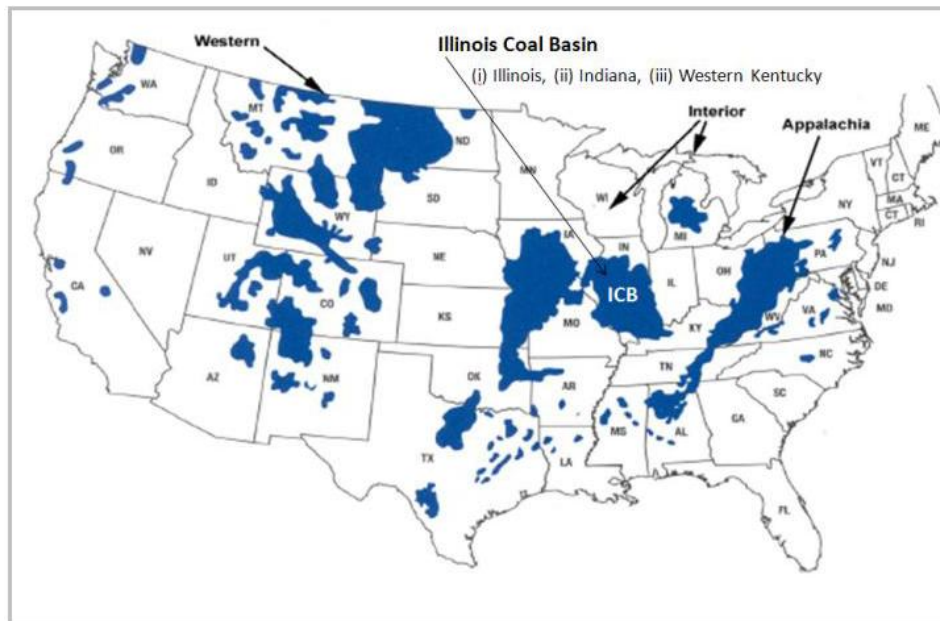


# 21<sup>st</sup> Century Coal Technology for Indiana

Brian H. Bowen  
Center for Coal Technology Research  
Energy Center at Discovery Park  
Purdue University

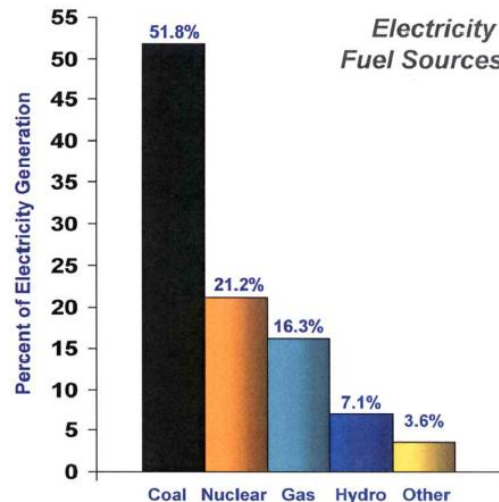
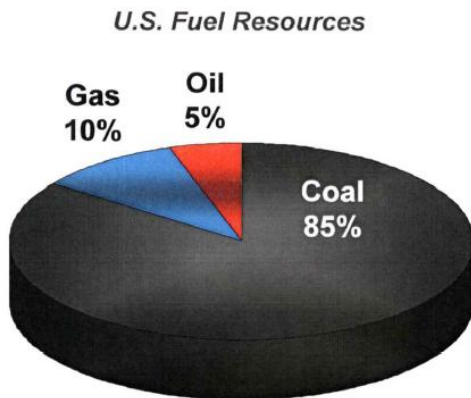
Kazakhstan Visiting Team to Purdue Energy Center  
May 6, 2009

<http://www.purdue.edu/dp/energy/CCTR/index.php>



# U.S. Energy Reserves with so Much Coal

- Importance of **energy security** & huge **U.S. coal reserves**
- How to **balance economics** & the environment



- Let's look at **USA/Indiana & Kazakhstan**
- Then **Indiana's coal projects**

Ultimately recoverable demonstrated reserves on Btu basis. Source: USGS, National Assessment of United States Oil and Gas Resources, U.S. Coal Reserves; Energy Information Administration Monthly Energy Review, May 2003, Table 7.2b, 2002 data.

## City Water Gets Cleaner & So Does Coal

Despite government regulations and incredible advancements & **improvements over the past 50 years** in water technology, the water issuing from home taps **is still quite contaminated**. Chlorine has been linked to asthma & other respiratory diseases, & excessive fluoride intake can lead to yellowed teeth, dental problems, & other serious health problems for young children.

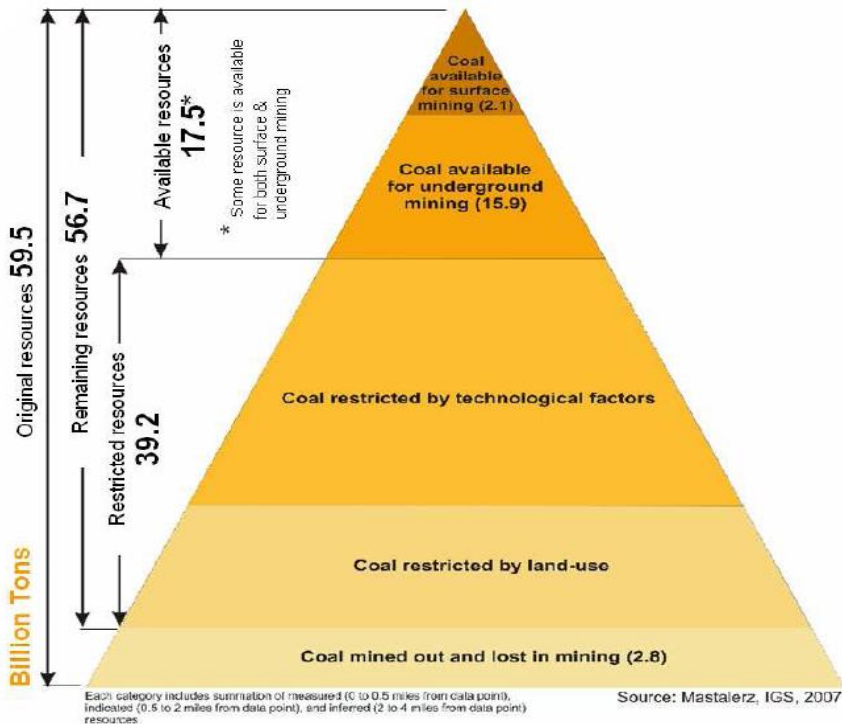


## Kazakhstan's Coal Reserves, Production & Consumption

Kazakhstan contains Central Asia's largest recoverable coal reserves, with **34.5 Billion short tons** of mostly **anthracitic and bituminous coal**. Kazakhstan **produced 106 million short tons (MTons) in 2006**, while consuming **78 MTons**, resulting in net exports of 28 MTons.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
<b>Coal (Million Short Tons)</b>											
Production ⓘ	78.1	65.9	81.7	87.2	81.3	93.6	95.8	95.4	106.1	95.2	NA
Consumption ⓘ	54.4	51.0	55.4	57.0	58.6	66.6	69.0	70.4	75.9	74.3	NA
Net Exports/Imports(-) ⓘ (Trillion Btu)	393.2	278.9	443.1	486.8	376.5	425.7	428.6	411.6	499.1	343.8	NA

# Indiana's Coal Resources



Indiana's 17.5 BTons of "Home Grown Energy" in reserves.  
There are hundreds of years of energy supply in the state

Indiana consumes 70 MTons/yr & produces 35 MTons/yr

## Illinois Coal Basin (Billion Tons)

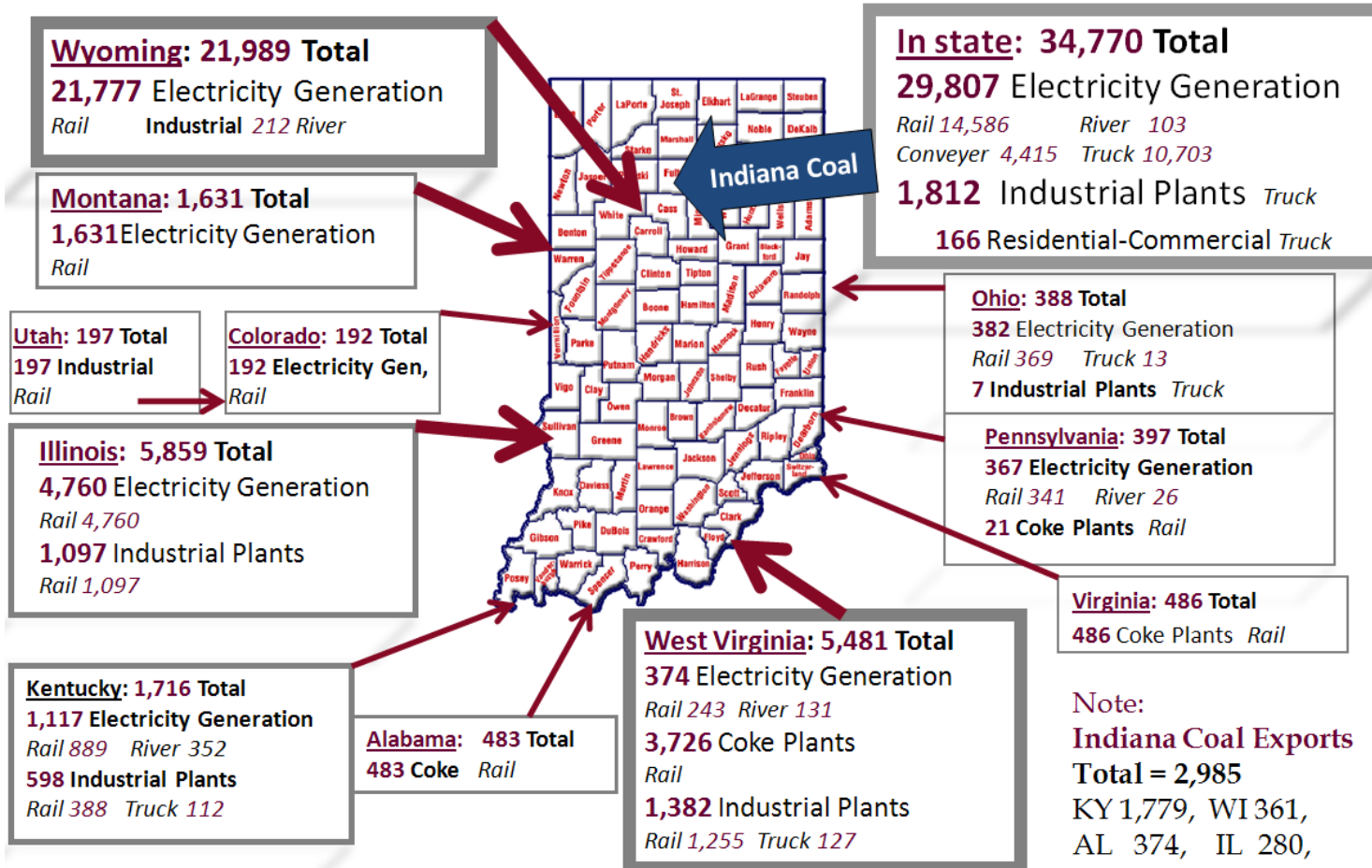
	Estimated Recoverable	Demonstrated Reserve Base
Indiana	4.134	9.637
Illinois	38.061	104.648
W. Kentucky	9.082	19.637
<b>TOTALS</b>		
IL Basin Coal	51.277	133.922
U.S. Total	269.457	497.708

# 2007 Coal Destination: Indiana

## 70.6 MTons Consumption, 34.7 MTons Production

State Total Consumption = 70,604 Thousand short tons

Methods of Transportation: Rail 52,441, Truck 12,935, River 813, Conveyor etc 4,415



Source: [http://www.eia.doe.gov/cneaf/coal/page/coaldistrib/coal\\_distributions.html](http://www.eia.doe.gov/cneaf/coal/page/coaldistrib/coal_distributions.html)

## **Kazakhstan Electricity & Coal**

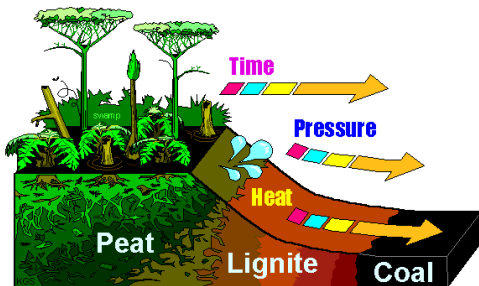
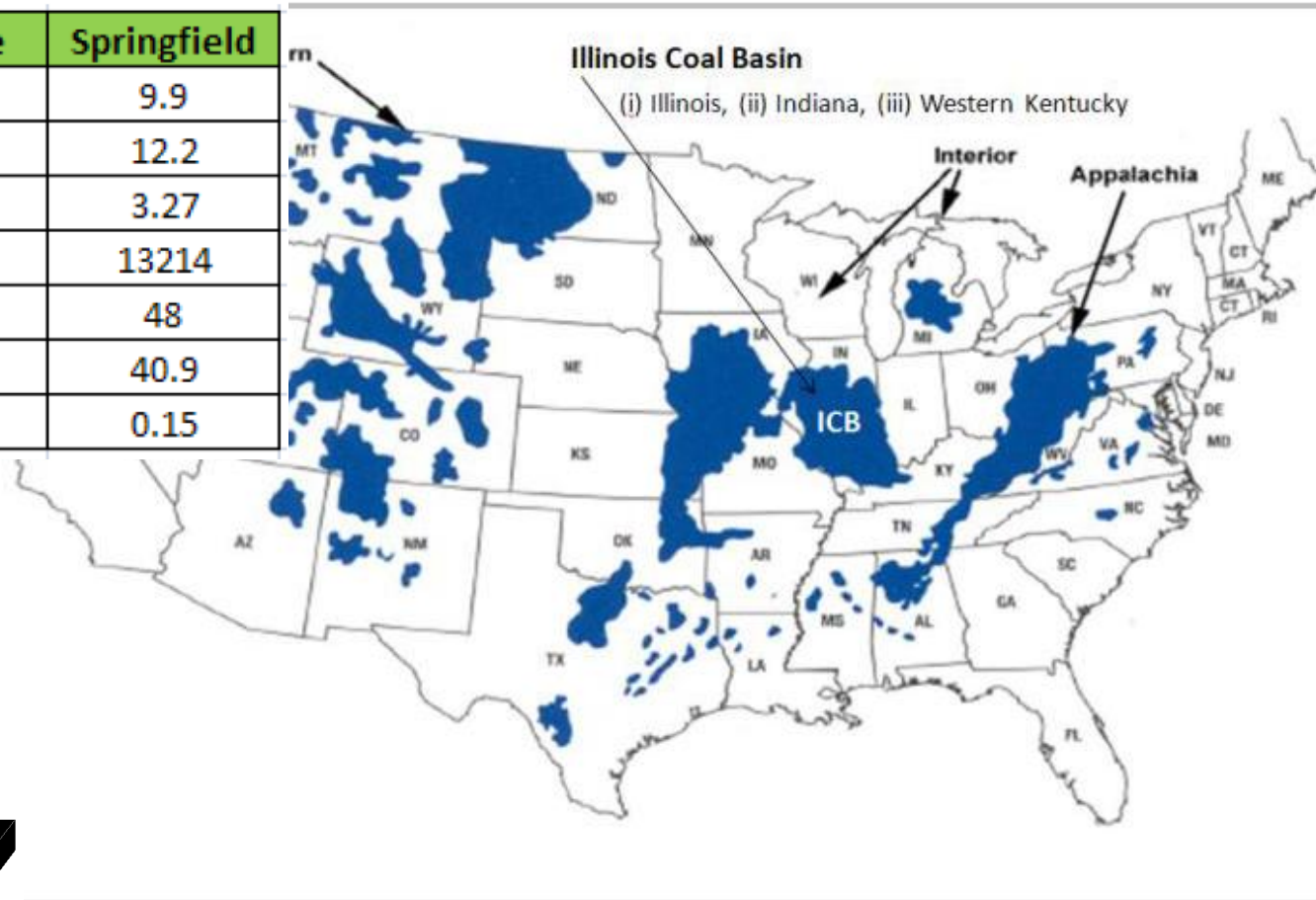
**Kazakhstan** has 71 power plants, including five hydroelectric power stations, giving the country an overall installed **generating capacity of 17 GW, 80% of which are coal fired**, & 12 % of which are hydroelectric. Almost 85 % of the country's power generation comes from coal-fired plants located in the northern coal producing regions.

**Indiana's 24 GW provides 95%** of it's electricity demand from coal-fired power plants.

# Indiana's Bituminous Coal Characteristics

## Illinois Coal Basin – Illinois, Indiana, W.Kentucky

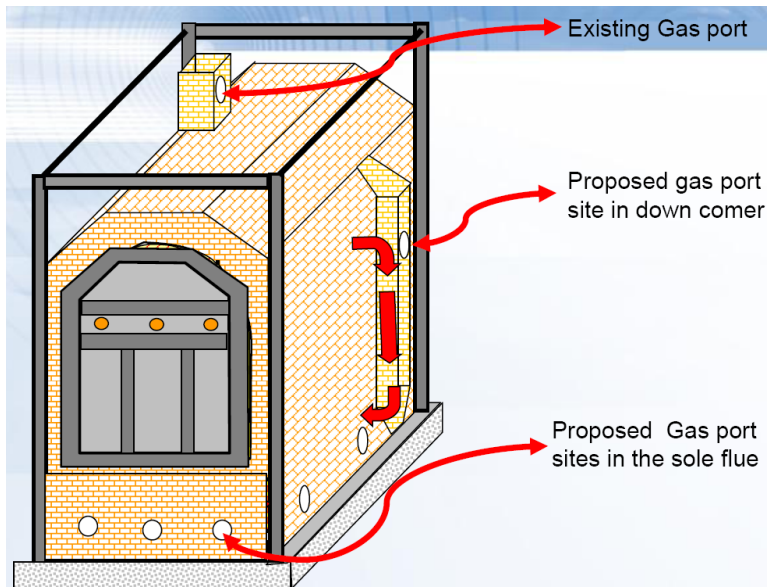
	Danville	Springfield
Moisture %wt	11.3	9.9
Ash %wt	13	12.2
Sulfur	2.65	3.27
Btu/lb (dry)	13050	13214
Fixed Carbon	48.4	48
Volatile Matter	39.1	40.9
Chlorine %	0.03	0.15



# Indiana's Coke & Rail Network

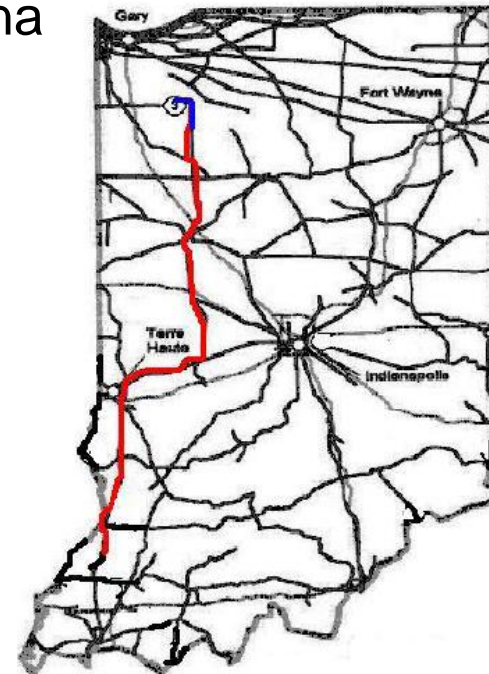
## CCTR & Purdue Calumet

How to replace the 6 Million tons (+) of imported metallurgical coal with Indiana coal



## CCTR & Purdue North Central

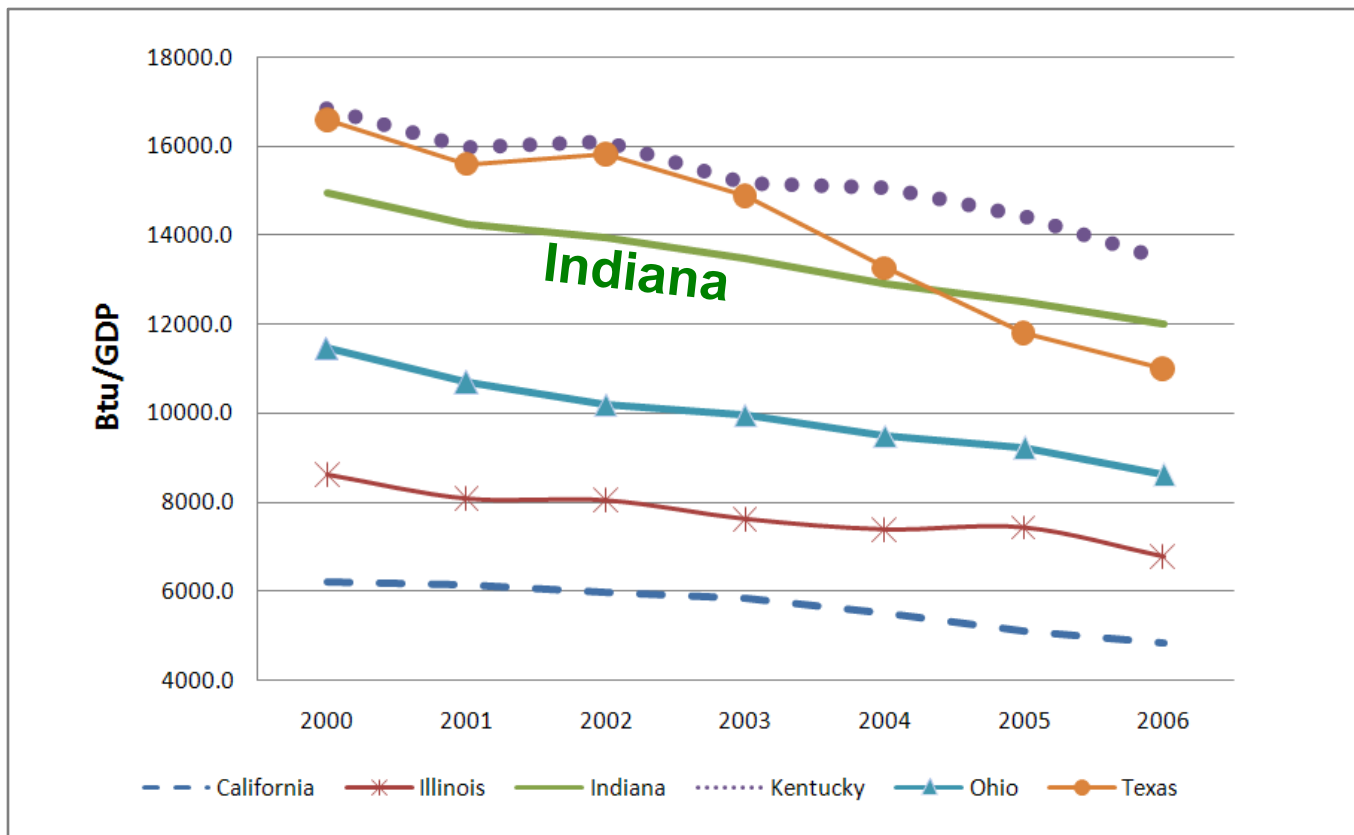
Software modeling of optional expansion and operational plans of the railroad network in Indiana



Scenario 6: Prosperity to Schahfer vis West link with North link

# Energy Intensity is Declining, Btu/GDP

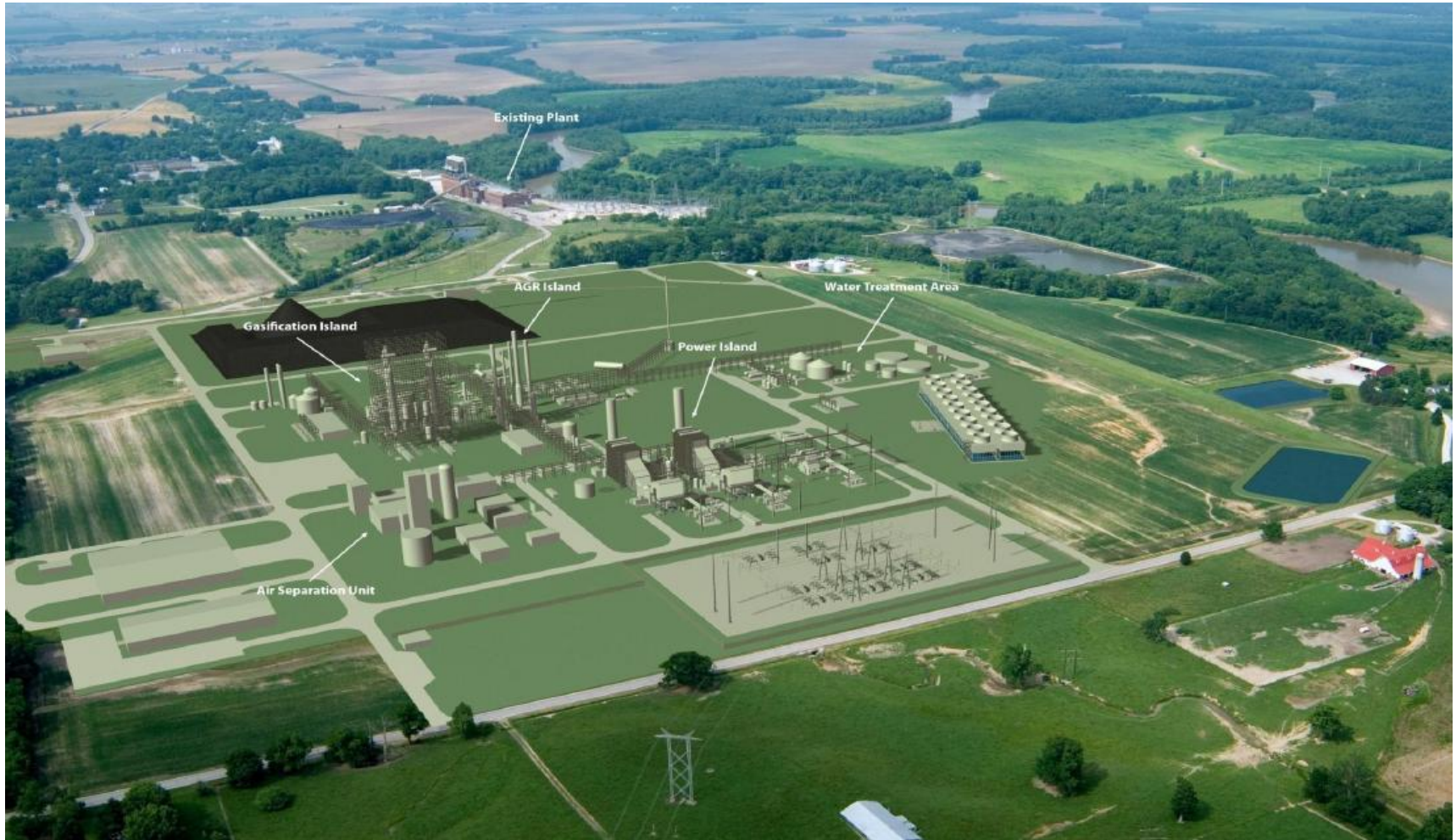
**Good news:** Promotion of improved energy efficiency, in US states ~ less energy is consumed per \$ of GDP



Sources: GDP Data is from :<http://www.bea.gov/regional/gsp/>Source: Energy Consumption Data is from EIA's webpage and GDP data is from Bureau of Economic Analysis

[http://www.eia.doe.gov/emeu/states/state.html?q\\_state\\_a=il&q\\_state=INDIANA](http://www.eia.doe.gov/emeu/states/state.html?q_state_a=il&q_state=INDIANA),  
[http://www.eia.doe.gov/emeu/states/state.html?q\\_state\\_a=il&q\\_state=ILLINOIS](http://www.eia.doe.gov/emeu/states/state.html?q_state_a=il&q_state=ILLINOIS), etc

# Duke Energy Indiana Edwardsport 630MW IGCC (800 MW)



Rob Burch, Duke Energy, Purdue University, April 16, 2009

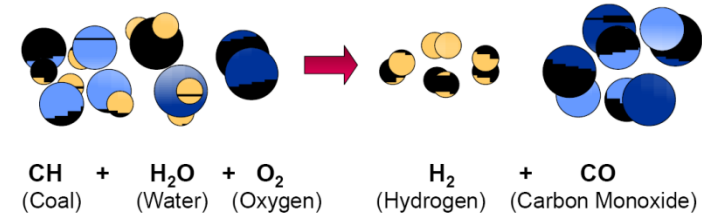
## **(1) Duke Energy Indiana, Edwardsport, 630MW IGCC (800 MW)**

- Net Output: 632 MW
- Heat Rate: < 9,000 Btu/kWH
- Target Availability: 85%
- Low Emissions Profile
- Total Installed Cost: \$2.35 billion
- Bulk Materials:
  - 1MM cubic yards of soil to be moved
  - 94,000 cubic yards of concrete
  - 12,000 tons of structural steel
  - 330,000 linear feet of piping
  - 3.6MM feet of electrical cable
- Projected Commercial Operation Date: Summer 2012

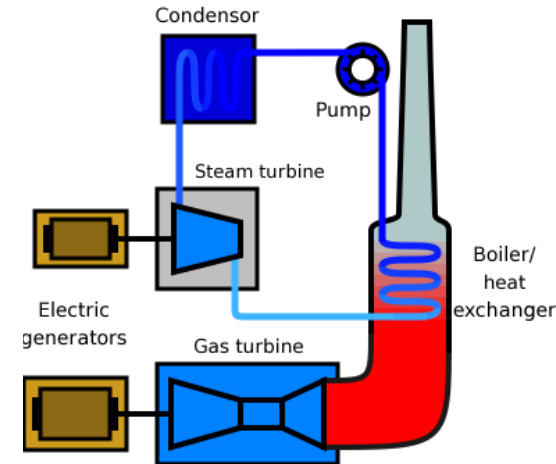
**(2) Wabash Valley  
IGCC plant** ~ one  
of the two IGCC  
power plants  
in the USA

# Edwardsport IGCC

- Two trains of General Electric radiant quench gasification equipment
  - Two 1,800 cubic foot entrained flow gasifiers
  - Two Radiant Syngas Coolers
  - Two trains of gas cooling particulate removal, sulfur conversion, and mercury removal equipment
  - Two trains slag of removal equipment
  - Two trains of sulfur removal consisting of physical solvent contact absorption – common stripper
- Two General Electric 7FB IGCC syngas combustion turbines
  - 232 MW Each
- Two Doosan, 2 pressure heat recovery steam generators
- One General Electric four flow, reheat steam turbine
  - 320 MW
- Two trains of Air Products air separation equipment – integrated into process
- One 345kV switchyard
- Balance of Plant Equipment
  - Coal unloading and handling system of truck and rail delivery of coal and removal of byproducts
  - Raw water supply and treatment
  - Wastewater treatment system
  - One 20 cell mechanical draft cooling tower
  - One General Electric Mark VIe distributed control system



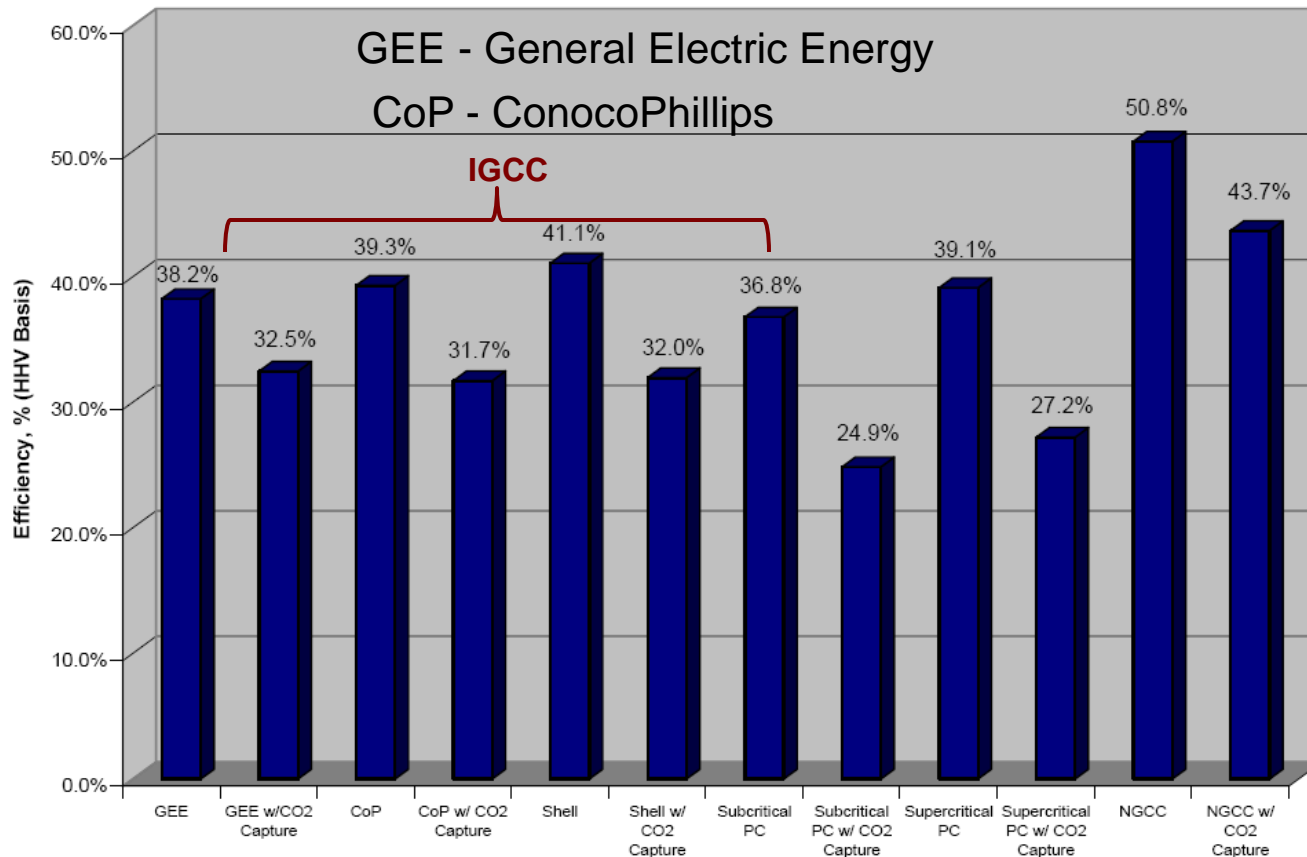
## Combined Cycle



**New federal administration  
FutureGen in Illinois  
IN & IL MOU**

# Net Plant Efficiency & Fossil Energy Options

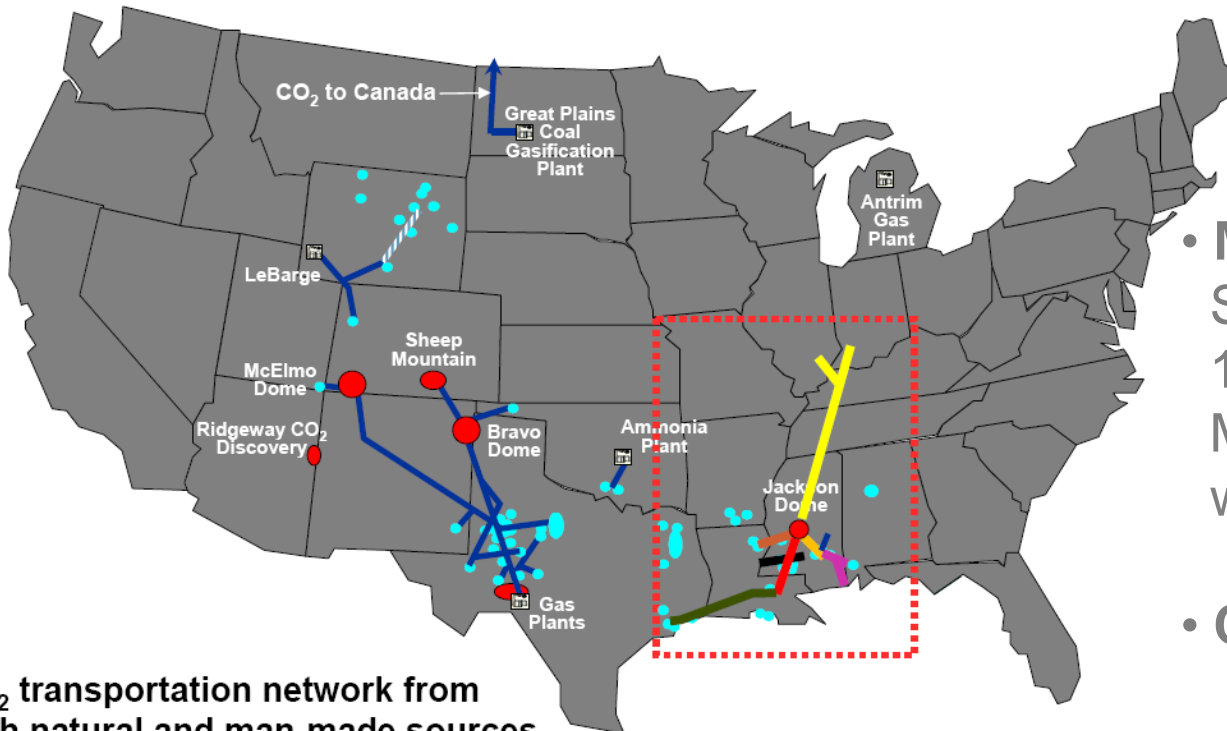
Higher efficiency means less operational expensive  
& reduced emissions per unit of MWh generated



- The most likely U.S. base-load coal technologies for the next 50 years?
- What will be the cost of electricity?

# CO<sub>2</sub> Use, Gas Pipelines, Carbon Highways

CO<sub>2</sub> use has +ve cash flow compared with storage



- **Midwest Consortium**  
Starting to pump  
1 MTons of CO<sub>2</sub> under  
Mount Simon Sandstone &  
will take 3 years
- **CO<sub>2</sub> pipeline project**

## Indiana Gasification LLC

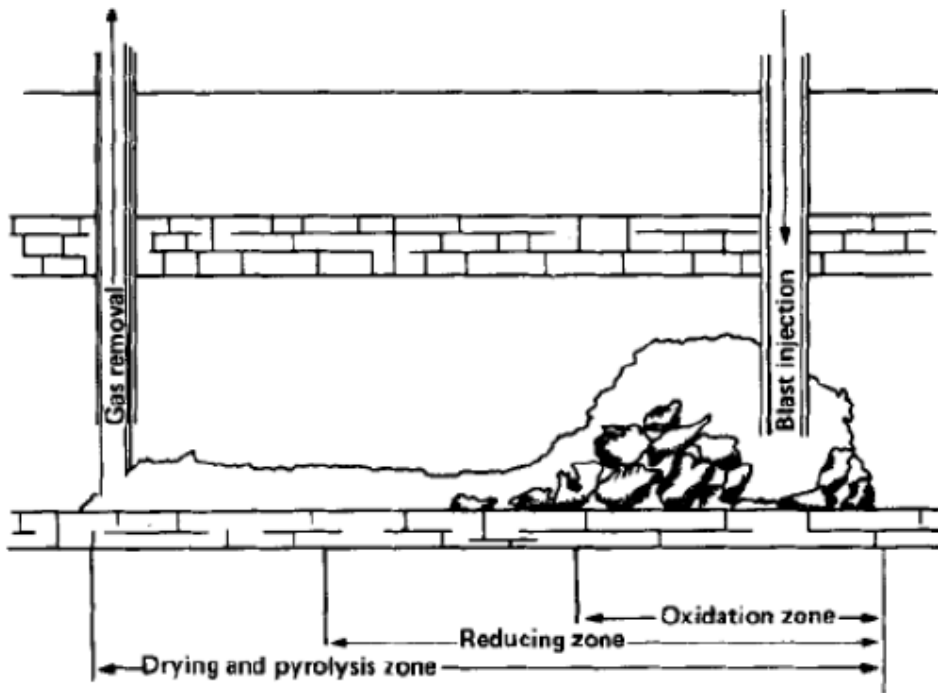
Using Indiana coal to produce synthetic gas

In 2007, the Indiana General Assembly enacted legislation that provided a tax credit for Indiana Gasification LLC to build a gasification plant in Southwest Indiana

# Underground Coal Gasification, UCG

CCTR & Purdue School of Chemical Engineering

UCG reduces capital expenditure & stores CO<sub>2</sub>  
Indiana site selection assessments



Thickness	Suitability
> 2.0 m	high
1.5 – 2.0 m	medium
1.0 – 1.5 m	low
< 1.0 m	unacceptable

Depth	Suitability
> 200 m	high
60 - 200 m	adequate
< 60 m	unacceptable

# CCTR Investigations into CTL Site Selection

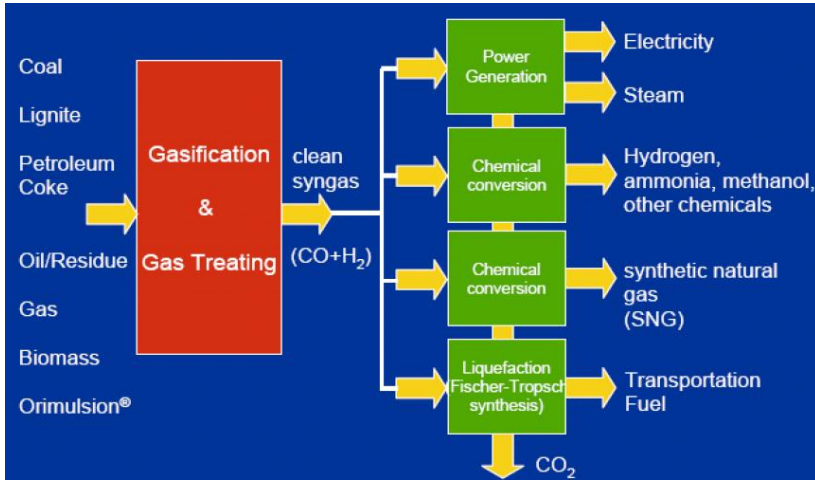
## 10 Criteria

- 1 Coal & natural gas availability for 10,000 B/D FT fuel
- 2 CO<sub>2</sub> 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

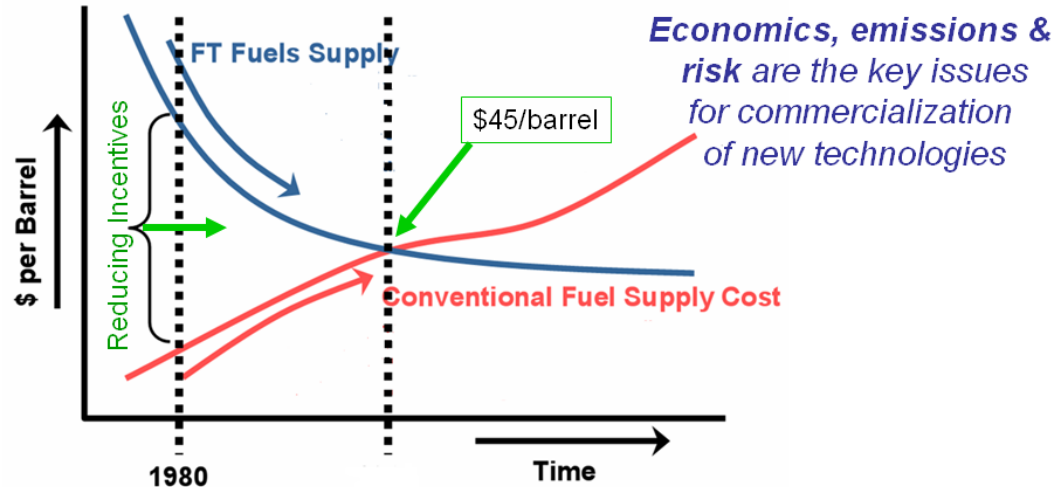
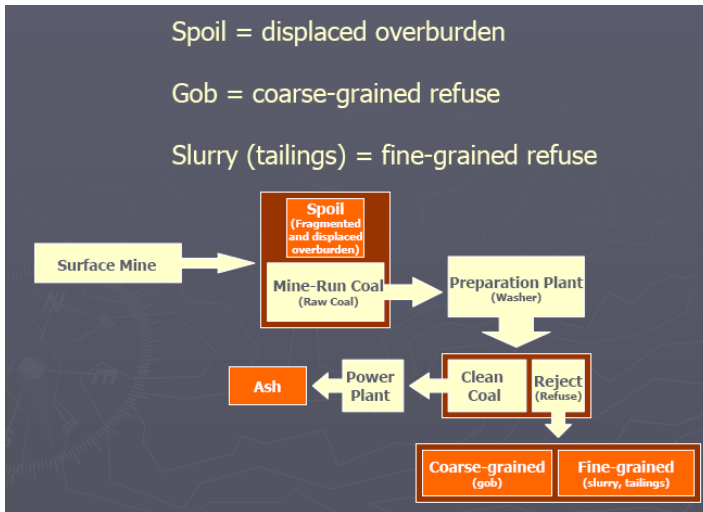
**NSA Crane**  
100 sq miles  
**MARTIN County**



# CTL, Slurry Reuse, Economic Studies



- Coal-To-Liquids, CTL options
- Reuse of coal slurry ponds
- CTL Economics Study
- Illinois Basin Alliance Study



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

<http://www.purdue.edu/dp/energy/CCTR/index.php>

**PURDUE UNIVERSITY** **Discovery Park** Energy Center

DP Centers Home People Research About Resources  Search

**CCTR**  
**Indiana Center for Coal Technology Research**  
Located in The Energy Center at Discovery Park, Purdue University

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**Energy Center Home**

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**Presentations**  
By Topic  
By Location

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**Research Reports**

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News

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**Director's Welcome**

Welcome to the website of the Center for Coal Technology Research (CCTR), an Indiana state agency located at Purdue University's Energy Center at Discovery Park. The legislated objective of the CCTR is to promote the use of Indiana's coal reserves in an economically and environmentally sound manner. To achieve this the CCTR concentrates on the development and implementation of strategic appropriate clean coal technologies through funding scoping studies, industrial and commercial application projects, long-term development projects, technology designs and demonstration projects, coal research seminars and forums, and educational materials. We hope you will find our website helpful and informative. Please send any questions you might have and requests for further information to our staff.

**Keeping Up with Coal Developments ...**

 *Assessment of the Quality of Indiana Coals for Integrated Gasification of IGCC Performance*  
Maria Mastalerz et al., Indiana Geological Survey ~ December 11, 2008

 Arch Coal, Inc. *Coal and the Economy*  
Robert W. Shanks, Arch Coal Inc. ~ December 11, 2008

 *Steel Production and the Industrial Economy*  
Eric Knorr, ArcelorMittal ~ December 11, 2008

## CCTR Funded Project Areas

- Indiana Coal Characteristics
- Indiana Coals for Coke
- Coal Transportation
- Slurry Ponds Evaluation
- Site Selection for Gasification
- Coal-To-Liquids Site Selection
- Plasma Arc Gasification
- Indiana Coal Forecasting
- UCG Gasification
- Benefits of Oxyfuel Combustion
- Economic Assessment of CTL
- Coal & the DOD
- FT Fuel & Engine Testing