Coal may be challenged, but coal is not dead!

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- Over 900 co-ops
- 42 million people in 47 states
- 75% of land mass
- 83% of counties fully or partially served
- 42% of nation’s distribution lines
- 7 customers/line mile
- 50% suburban and 25% micro urban
- Largest aggregation of coal power plants
G&T Cooperative Service Area - 2014

[Map showing the G&T Cooperative Service Area with various regions and states highlighted.]
Existing Co-op Generation Fuel Mix

- Coal: 70%
- Gas: 19%
- Nuclear: 10%
- Other: 1%

Source: 2012 Ventyx, June 2013
Unique Cooperative Characteristics

- Stakeholders are the electric customers
- Stakeholders for a G&T are CEO’s of distribution cooperatives
- 100% debt financing
- Low cost of capital
- Key mission is to provide affordable and reliable electricity, not return on equity
- Coops are not for profit
NRECA GEC Technical Advisors

- Tri-State G&T, CO/UT/NM/WY
- Arkansas Electric Power Cooperative, AR
- Arizona Electric Power Cooperative, AZ
- Associated Electric Cooperative, Inc. MO/OK/IA
- Basin Electric Power Co-op, MN/WY/ND/SD/MN/IA
- Buckeye Power, OH
- Corn Belt Power Cooperative, IA
- Deseret Power Electric Cooperative, UT
- East Kentucky Power Cooperative, KY
- Golden Spread Electric Cooperative, Inc. TX
- Great River Energy, MN
- Hoosier Energy, IN
- Oglethorpe Power Cooperative, GA
- Old Dominion Electric Cooperative, VA
- Power South Electric Cooperative, AL
- San Miguel Electric Cooperative, Inc. TX
- Seminole Electric Power Cooperative, FL
- Southern Illinois Power Cooperative, IL
- South Texas Electric Cooperative, TX
- Sunflower Electric Power Cooperative, KA
- Western Farmers Electric Cooperative, OK
- Wolverine Power, MI
- TVA as an associated member, TN/MS/AL/GA/NC/VA/KY
Environmental Regulation Train Wreck
(Per Williams and Strawn LLC, June 2014)

Train Wreck Timeline for the Moment

- **Jan. 15, 2013**: EPA finalizes new PM$_{10}$ NAAQS
- **April 19, 2013**: Effluent guidelines rule proposed
- **June 2013**: 1-hour SO$_2$ NAAQS final area designations expected

- **Dec. 2011**: EPA finalizes MATS rule
- **July 7, 2012**: DC Circuit upholds NO$_x$ NAAQS
- **Aug. 21, 2012**: DC Cir Vacates CSAPR
- **June 2013**: 316(b) final rule expected
- **May 2014**: Effluent Guidelines final rule expected
- **April 16, 2015**: Initial MATS compliance
- **April 16, 2016**: Possible extended MATS compliance

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<tbody>
<tr>
<td>Early 2012 GHG NSPS for New EGUs proposed rule</td>
<td>Early 2012 GHG Tailoring Rule Phase 3 proposed no new sources</td>
<td>2013 Rulemaking on 1-hour SO$_2$ NAAQS Implementation expected</td>
<td>2014 New ozone NAAQS expected</td>
<td>2014 Final coal combustion residuals rule expected</td>
<td>2016</td>
</tr>
</tbody>
</table>

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MATS, NSR and natural gas market driving retirement of 350 plus utility coal units; 50 plus GW’s

Units built before 1970 at risk

TVA retiring 2,700 MWs

Southern Company is retiring 2,061 MWs of coal and oil-fired capacity

In addition to retirements, utilities and co-ops looking at natural gas repowering, new gas generation at existing plans and greenfield natural gas generation

Environmental Train Wreck is still in progress
Coal-fired Capacity

Why are utilities retiring coal-fired capacity when additional capital investments will be required for new natural gas fired combined cycle gas turbines?

Capital Cost ($/kW)

Retrofit capital cost is much lower cost than building replacement units

Thanks to Block Andrews of Burns and McDonnell LLC
With Low Natural Gas Prices CCGT Total Variable Operating Costs could be less than Coal Fired Power Plant with future Environmental Controls. (Note this assumes that EPA CCR rule doesn't require Transportation to New Landfills)

Thanks to Block Andrews of Burns and McDonnell LLC
Possible Impact of EPA CCR Rule on Coal Dispatch?

• If the cost of transporting ash to a new landfill from a bituminous coal-fired plan costs $30/ton ash this could add >$1/MWH to the dispatch cost for the unit or $3 million a year.

• If the cost of transporting ash to a new landfill from a Lignite or sub-bituminous coal-fired power plant costs $30/ton ash this could add >$3/MWH to the dispatch cost for the unit or $9 million a year.

• If the variable operating cost for a coal-fired unit becomes greater than a gas-fired CCGT, the margin for the coal-fired unit will disappear.
  – Plant capacity factor will decrease.
  – How will the operating staff fixed costs be covered?
  – If the operating staff fixed cost can’t be covered, the coal-fired power plant will have to retire.

• CCR’s must be converted from a liability to an asset generating revenues.
Maximize Use of Coal Combustion Byproducts

- Gypsum wallboard
- Blended cement
- Portland cement
- Cenospheres
- Concrete products
- Structural fills
- Road base
- Waste stabilization
- Fly Ash (~80%)
- Bottom Ash (~20%)

Thanks to Timothy McDonnell with Arizona Public Service
Current Coal Combustion By-product

- 71.7 million tons fly ash produced nationally (2007 data)
- 18.1 million tons bottom ash and 12.3 million tons FGD gypsum
- 47% of ash and gypsum used in construction
- Dependent on local markets, hauling costs, economy
- Beyond just utilization – must consider ash material Reduction, Conversion and Reclamation options

Thanks to Timothy McDonnell with Arizona Public Service
• Magmill – dry magnetic cleaning of pulverized coal w/maximized removal of pyrite and other minerals
• Techinomics Inc. – density classifier to remove ash
• Magmill and/or classifier will need carbon recovery
• Carbon Recovery Alternatives:
  – Separation Technologies (ST) Inc. extraction process
    • Electrostatis concentration and recovery of carbon from ash
    • Concentrated carbon recycled as boiler fuel input
  – PMI Ash Technologies LLC carbon burn-out technology
    • Eliminate carbon in remaining inorganic ash material
    • Cleaned ash/ore suitable for “Mining”
    • Exothermic heat recovery to plant

Thanks to Timothy McDonnell with Arizona Public Service
• Dry magnetic cleaning of pulverized coal
• APS power plant coal tested at Magmill pilot site
• Reduce Ash, SO2, Hg
• Improve power plant performance & reliability
• Carbon recovery to plant
• “Mining” ash concentrate
• Plant demo(s) ??

Thanks to Timothy McDonnell with Arizona Public Service
• Rotating throat-ledge cover system
• Demonstration at Gavin power plant – AEP
• Pyretic rock is efficiently removed from the pulverizer
• Increased primary air velocity but not flow mass
• Improved coal fineness and boiler combustion

Thanks to Timothy McDonnell with Arizona Public Service
Coal Ash “Mining”

Figure 4. Flow Sheet for alumina, silica and iron recovery from ash

- Ash beneficiation
- ST magnetic separator
- Fly Ash
- Carbon to Boiler

Process into Pure Silicate Products:
- Silicates, Silica, Zeolites, White
- Soot, Glass Components, Ceramics, Cement, [Aerogel] and Other

Alumina Concentrate
- Alloys
- Refractories
- Building materials
- Alumina Production
- “Mud”
- Portland Cement

Hydro alkaline Silica Extraction
- Alumina Production
- Silicate Alkaline Solution
- Regeneration

[FLY] ASH
- Activation
- Magnetic Separation
- Fe₂O₃ - Concentrate

variant operations
### What about Selected Commercial Players Developing and Scaling up Processes to recover Valuable Metals and Products from Fly Ash?

<table>
<thead>
<tr>
<th>Company</th>
<th>Target Metals</th>
<th>Key Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>China Shenhua Group</td>
<td>Al, Ga</td>
<td>Commercial Scale plant producing 1 million tones alumina at 80% recovery as well as gallium and silica products</td>
</tr>
<tr>
<td>Elixsys</td>
<td>Al, trace metals</td>
<td>Scaling up multistep process with aim of converting 100% coal ash to products</td>
</tr>
<tr>
<td>Emissions Resource Group</td>
<td>Various e.g. Mg, Ti, Al, REEs</td>
<td>Already recover metals for clients during their ash pond remediation process, but wouldn’t specify any details</td>
</tr>
<tr>
<td>Expansion Energy</td>
<td>Various e.g. Ga, Ge, Ni, U, V, Fe, REEs, Zr</td>
<td>Developed system to capture CO₂ to mineralize coal ash</td>
</tr>
<tr>
<td>Latrobe Magnesium</td>
<td>Mg</td>
<td>Plant is under construction in Australia, due to begin production in 2016</td>
</tr>
<tr>
<td>Naval Research Laboratory</td>
<td>REEs</td>
<td>Developing ionic liquid approach to REE extraction</td>
</tr>
<tr>
<td>Orbite Aluminae</td>
<td>Al, Sc, Ga (others to follow)</td>
<td>Extending and modifying their aluminum waste processing to include coal ash</td>
</tr>
<tr>
<td>RockTron</td>
<td>REEs, hollow glass spheres, solid glass spheres, solid magnetite microspheres</td>
<td>Processes to separate REE rich fractions of coal ash</td>
</tr>
</tbody>
</table>

Thanks to Lucinda Tolhurst, Director, Lucid Insight Ltd, lucinda@lucid-insight.com, www.lucid-insight.com
What is the total valuation for all of the metals in various fly ash around the world?

(US$/MT fly ash)

Total maximum value for elements above: $46,529
Total minimum value for elements above: $4,475
Maximum value of REE (all where prices obtained): $436

Thanks to Lucinda Tolhurst, Director, Lucid Insight Ltd, lucinda@lucid-insight.com, www.lucid-insight.com
More trouble on the horizon

- The 800 pound gorilla in the room: The EPA Clean Power Plan IAW The Clear Air Act Section 111(d)
- *EPA Proposal to Regulate Greenhouse Gas Emissions from Existing Fossil-Fueled Electric Generation Units*
Possible Impact of the EPA proposal on Coal fired power plants

Building Block 1
Improve efficiency of existing coal plants

Building Block 2
Increase reliance on CC gas units

Building Block 3
Expand use of renewable resources & sustain nuclear power production

Building Block 4
Expand use of demand-side energy efficiency

Gone?

Going

Going

Coal Plant
**EPA Timeline**

- **June 2014**: Draft Rule Issued
- **October 2014**: Deadline to provide comments to EPA
- **June 2015**: Rule finalized
- **June 2016**: State implementation plans due
- **June 2017**: State plans due (with one year extension)
- **June 2018**: Multi-state plans due (with 2-year extension)
- **January 2020 – 2029**: Interim goal in effect
- **January 2030**: Proposed goal in effect

**Comments to EPA**
- **June 2014**: Draft Rule Issued
- **June 2015**: Rule finalized

**Litigation**
- **October 2014**: Deadline to provide comments to EPA

**Discussions with States**
- **October 2014**: Discussions with States, Administration and Political Pressure

**Discussions with EPA, Administration and Political Pressure**
• Potential for Incremental Improvements in CO$_2$ @ <$0/ton for Existing Power Plants Demos Funded by Alberta CCEMC

• Coalvation LLC Enzergy™ Bio-enzymatic Treatment of coal
  – 5% less fuel
  – 5% less CO$_2$
  – 22% removal of NO$_x$
  – 33% removal of SO$_2$
System Setup at Taiwan Plant

- Concentrated enzyme shipped in 200-liter blue plastic drums
- Plant dilutes it 30x with water in steel storage tanks
- Resulting 6,000 liters can treat 2,000 tons of coal
Applying Enzergy™ at Taiwan Plant

• Bio enzyme sprayed on coal three times:
  1. When trucks arrive
  2. During unloading
  3. On its way to the silo

• Not ideal configuration: coal is sprayed but not mixed, and the solution soaks for only 8 hours
• Improve boiler efficiency by removing boiler deposits and fouling, reduce soot blowing frequency
• Improve ability to recycle bottom and fly ash
• Will allow use of lower cost stainless steel and carbon steel Condensing Heat Exchangers to boost 4%-6%
• Capture moisture from flue gas as process water
Will new coal-fired power plants ever be economically viable again?

• Only if the cost for capturing CO\textsubscript{2} can be reduced to a cost less than the CO\textsubscript{2} can be sold for beneficial uses like Enhanced Oil Recovery (EOR)
  – i.e. <\$35/ton CO\textsubscript{2}

• Only if processes can be developed to convert the CO\textsubscript{2} into high value liquid fuels and chemicals while paying for the CO\textsubscript{2} at (>\$35/ton CO\textsubscript{2})
Current Costs for Conventional CCS Options

• Post Combustion Capture
  – $65/ton CO₂ or another $65/MWh added to a new Supercritical PC unit + WFGD + SCR
• Oxy-combustion
  – $54/ton CO₂ or another $54/MWh added to a new Sub-Critical PC unit + WFGD + SCR
• Pre-Combustion Capture with IGCC
  – $41/ton CO₂ or another $41/MWh added to a new IGCC
• Chemical Looping Combustion Potential
  – $19/ton to $35/ton CO₂ or another $19/MWh to $35/MWh added to a new Circulating Fluidized Bed Combustor
Promising Advancements for CO$_2$ Capture for >90% capture for Existing Coal Fired Power Plants

- **Sustainable Energy Solution Cryogenic Carbon Capture (CCC) Post Combustion Capture** -> $20/ton CO$_2$ with Energy Storage possible
- **Inventys Veloxo Therm™ Post Combustion Capture** - $15/ton CO$_2$
- **Environambient LLC Multi-Pollutant Control and Carbon Capture Post Combustion Capture** - <10%/ton CO$_2$
Levelized Cost of Electricity (LCOE in Cents/kWh) with and without CCS, CCUS, CCU for New Dispatchable Power Plants.
Levelized Cost of Electricity (No ITC or PTC) New Generation Plan for Electric Cooperatives Non-Dispatchable Technologies

Cents/kWh (2014$)

- Wind: 6.3 Cents/kWh (Capital: 5.3, O&M: 1.0)
- Photovoltaics: 5.3 Cents/kWh (Capital: 4.9, O&M: 0.4)
- Solar Thermal: 14.6 Cents/kWh (Capital: 13.7, O&M: 0.9)
Monitoring Sustainable Energy Solutions (SES)
Cryogenic Carbon Capture (CCC) Post Combustion
Monitoring SES CCC Post Combustion Capture of CO₂

DE sublimating heat exchanger

1 ton of CO₂ per day skid sent to a power plant
Sustainable Energy Solution (SES) Cryogenic Carbon Capture (CCC) Post Combustion (DOE ARPA-funding) Producing Excess LNG During low cost off peak periods with ~30% parasitic loads

Normal Operation
Sustainable Energy Solutions (SES) Cryogenic Carbon Capture (CCC) Post Combustion Capture Using stored NLG during Peak Periods to Produce Solid CO₂ with ~0% Parasitic loads

Energy Storing
• The VeloxoTherm™ is an intensified temperature swing adsorption (TSA) process
• The heart of the VeloxoTherm™ process is its proprietary structured adsorbent.
  – Flue gases contact the structured adsorbent
  – Only CO2 becomes trapped on the material
  – Adsorbent saturates with CO2 and is regenerated using low quality steam
• ~$15/ton CO2
Monitoring Enviroambient Multi-Pollutant Control and CO₂ Capture

- Multi-pollutant control removal efficiency
  - >98% SO₂
  - >98% NOₓ
  - >99% acid gases
  - >95% Mercury
- CO₂ capture and removal
  - Low L/G ratio 30%
  - High L/G ratio >70%

5 MW equivalent Enviroambient multi-pollutant control and carbon capture reaction previously in Louisville, KY
Monitoring Enviroambient’s Multi-Pollutant and CO₂ Removal Process

Operating Conditions (8/14/2012)

<table>
<thead>
<tr>
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<th>Inlet (ppm)</th>
<th>Outlet (ppm)</th>
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<tbody>
<tr>
<td>NOx</td>
<td>43.36 (ppm)</td>
<td>0.44 (ppm)</td>
</tr>
<tr>
<td>SO₂</td>
<td>216.58 (ppm)</td>
<td>0.00 (ppm)</td>
</tr>
<tr>
<td>CO₂</td>
<td>13,865 (ppm)</td>
<td>3,352 (ppm)</td>
</tr>
</tbody>
</table>

Eastern Bituminous Coal Ultimate Analysis

<table>
<thead>
<tr>
<th>Element</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Carbon</td>
<td>69.90%</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>4.70%</td>
</tr>
<tr>
<td>Oxygen</td>
<td>6.40%</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>1.20%</td>
</tr>
<tr>
<td>Sulfur</td>
<td>2.20%</td>
</tr>
<tr>
<td>Ash</td>
<td>13.20%</td>
</tr>
<tr>
<td>Moisture</td>
<td>2.40%</td>
</tr>
<tr>
<td>Heating Value</td>
<td>12,644 Btu/lb</td>
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Enviroambient is looking for a host site to demonstrate a 25 MW CO2 capture reactor.
• $160 million private, $10 million county $25 million DOE
• 1 ton CO₂ = 125 gallons ethanol + 25 gallons light distillate
• 27 patents and 50 pending
• 6 acre Process Development Unit (PDU)
• 10,000 gallons/acre per year
• 80 tons of CO₂ used per acre per year
• 1.25 gallons of fresh water produced per gallon of ethanol
• Southern Climates
• 10,000 acres costs about $800 million
• Produces 80 million gallons worth about $184 million
• Produces about 120 million gallons fresh water from saline aquifers
• CO₂ cost is ~7% of revenue at $25/ton CO₂ and IRR>15%
• Dramatic improvement over corn to ethanol plants using high purity waste CO₂ of 400 gallons per acre versus 8000 gallons
Algenol Downstream Processing Units

- Algae / Salt Water Separation Unit
- Vapor Compression Steam Stripping Unit
- Membrane Dehydration Skid
- Hydrothermal Liquefaction Unit
Chemical Catalytic conversion of CO₂ to Liquid Fuels

Converting Liability to Revenue

• Boudouard reaction
• Catalytic reaction
• Microwave heating and catalytic reaction
Levelized Cost of Electricity with and without CCS New Generating Plant for Electric Cooperatives Dispatchable Technologies with $25/ton CO₂ credit for EOR.
Questions?

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