Environmental Performance of IGCC Repowering for Conventional Coal Power Plants

GASIFICATION TECHNOLOGIES CONFERENCE
SAN FRANCISCO, CALIFORNIA
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PHIL AMICK, VICE PRESIDENT, COMMERCIAL DEVELOPMENT
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SOLID FUEL GASIFICATION IS OUR ONLY BUSINESS
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WHY REPOWER OLDER COAL FIRED UNITS?

Emissions Reduction with Capacity Increase
Efficiency Improvement
Less Social Impact
Improved Development Schedule

Wabash River Case Study
E-GAS TECHNOLOGY FOR GASIFICATION

WABASH RIVER
E-GAS TECHNOLOGY FOR GASIFICATION

WABASH REPOWERING

Fuel Handling → Slurry Prep → Gasifier → Sulfur Removal → Water Treatment

Slag / Frit Handling → Gasifier HTHR Filtration → Sulfur Recovery → Switch Yard

Existing

Cinergy

WREL

GT HRSG

STG & Aux

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Environmental Performance of IGCC Repowering for Conventional Coal Power Plants
E-GAS TECHNOLOGY FOR GASIFICATION

Wabash Facility Location

Steam Turbine

Combustion Turbine

Gasification Plant

Oxygen Plant
E-GAS TECHNOLOGY FOR GASIFICATION

Wabash River Project Overview

- Coal Gasification Combined Cycle Repowering
- 262 MWe Net Output by repowering 100 MW 1953 PC Unit
- Operational since 1995
- Bituminous Coal and Pet coke, up to 7 % S
- Heat Rate Improved by 20% (~ 8900 Btu/kWh HHV)
- Cleanest Coal/Coke Fired Power Plant in the World
E-GAS TECHNOLOGY FOR GASIFICATION

Wabash River Project Overview

- E- Gas Technology Gasification Process
  - Oxygen Blown, Slurry Fed
  - Continuous Slag Removal (No lock hoppers)
- High Temperature Heat Recovery (~ 1800 DegF)
- Medium Temperature Char Filtration (~ 750 DegF)
  - Metallic Elements, Dry Filtration
- COS Catalyst, MDEA Acid Gas Removal
- Claus based Sulfur Recovery
- Recycle of SRU Tailgas and Char to gasifier
- General Electric 7FA Gas Turbine, Dual Fuel (NG/Syngas)
<table>
<thead>
<tr>
<th>E-GAS TECHNOLOGY FOR GASIFICATION</th>
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</thead>
<tbody>
<tr>
<td>AIR EMISSION POINTS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Turbine/HRSG Stack</td>
<td>225 Ft.</td>
</tr>
<tr>
<td>Auxiliary Boiler Stack</td>
<td>50 Ft.</td>
</tr>
<tr>
<td>Tail Gas Incinerator Stack</td>
<td>310 Ft.</td>
</tr>
<tr>
<td>Flare</td>
<td>180 Ft.</td>
</tr>
<tr>
<td>Cooling Tower</td>
<td>30 Ft.</td>
</tr>
</tbody>
</table>
E-GAS TECHNOLOGY FOR GASIFICATION
E-GAS TECHNOLOGY FOR GASIFICATION

SO x Control

- IGCC is permitted for 0.25 lb SO2/MMBtu (split between Cinergy and WREL emission sources)
- Normally running at ~0.12 – 0.13 lb SO2/MMBtu
- As low as 0.03 lb SO2/MMBtu has been achieved
E-GAS TECHNOLOGY FOR GASIFICATION

SO₂ EMISSIONS

LBS. SO₂ / MMBtu of Coal F

- Existing 1953 Station
- New Source Performance Standards
- Wabash
E-GAS TECHNOLOGY FOR GASIFICATION

NO x Control

GE 7FA combustion turbine with steam injection (1992 purchase order)
Product syngas moisturized and pre-heated prior to delivery
Permitted for 25 ppm NO x
Has run as low as 18 ppm
E-GAS TECHNOLOGY FOR GASIFICATION

NOX EMISSIONS

LBS. NOX / MMBtu of Coal Feed

EXISTING

IGCC

0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

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E-GAS TECHNOLOGY FOR GASIFICATION

PARTICULATE EMISSIONS

Combustion Turbine exhaust stack operates at <5% opacity (continuous on-line monitoring), Zero Visual Opacity

Product syngas (prior to delivery to the CT) has no measurable particulates (below detection limits)

Primary source of particulate emissions are from Flare, Tail Gas Incinerator Stack (tank vent system) and Cooling Tower
### E-GAS TECHNOLOGY FOR GASIFICATION

#### EMISSIONS COMPARISON

<table>
<thead>
<tr>
<th>Emissions, lb/MWh</th>
<th>SO2</th>
<th>NO x</th>
<th>CO</th>
<th>PM-10</th>
<th>VOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1 before Repower</td>
<td>38.2</td>
<td>9.3</td>
<td>0.64</td>
<td>0.85</td>
<td>0.03</td>
</tr>
<tr>
<td>IGCC*</td>
<td>1.07</td>
<td>0.75</td>
<td>0.55</td>
<td>0.09</td>
<td>0.02</td>
</tr>
</tbody>
</table>

*Based on actual reported emissions in 1999

Mercury emissions for 1999 <0.00001 lbs/MWh
## E-GAS TECHNOLOGY FOR GASIFICATION

### EMISSIONS COMPARISON

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<tbody>
<tr>
<td>Unit 1 before Repowering</td>
<td>38.2</td>
<td>9.3</td>
<td>0.64</td>
<td>0.85</td>
<td>0.03</td>
</tr>
<tr>
<td>IGCC (1999 annual average)</td>
<td>1.075</td>
<td>0.75</td>
<td>0.555</td>
<td>0.09</td>
<td>0.09</td>
</tr>
</tbody>
</table>

**Emissions Reduction TPY**

- 5505
- 1179
- (83)
- 101
- (25)

Comparing 100 MW PC unit running 35% availability and 262 MW IGCC running 75% availability

(5.6 X more megawatt hours produced)
E-GAS TECHNOLOGY FOR GASIFICATION

Steam Turbine Condenser

Power Block

Gasification Island, ASU, CWT

New WW Pond

Old Power Plant

Ash Pond Outfall 002

Metering Point
E-GAS TECHNOLOGY FOR GASIFICATION

WATER BALANCE – OUTFALL 002

Added Discharge from new project 0.72 mgd
Savings from PC Boiler Decommissioning (0.57)

Net Increase to Outfall 002 0.15 mgd

(2.8 % increase for overall station, with increase from overall 880 MW to 1100 MW capacity)
E-GAS TECHNOLOGY FOR GASIFICATION

River Water

Water Trtmt

Combined Cycle

Gasification

Demin Rinse
0.086 mgd

Clarifier Sludge
0.086 mgd

Boiler Blowdown
0.014 mgd

Cooling Tower BD
0.014 mgd

Process Blowdown
0.144 mgd
Soon to MVR

NO x Control
Stm Inj & SG Moisturization
0.432 mgd
**E-GAS TECHNOLOGY FOR GASIFICATION**

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**Process Wastewater Analysis**

Comparison of process wastewater quality of E-Gas gasification compared to typical PC based power generation for Group I metals and Cyanide:

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>E-Gas Coal</th>
<th>E-Gas Petcoke</th>
<th>PC Power Plant* (Median Values)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic, ppm</td>
<td>&lt;0.05</td>
<td>&lt;0.04</td>
<td>0.17</td>
</tr>
<tr>
<td>Cadmium, ppm</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>0.005</td>
</tr>
<tr>
<td>Chromium, ppm</td>
<td>&lt;0.010</td>
<td>&lt;0.010</td>
<td>0.049</td>
</tr>
<tr>
<td>Mercury, ppm</td>
<td>&lt;0.0002</td>
<td>&lt;0.0002</td>
<td>0.0008</td>
</tr>
<tr>
<td>Nickel, ppm</td>
<td>&lt;0.02</td>
<td>&lt;0.04</td>
<td>0.10</td>
</tr>
<tr>
<td>Selenium, ppm</td>
<td>&lt;0.20</td>
<td>&lt;0.10</td>
<td>0.13</td>
</tr>
<tr>
<td>Cyanide, ppm</td>
<td>&lt;0.2</td>
<td>&lt;0.1</td>
<td>No Data</td>
</tr>
</tbody>
</table>

Interim Pond (102) Discharge Limits

Interim Pond established as part of the Repowering Plant and as an add-on to Cinergy’s NPDES permit for the main Generating Station

Maximum monthly average discharge limitations set for critical coal contaminants for the interim pond are less than National Drinking Water Quality Standards (40 CFR 141.62)

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Permit Limit (Monthly Average)</th>
<th>NDWQS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic, ppm</td>
<td>0.018</td>
<td>0.050</td>
</tr>
<tr>
<td>Cyanide, ppm</td>
<td>0.019</td>
<td>0.200</td>
</tr>
<tr>
<td>Selenium, ppm</td>
<td>0.017</td>
<td>0.050</td>
</tr>
</tbody>
</table>
Process Wastewater Compliance

To meet the stringent waste water requirements of the Interim Pond (102), WREL undertook testing and evaluation of several treatment technologies for removing the contaminants of concern.

• Chemical Induced Precipitation
• Reverse Osmosis
• Mechanical Vapor Recompression (MVR)

MVR proved to be the only acceptable solution for meeting compliance limits.
E-GAS TECHNOLOGY FOR GASIFICATION

Process Wastewater Compliance

100 GPM Mechanical Vapor Recompression process to strip and dehydrate (to a salt) the majority of the contaminants in a selected process wastewater stream with beneficial water re-use of the condensed vapor.

Contract issued in May of 2001

Construction complete by mid-September of 2001 awaiting restart of the CT for final operational testing.
Sulfur

Removed from the syngas chemically after the gasification process
Produced as 99.99% pure elemental sulfur
Leaves plant in railcars
Sold to Broker for agricultural applications, over 40,000 tons to date
E-GAS TECHNOLOGY FOR GASIFICATION

Slag

Black, glassy sandlike material
Inert, passes TCLP
Generally 3-10% Carbon in Coal Operations
Marketed for asphalt, construction backfill, landfill cover applications
Production is proportional to ash & flux content in feed
E-GAS TECHNOLOGY FOR GASIFICATION

Slag Analysis

Analysis mirrors ash content of coal, with < 5% carbon and sulfur

Typical Analysis (Coal Operation, August 1999)

<table>
<thead>
<tr>
<th>ASH</th>
<th>SiO2</th>
<th>51.8 %</th>
<th>Al2O3</th>
<th>18.7%</th>
</tr>
</thead>
<tbody>
<tr>
<td>TiO2</td>
<td>0.9</td>
<td></td>
<td>Fe2O3</td>
<td>20.3</td>
</tr>
<tr>
<td>CaO</td>
<td>4.2</td>
<td></td>
<td>MgO</td>
<td>0.8</td>
</tr>
<tr>
<td>Na2O</td>
<td>1.0</td>
<td></td>
<td>K2O</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Trace Metals same as coal ash, but now captured in non-leaching glassy matrix:

Lead, Nickel, Arsenic, Selenium, Chrome, Antimony, Zinc, Vanadium and Nickel

<300 ppm individually <1000 ppm aggregate
## Coal Slag Analysis – Leachability

<table>
<thead>
<tr>
<th>Component</th>
<th>RCRA Limit</th>
<th>UTS Limit</th>
<th>Wabash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antimony</td>
<td>-----</td>
<td>2.1 mg/l</td>
<td>not tested</td>
</tr>
<tr>
<td>Arsenic</td>
<td>5 mg/l</td>
<td>5.0 mg/l</td>
<td>below UTS</td>
</tr>
<tr>
<td>Barium</td>
<td>100 mg/l</td>
<td>7.6 mg/l</td>
<td>below UTS</td>
</tr>
<tr>
<td>Beryllium</td>
<td>-----</td>
<td>0.014 mg/l</td>
<td>not tested</td>
</tr>
<tr>
<td>Cadmium</td>
<td>1 mg/l</td>
<td>0.19 mg/l</td>
<td>below UTS</td>
</tr>
<tr>
<td>Chromium (total)</td>
<td>5 mg/l</td>
<td>0.86 mg/l</td>
<td>below UTS</td>
</tr>
<tr>
<td>Cyanides (total)</td>
<td>-----</td>
<td>590 mg/kg3</td>
<td>below UTS</td>
</tr>
<tr>
<td>Mercury (non WW)</td>
<td>0.20 mg/l</td>
<td>0.20 mg/l</td>
<td>below UTS</td>
</tr>
<tr>
<td>Mercury (all other)</td>
<td>0.02 mg/l</td>
<td>0.025 mg/l</td>
<td>below RCRA</td>
</tr>
<tr>
<td>Nickel</td>
<td>-----</td>
<td>5 mg/l</td>
<td>below UTS*</td>
</tr>
<tr>
<td>Selenium</td>
<td>1 mg/l</td>
<td>0.16 mg/l</td>
<td>below UTS</td>
</tr>
<tr>
<td>Silver</td>
<td>5 mg/l</td>
<td>0.3 mg/l</td>
<td>below UTS</td>
</tr>
<tr>
<td>Thallium</td>
<td>-----</td>
<td>0.078 mg/l</td>
<td>not tested</td>
</tr>
<tr>
<td>Vanadium</td>
<td>-----</td>
<td>0.23 mg/l</td>
<td>below UTS*</td>
</tr>
<tr>
<td>Zinc</td>
<td>-----</td>
<td>5.3 mg/l</td>
<td>not tested</td>
</tr>
</tbody>
</table>

*Single pass and recycle ( * single pass only)
WABASH RIVER
SOCIAL IMPACT
E-GAS TECHNOLOGY FOR GASIFICATION

PROJECT SITE

Repowering Unit 1 (90 MW) of Six Unit 888 MW PC plant
Approximately 40 Acres on existing powerplant and coal mine property
Site located on reclaimed mine entrance area
Viking and Saxton coal mines (abandoned) underly the site
Nearest residence one half mile away (nearer existing plant)
E-GAS TECHNOLOGY FOR GASIFICATION

PROJECT BENEFITS

Thousands of Tons of Emissions Reductions, More Power
Neighbors already live next to old coal fired plant - IMBY

1000 Construction Jobs
100 Permanent Jobs
Expanded Tax Base
More Coal Mining Jobs

Accelerated Permitting Schedule
### WABASH RIVER PROJECT SCHEDULE

<table>
<thead>
<tr>
<th>MILESTONES</th>
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<th>92</th>
<th>93</th>
<th>94</th>
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<tbody>
<tr>
<td>Proposal for Clean Coal IV</td>
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<td>DOE Selection</td>
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<td>IURC Approval</td>
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### ENVIRONMENTAL PERMITS

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<td>Environmental Information Vol</td>
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<td>NEPA Process</td>
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### MAJOR EQUIPMENT FABRICATION

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### CONSTRUCTION

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### START-UP

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</table>
E-GAS TECHNOLOGY FOR GASIFICATION

Next Step IGCC Applications for Coal

EVEN BETTER!

<table>
<thead>
<tr>
<th></th>
<th>Wabash</th>
<th>Current IGCC 2001 Award</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Rate, Btu/kWh HHV</td>
<td>8900</td>
<td>8400</td>
</tr>
<tr>
<td>SO x, lb/MMBtu</td>
<td>0.13</td>
<td>0.04</td>
</tr>
<tr>
<td>NO x, ppm</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>Particulate (PM10)</td>
<td>0.011</td>
<td>0.011</td>
</tr>
<tr>
<td>Hg, lb/trillion Btu</td>
<td>3.2 (50%)</td>
<td>0.3 (95%)</td>
</tr>
</tbody>
</table>
E-GAS TECHNOLOGY FOR GASIFICATION