Coal Gasification
Now Is The Time
Indiana Is The Place

TATA Chemicals Innovation Centre Visit
Purdue University

May 22, 2008

Brian H. Bowen, Marty W. Irwin
765-494-1873  bhbowen@purdue.edu
The purpose of the Center for Coal Technology Research, CCTR (created by state legislation in 2002) is to address the vital issue of determining suitable coal technologies which will meet the economic & environmental priorities of Indiana.

2008 research areas important to coal & which are being considered: (1) gasification technology (2) infrastructure expansion (3) carbon management

CCTR is a state agency providing seed grants to appropriate coal technology proposals.
U.S. Coal Basins & Energy Supplies from Coal

Illinois Coal Basin, ICB
Illinois, Indiana, W.Kentucky

Bitumimous Coal
- Heat Content 11,000 Btu/lb
- Sulfur 2.1 % weight
- Ash 8.9% weight

http://www.eia.doe.gov/emeu/mer/overview.html
Indiana’s Coal Resources & Electricity Demand Growth

Current production = 35MTons/year
17.5 Billion/35 Million = 500 years

Coal (Low price, $1-2/MBtu)
Nuclear (12 - 15 years?)
Natural gas (High price, $8-9/MBtu)

45.9% increase

USGS Availability System

Source: Mistleaz, IGS, 2007

Each category includes summation of assessed (0 to 0.5 miles from data point), indicated (0.5 to 2 miles from data point), and inferred (> 2 miles from data point) resources.
Midwest ISO 2008-2027, Futures Scenarios
Cumulative New Generation Capacity (MW)

MISO Modeling Results
2006 Coal Destination: Indiana

69 MTons Consumption, 35 MTons Production

State Total Consumption of 65,046 (Thousand short tons) & Methods of Transportation

**Wyoming:** 11,927 Total
- 11,686 Electricity Generation
  - Rail
  - Industrial: 240 River
- 2,226 Total
  - 2,226 Electricity Generation
  - Rail

**Montana:** 2,226 Total
- 2,226 Electricity Generation
  - Rail

**Utah:** 164 Total
- 164 Industrial
  - Rail

**Colorado:** 153 Total
- 109 Electricity Gen.
  - Rail: 44 Industrial

**Illinois:** 6,450 Total
- 5,347 Electricity Generation
  - Rail: 4,672 River: 428 Truck: 589
  - 761 Industrial Plants
  - Rail: 675 Truck: 86

**Kentucky:** 1,371 Total
- 882 Electricity Generation
  - Rail: 530 River: 352
  - 489 Industrial Plants
  - Rail: 392 Truck: 97

**Alabama:** 946 Total
- 944 Coke
  - Rail

**West Virginia:** 7,434 Total
- 1,131 Electricity Generation
  - Rail: 873 River: 257
  - 4,525 Coke Plants
  - Rail
  - 1,778 Industrial Plants
  - Rail: 1,587 Truck: 191

**In state:** 32,965 Total
- 30,532 Electricity Generation
  - Rail: 17,021 River: 30
  - Conveyor: 3,606 Truck: 12,308
  - 2,379 Industrial Plants
  - Truck
  - 54 Residential-Commercial

**Ohio:** 195 Total
- 188 Electricity Generation
  - Rail: 73 River: 96 Truck: 19
  - 7 Industrial Plants
  - Truck

**Pennsylvania:** 546 Total
- 475 Electricity Generation
  - Rail: 223 River: 251
  - 68 Industrial Plants
  - Truck

**Virginia:** 670 Total
- 670 Coke Plants
  - Rail

**Indiana Destination Totals:**
- 52,917 Electricity Generation (81%)
  - [this includes 5,127 synfuel]
- 6,140 Coke Plants (9%)
- 5,932 Industrial Plants (9%)
- 57 Resid-Com (1%)

Source: http://www.eia.doe.gov/oiaf/coalpage/coaldistrib/coal_distributions.html
Uncertainty on CO₂ Legislation & Coal-Fired Power Plant Emissions

2006 Indiana Utilities, Amounts Emitted

<table>
<thead>
<tr>
<th>Thousand Metric Tons</th>
<th>Lbs/MWh</th>
<th>Examples of Control</th>
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<tbody>
<tr>
<td>SO₂</td>
<td>758.0</td>
<td>12.8</td>
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<tr>
<td>NO₂</td>
<td>202.0</td>
<td>3.4</td>
</tr>
<tr>
<td>CO₂</td>
<td>121,950.0</td>
<td>2,060.0</td>
</tr>
</tbody>
</table>

Wet & dry FGD processes

Staging, low-NOₓ burners, SCR, SNCR

Amine scrubbers

Source: [http://www.eia.doe.gov/cneaf/electricity/st_profiles/indiana.html](http://www.eia.doe.gov/cneaf/electricity/st_profiles/indiana.html)

Indiana Power Plants produce 148 MTons of CO₂/ year
Emissions & Legislative Uncertainty

Uncertainty is key policy word for CO\textsubscript{2}. Planners & investors are in limbo. The magnitude of the costs for carbon management will be huge.

Currently there is no CO\textsubscript{2} regulation. Considerable debate on CO\textsubscript{2} trading, tax, capture & storage in coming years, but for how long?

CO\textsubscript{2} capture is easier & cheaper with pre-combustion (IGCC) than with post-combustion on existing power plants. Oxyfuel is an option being assessed.

Coal continues to be the most stable & cheapest energy source.
Gasification, CCS, CTL
Gasification, Carbon Capture & Sequestration, Coal To Liquids

Indiana’s Wabash Valley IGCC Developments:
• Wabash River Gasification Project, 1994, DOE Clean Coal Technology (CCT) Demonstration Program
• Edwardsport (20% CO₂ capture study), Duke Energy
• CTL latest development at Crane (Martin County), SAIC

Air Force Energy Bill (Fuel) exceeds $10M per day. Every $10/barrel increase drives up AF fuel costs $600M per year - security, CO₂ capture, sequestration, DOD

Midwest Sequestration Consortium, Indiana Geological Survey CFA (Midwest Coal Fuel Alliance), Purdue Teams
Existing, Wabash River Gasification

- **Started in 1994,** it was the most visited DOE research site outside of national labs for > 10 yrs
- The **longest continuously operating coal and pet coke gasifier** in the US
- Now it is **a full gasification production site** supplying syngas to Duke’s Wabash River power station using pet coke as a fuel source.
- CCTR and Purdue University want to put 1 or 2 graduate engineering students at the Wabash site for the purpose of determining the **training and education needs** of future gasifier workers
- **This facility is ready today to work on CO₂ capture,** it is already built & functioning, & designed for research activity.
- The **best short term site** for CCS testing
IGCC in the Wabash Valley

1995 Fully operational Wabash IGCC, Terre Haute, Indiana
2007 Only two IGCC plants exist in the U.S.

Unit #1 is the IGCC 292MW unit,
191MW Gas Turbine,
100MW Steam Turbine
(Total generation at site is 960MW)

Indiana Initiative:
2012 Edwardsport IGCC, Indiana
Largest IGCC in United States
Duke Energy

630MW IGGC
20% CO₂ capture study
Edwardsport IGCC
Planned  630 MW for 2012

The only IGCC that has both air permits & regulatory authority to be built

• Edwardsport has a **market in place** for its electrical production adding to the Duke Indiana capacity, a capacity that is sorely in need of new generation.
• Duke will **study how to reduce CO₂ emissions by 20%**
• Other **future IGCC facilities** will use Edwardsport as a model not only of how to build an IGCC, but also how to accommodate CO₂ capture
• Sequestration potential at site in **Mt Simon Sandstone geological formations**
Synfuels: 1-2 barrels of liquid fuel from 1Ton of Indiana coal

USAF, December 2007, C-17 cargo plane was first aircraft to fly across the continental US fueled by a 50/50 synfuel mixture composed of standard JP-8 & FT fuels
Criteria for Indiana’s NSA Crane Naval Base Gasification & Coal-To-Liquids

10 Criteria
1. Coal & natural gas availability for 10,000 B/D FT fuel
2. CO₂ sequestration potential
3. Land/real-estate requirements
4. Transportation infrastructure (rail, roads & waterways)
5. Electricity transmission lines & available power
6. Gas & oil pipelines
7. Water requirements & resources
8. Waste disposal/environmental issues
9. Labor force requirements/availability
10. Economic impact

* Many other potential sites in Indiana

http://www.purdue.edu/dp/energy/CCTR/
The key to the system will be the capture of CO$_2$ for sale to industry. At this size facility CO$_2$ could be captured, technologically viable. A good test case for how to scale up CO$_2$ technology.
Indiana Gasification LLC is planning to build a $1.5 Billion coal gasification plant, scheduled to be online in 2011.

Indiana’s 3 largest gas utilities, Vectren Corp., Northern Indiana Public Service Co. (NIPSCO) & Citizens Gas have signed a letter of intent for 30-years to use about 2/3 of the substitute natural gas that will be produced to help meet residential and commercial gas demand.

The plant will use GE Energy’s gasification technology.

The plant will operate with extremely low emissions of regulated air pollutants & will isolate CO₂ so that it can be captured & develop a CO₂ sequestration demonstration project.
Indiana Gasification Inc. This large scale coal gasifier will convert coal, 40 Bcf, to usable natural gas for distribution through the existing gas pipeline system. The location of this facility would also make it ideal as a source of CO$_2$ for the proposed CO$_2$ pipeline (Indiana, Illinois, Ohio)

Midwest Geological Sequestration Consortium
MGSC - Phase III Project Awarded
The Midwest Geological Sequestration Consortium (MGSC), & the Illinois State Geological Survey (ISGS) have been awarded a $66.7M contract from the U.S. DOE to conduct a Phase III large-scale sequestration demonstration project in the Mt. Simon Sandstone, 1MTon/3 years
Indiana & Underground Coal Gasification

2008 – Indiana study on UCG potential

Infrastructures

- Over **95%** of Indiana’s electricity is generated from coal & **50%** of the coal consumed in the state is imported (WY, IL, WV, VA, PA). How can we encourage greater use of Indiana coals?

- Indiana is home to roughly **22%** of the domestic base steel production for the United States. One essential raw material needed by this industry is coke. Initial CCTR project results indicate that it is **possible to use blended coal with up to 40% Indiana coal** in a non recovery coke oven.

- There are bottlenecks in the rail system as well as in the power grid. The export and import of electricity is limited by the load capabilities of the lines. MISO is planning the regional power grid. **What is the scope for increased coal use in the MISO plans?**
# Midwest Coal Production & Consumption

## Indiana Electricity or Coal to MI & WI?

### Wisconsin 2002 coal imports (MTons) from
- WY 21.80, MN 2.92, CO 1.50, IL 0.66, UT 0.66, PA 0.60, IN 0.39, KY 0.09

### Michigan 2002 coal imports (MTons) from
- WY 12.87, MN 6.46, WV 3.62, KY 3.52, PA 1.01, CO 0.39, OH 0.26, VA 0.12

<table>
<thead>
<tr>
<th></th>
<th>2004 Coal Consumed (MTons)</th>
<th>2005 Coal Production (MTons)</th>
<th>2004 Electricity Net Flow <em>(GWh)</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Indiana</td>
<td>73.7</td>
<td>34.5</td>
<td>-42.0</td>
</tr>
<tr>
<td>Michigan</td>
<td>38.5</td>
<td>0.0</td>
<td>-6.6</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>26.7</td>
<td>0.0</td>
<td>+33.3</td>
</tr>
</tbody>
</table>

*Net interstate flow of electricity: -ve is net export, +ve is net import*

Source: [http://www.eia.doe.gov/emeu/states/sep_use/total/use_tot_in.html](http://www.eia.doe.gov/emeu/states/sep_use/total/use_tot_in.html)
[http://www.eia.doe.gov/emeu/aer/coal.html](http://www.eia.doe.gov/emeu/aer/coal.html)
[http://tonto.eia.doe.gov/FTPROOT/coal/coaldistrib/d_mi.html](http://tonto.eia.doe.gov/FTPROOT/coal/coaldistrib/d_mi.html)
The Midwest ISO ensures reliable operation & equal access to 93,600 miles of interconnected, high voltage power lines in 15 U.S. states & the Canadian province of Manitoba. Managing one of the world’s largest energy markets, the company clears more than $2 Billion in energy transactions monthly. MISO was approved as nation’s first permanent regional transmission organization (RTO) in 2001.

Challenges facing Midwest ISO: Transmission Corridor West to East? Future capacity expansions, wind, coal, etc?

**Midwest Transmission & Generation & MISO Footprint in 15 states**

**The Midwest ISO** ensures reliable operation & equal access to 93,600 miles of interconnected, high voltage power lines in 15 U.S. states & the Canadian province of Manitoba. Managing one of the world’s largest energy markets, the company clears more than $2 Billion in energy transactions monthly. MISO was approved as nation’s first permanent regional transmission organization (RTO) in 2001.

**MISO 156 GW**
- 920,000 sq miles
- 52% Coal, 1% Hydro
- 23% Gas, 8% Nuc

**India 150 GW**
- 1,268,000 sq miles
- 62% Coal, 27% Hydro
- 10% Gas, 3% Nuc
Coke & Coal By Rail

World Coke Production: 2005 forecasts indicate that the US would produce 11.5 MTons of coke, but required 17.0 MTons for blast furnace, foundry, and related uses. At present no IN coal is being used.

Railroad Study: Specific logic for each station in the timetable according to the notation and interlock columns are included in the simulation. Train speed, with appropriate random factors are also defined by the timetable on a station-by-station basis.
Coal Gasification in Illinois, Ohio, & Kentucky

Global Energy’s Lima Project On Track to Become Third U.S. IGCC Plant - Sequestration Plans to Follow Ohio (Under construction)
The petcoke-fired co-production Lima plant is set to start producing 600MW of electricity, 26 Bcf/year of pipeline quality synthetic natural gas & 12 million scf/day of hydrogen in 2008.

Baard Energy CBTL Project
- 50,000 barrels/day CBTL plant at Wellsville, Ohio on Ohio River
- Builds on Buggenum C/B co-gasification experience:
  - Shell gasifier
  - Up to 30% biomass planned
  - CCS planned...CO₂ for EOR (nearby oil field) or stored in deep saline formation
- GHG emission rate for FTL ~ ½ rate for crude oil-derived products displaced...IF fired with 30% biomass and 85% of C not contained in products is captured as CO₂

Kentucky Coal Gasification Incentives Bill:
Aims at creating incentives in the form of income & sales tax rebates for coal gasification & alternative fuel plants

TEC, Taylorville Energy Center, Illinois
# Coal Gasification in Illinois & Ohio

## Under Construction & Proposed

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Technology</th>
<th>Location</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Clean Coal Fuels (ACCF)</td>
<td>CTL</td>
<td>Illinois</td>
<td>Proposed</td>
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<tr>
<td>Cardinal Energy Project</td>
<td>IGCC</td>
<td>Illinois</td>
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<tr>
<td>Clean Coal Power Phase 1</td>
<td>IGCC</td>
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<td>Drummond Co. (Birmingham, AL)</td>
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<td>Peabody Energy / Arclight Capital</td>
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<td>Power Holdings of Illinois LLC</td>
<td>Coal-to-SNG</td>
<td>Illinois</td>
<td>Pre-FEED</td>
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<td>Rentech Energy Midwest Corp. (REMC)</td>
<td>Fertilizer/CTL</td>
<td>Illinois</td>
<td>Shelved</td>
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<td>Taylorville Energy Center</td>
<td>IGCC/SNG</td>
<td>Illinois</td>
<td>Feasibility Study</td>
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<td>Secure Energy Inc.</td>
<td>SNG</td>
<td>Illinois</td>
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<tr>
<td>Southern Illinois University-Carbondale (SIUC) IGCC</td>
<td>IGCC</td>
<td>Illinois</td>
<td>Feasibility Study</td>
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<td>Air Force</td>
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<td>American Clean Coal Fuels (ACCF)</td>
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<td>Americal Electric Power’s Ohio Power</td>
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<td>Baard Generation 2 project</td>
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<td>Lima Energy Co. / Cincinnati (Global Energy)</td>
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[http://www.zeuslibrary.com/VEL/Gasification/]  

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## Coal Gasification in Kentucky & India
### Operational, Under Construction, Planned & Proposed

<table>
<thead>
<tr>
<th>Project</th>
<th>Type</th>
<th>Location</th>
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<td>Appalachian Power</td>
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<td>Cash Creek Generation</td>
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<td>Peabody Energy</td>
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<td>BP &amp; Reliant Industries Ltd. UCG projects</td>
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<td>Energy Quest's Indian IGCC Projects</td>
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<td>GAIL/Coal India Coal-to-Fertilizer Project</td>
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<td>Gujarat UCG Project Well</td>
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<td>Reliance Industries' CTL Project</td>
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<td>RIL’s Petcoke Gasification Project</td>
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<td>Singareni UCG Project</td>
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[http://www.zeuslibrary.com/VEL/Gasification/]
Investment in Indiana

- Indiana **Gross State Product** is $211 Billion (2005)
- Coal adds $750+ Million and 2,836 jobs to the Indiana economy ($2B total impact & 11,000 direct/indirect jobs)
- Coal, unlike petroleum or natural gas, has its **entire economic impact within the state’s borders**
- Coal is mined, washed, transported, consumed & the waste is recycled or disposed within the state; each phase generating jobs & revenue streams
- The **coal dollar multiplies faster & further** than any other industrial economic activity. How best to use it?

* Expanding the Utilization of Indiana Coals, page 20
More Coal – But are We Ready?

The Energy Workforce of the Future

- All energy industries face issues
  - Coal miners are retiring; average age 51
  - Technologies are changing
  - Boilermakers are offshore
  - Nuclear welders do not exist
  - Stigma of a vocational technical education
  - Power generation industry – average age 50
    - Employs 1 million nationwide
    - ½ workforce retirement in 5-10 years
    - 62% of managers are 50 and older
    - 61% of line superintendents are 50 and older
    - 43% of foremen are 50 and older

southern states energy board
Conventional & Future Liquid Fuel Use
Coal Investments for India & Indiana

Economics, emissions & risk are the key issues for commercialization of new technologies

With crude oil costing $135 per barrel there is increasing interest in coal gasification & CTL

Variable incentive starts at $45/barrel & no losses/risks occur