identify the most economical cooling and condensing systems
  - Compare the expense of recovery to the benefit of water recovered
- Cooling/condensing systems evaluated:
  - Air
  - Geothermal water
  - Closed-loop system with coolant (Dowtherm)

Overview of Phase 1 Findings

- The value of water was the greatest in arid regions or where there is competition for water.
  - Lack of cooling water can result in plant derating or, in severe cases, closure.
- 30% recovery of water would be economically viable.
  - Ambient air was the most economical method.
- After ambient air is used to condense water vapor, the warm air may be used for space heating, providing additional benefit.

Determine a Market Value of the Water Recovered

Many industries/utilities withdraw water from proximal water bodies.

- What is the range that the power industry pays for water:
  - A typical rule of thumb is $1–$4 per 1000 gallons (1).
- What does it cost industries that purchase water from municipalities?
- What do other high-water-use industries pay for water?

Charges	Thermoelectric Power Industry Range (1)	Grand Forks, North Dakota (2)	Laughlin, Nevada (3)	Oil Field Use in Southwest North Dakota (4)
Meter Charge, $/month	–	506.14	201.19	–
Supply, $/1000 gallons	0.50–3.00	2.16	4.58	6–25
Transportation to and from Site, $/1000 gallons	0.13–1.20	–	–	30–333
Commodity Charge, $/1000 gallons	–	–	0.20	–
Reliability, % of total	–	–	2.5	–
Wastewater Treatment, $/1000	0.22–4.28	2.41	2.24	
Deep-Well Injection for Disposal, $/1000	–	--	–	12–42
Total Costs, $/1000 gallons	0.85–8.48	4.57	6.77	48–400

(1) EPRI. Comparison of Alternate Cooling Technologies for U.S. Power Plants: Economic, Environmental, and Other Tradeoffs, 2004.
(2) www.grandforksgov.com/gfgov/home.nsf/Pages/Utilities (accessed Nov 2009).
(3) www.lvvwd.com/custserv/bill_pay_rates_thresholds.html (accessed Nov 2009).
(4) Cowan. R.M.; Kalenze. N.S.; Kurz. B.A.; Shockey. R.S.; Stepan. D.J.; Harju. J.A.; Ziman. J.J. Bakken Water Opportunities Assessment – Phase 1.

Compare the Expense of Recovery to the Benefit of Water Recovered

- Comparing water value to lost generating capacity:
  - Average summertime derating is approximately 6.4%, with a maximum of 34.48% at lignite- and Powder River Basin (PRB) coal-burning plants. Some summer derating is normal; large derates may be due to insufficient cooling or lack of water for cooling (1).
    - 11.5% of these plants derate by 16% or more.
    - 6% of these plants derate by 20% or more.
  - A closed-loop water-cooled power plant consumes an average of 480 gallons per megawatt (2).
    - National average industrial retail electrical rate is $0.07/kWh (3).
    - Compared to lost generation, water has a calculated value of 14.6¢/gallon, or $150/1000 gal.
- Compare to the cost of air-cooled condensers:
  - Completely air-cooled power plants are possible: Wyodak Station in Gillette, Wyoming, and Matimba Power Station in Africa, with 30 years and 14 years of operation, respectively.
    - Capital cost two to three times higher than wet cooling (4, 5).

(1) www.netl.doe.gov/energyanalyses/pubs/cppd/ (accessed May 2010).

(2) www.circleofblue.org/waternews/wp-content/uploads/2010/08/EPRI-Volume-3.pdf.

(3) www.eia.doe.gov/cneaf/electricity/epm/table5_3.html (accessed May 2010).

(4) http://engineeringcases.knovelblogs.com/2010/02/17/air-cooled-versus-water-cooled-steam-condensers-for-power-boilers (accessed Nov 2010).

(5) http://social.csptoday.com/industry-insight/cooling-cost-efficiency-vs-water-usage (accessed Nov 2010).

Identify Most Economical Cooling and Condensing System

- Cooling/condensing systems evaluated:
  - Air
  - Geothermal water
  - Closed loop coolant system (Dowtherm)
- Simple payback period range 0.3–13 yr for 30% water recovery.
  - This project used quotes and heuristics for project costs to find payback periods.
    - Calculated with space-heating potential of heated cooling media
    - Difference in minimum water costs and most expensive water costs
- Explored option of using SPX's Air2Air heat exchanger to condense LFE exhaust.

Sources: McQuay International, Geothermal Heat Pump Design Manual, Application Guide AG 31-008, 2002.
Refrigerating-Heating Inc. Phone conversation, November 12, 2009.
Fox, Michael; C. Emery Nelson, Inc. Phone Conversation, September 16, 2009.
Ken Mortensen; SPX Cooling Technologies.

Calculations Show Most Economical Cooling and Condensing System Is SPX's Air2Air Heat Exchanger

- SPX's heat exchanger:
  - Lightweight plastic, 1200 lbm/module
  - Inexpensive, $3750/module, 112 modules needed for all of Coal Creek Station's LFE
  - Estimated cost of water condensed, roughly $5/1000 gallons (at 1-GW facility):
    - Depending on climate, cost of installation, plant feedstock, and local pay scale, cost of water could range from $3.50 to $8.79/1000 gallons.
    - Assumed: Installation labor $100/hour, project life of 20 years, lignite feedstock, space-heating potential not included, and hypothesized 200,000 gpd recovered.
- Using SPX equipment, recovery of water from low-rank coals has a cost within EPRI's acceptable range.

Proposed Phase 2 Demonstration Project

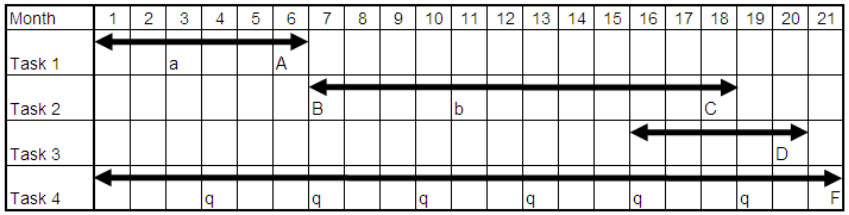
Phase 2 Goal

- Demonstrate cost-effective water recovery from the drying of low-rank coals

Project Objectives

- Design and installation of water recovery and data acquisition system
  - — Single SPX module, slipstream pilot scale
  - — Continuous monitoring of flow, pH, conductivity, and temperature
- Water Recovery System Testing
  - — Yearlong test for data on reliability and operation in temperature extremes (-20 to 100 F)
- Economic Evaluation and Market Assessment
  - — Validate economics
  - — Assess markets for upgraded low-rank coal and water by-product.
- Management and Reporting
  - — Data collection and interpretation
  - — Quarterly reports
  - — Final report

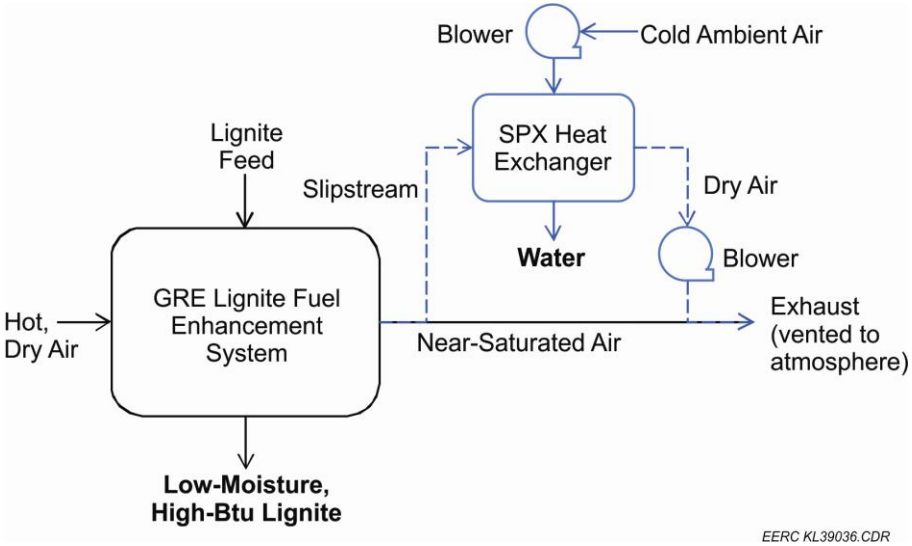
Objectives	Duration
Design & Installation of Water Recovery System with Data Acquisition	Month 1-6
Water Recovery System Testing	Month 7-18
Economic Evaluation & Market Assessment	Month 16-21
Management & Reporting	Month 1-24



Milestones	Decision Points
[A] Complete system installment	[a] Part Selection and Purchasing Complete
[B] Water Recovery System Start-up & Shakedown	[b] Achieve Minimum Condensate Rate of 8 gpm
[C] Water Sampling Completed	[q] Quarterly Reports
[D] Economics and Market Assessment Completed	
[F] Final Report	

Proposed Phase 2 Demonstration Project

- Pilot-scale testing of SPX system at GRE facility:
  - Test will occur on the 16th floor of Coal Creek station
- Slipstream of LFE exhaust with one Air2Air module:
  - 1200 lbm/module
  - ~1 inch water column pressure drop
  - Anticipated water recovery of 8–16 gpm
- Water quality is anticipated to be high.
  - Tests that will be conducted
    - pH
    - Alkalinity
    - Major cations
    - Major anions
    - TOC
    - TDS



Proposed Phase 2 Demonstration Project

- Slipstream pilot-scale system at Coal Creek Station
  - + $32,000 GRE contribution
  - + $23,500 SPX contribution
  - + $250,000 EPRI contribution
  - + $250,000 North Dakota Industrial Commission match
  - + $500,000 EERC–DOE match

  Total Project Cost = $1,055,500
- EPRI leverage of its money 4/1

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