



Indiana Center for Coal Technology Research
Located in the Energy Center at Discovery Park, Purdue University

**Coal Gasification
Now Is The Time
Indiana Is The Place**

**TATA Chemicals Innovation Centre Visit
Purdue University**

May 22, 2008

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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**

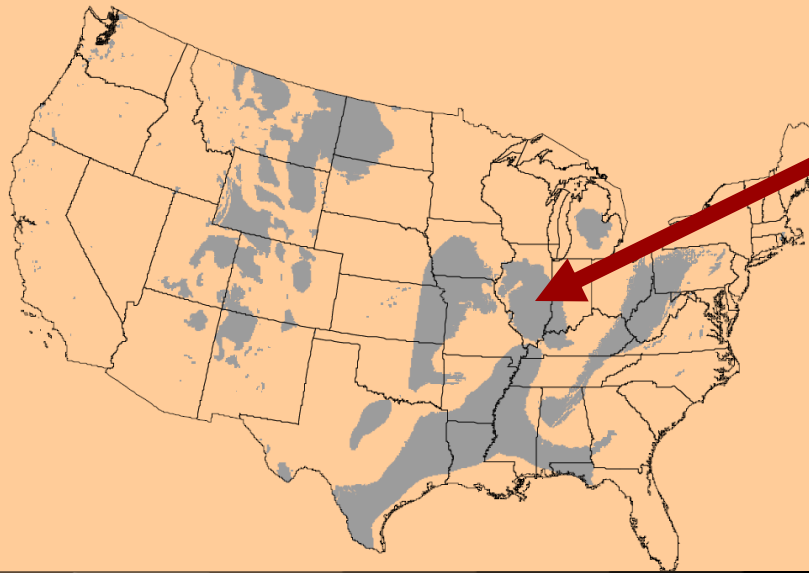
2008 research areas important to coal & which are being considered:

- (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

Bituminous Coal

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

	Total Energy Supplied					Electric Power Industry				
2006	<i>Coal</i>	<i>Nat Gas</i>	<i>Petrol</i>	<i>Nuc</i>	<i>Hydro & Renew</i>	<i>Coal</i>	<i>Gas</i>	<i>Petrol</i>	<i>Nuc</i>	<i>Hydro & Renew</i>
USA	22.0%	23.0%	39.0%	8.0%	7.0%	49.0%	20.0%	1.6%	8.0%	7.0%
Indiana	51.3%	17.7%	29.4%	0.0%	1.6%	94.8%	4.2%	0.1%	0.0%	0.9%



Indiana's Coal Resources & Electricity Demand Growth

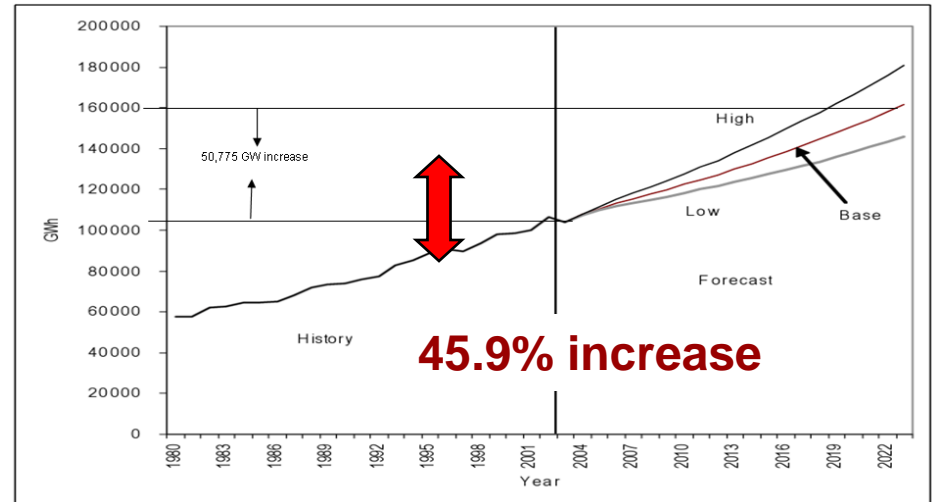
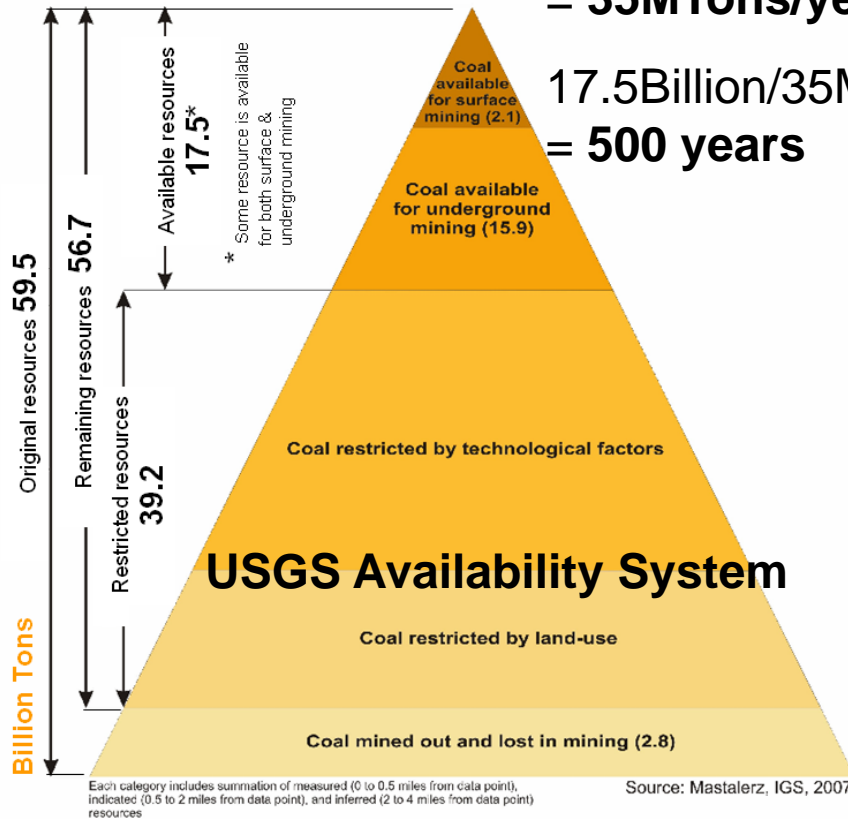
Current production
= **35MTons/year**

17.5Billion/35Million
= **500 years**

Coal (Low price, \$1-2/MBtu)

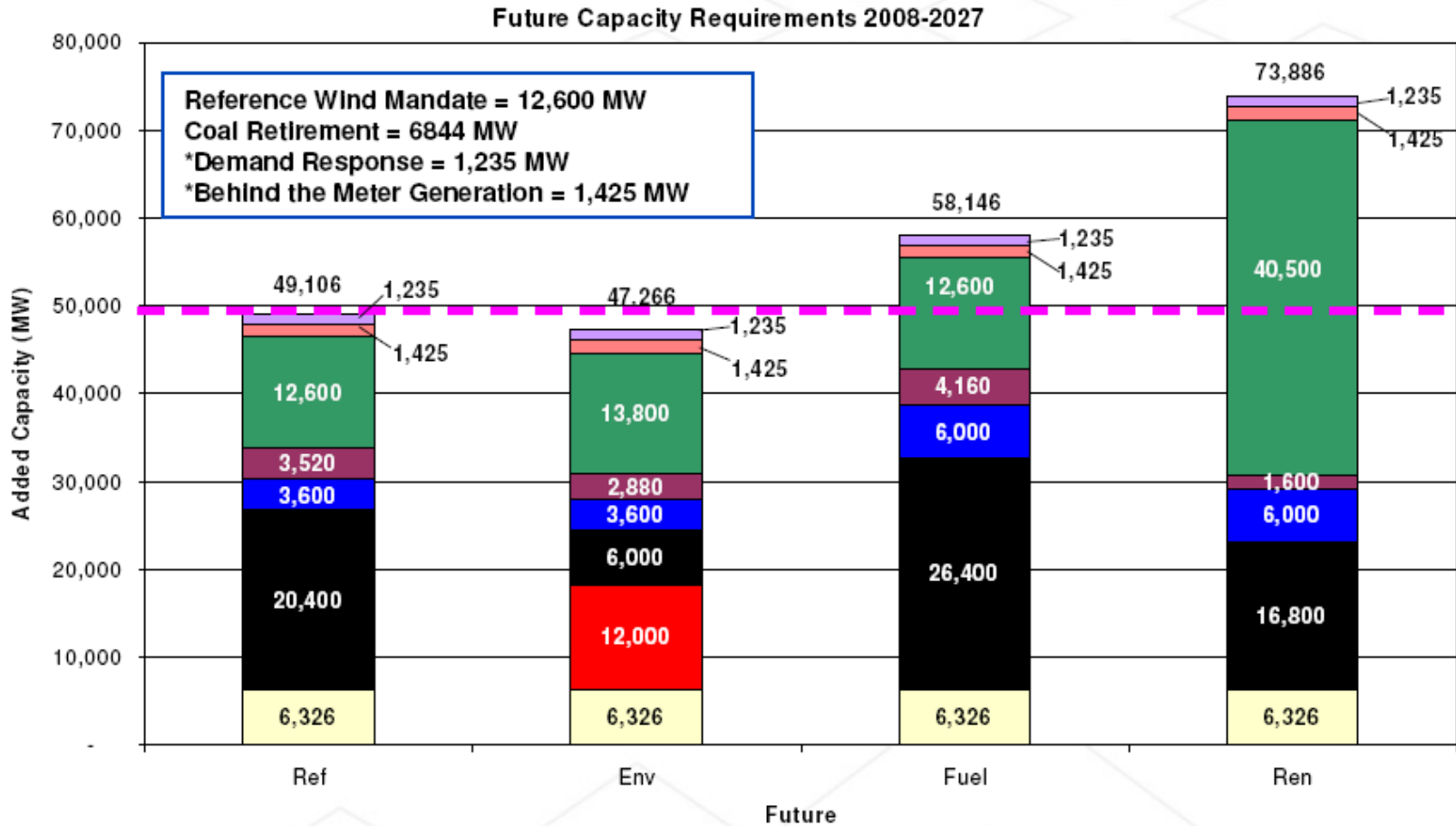
Nuclear (12 - 15 years?)

Natural gas (High price, \$8-9/MBtu)

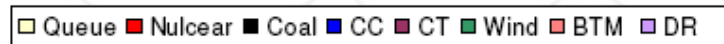




Midwest ISO 2008-2027, Futures Scenarios Cumulative New Generation Capacity (MW)



MISO Modeling Results

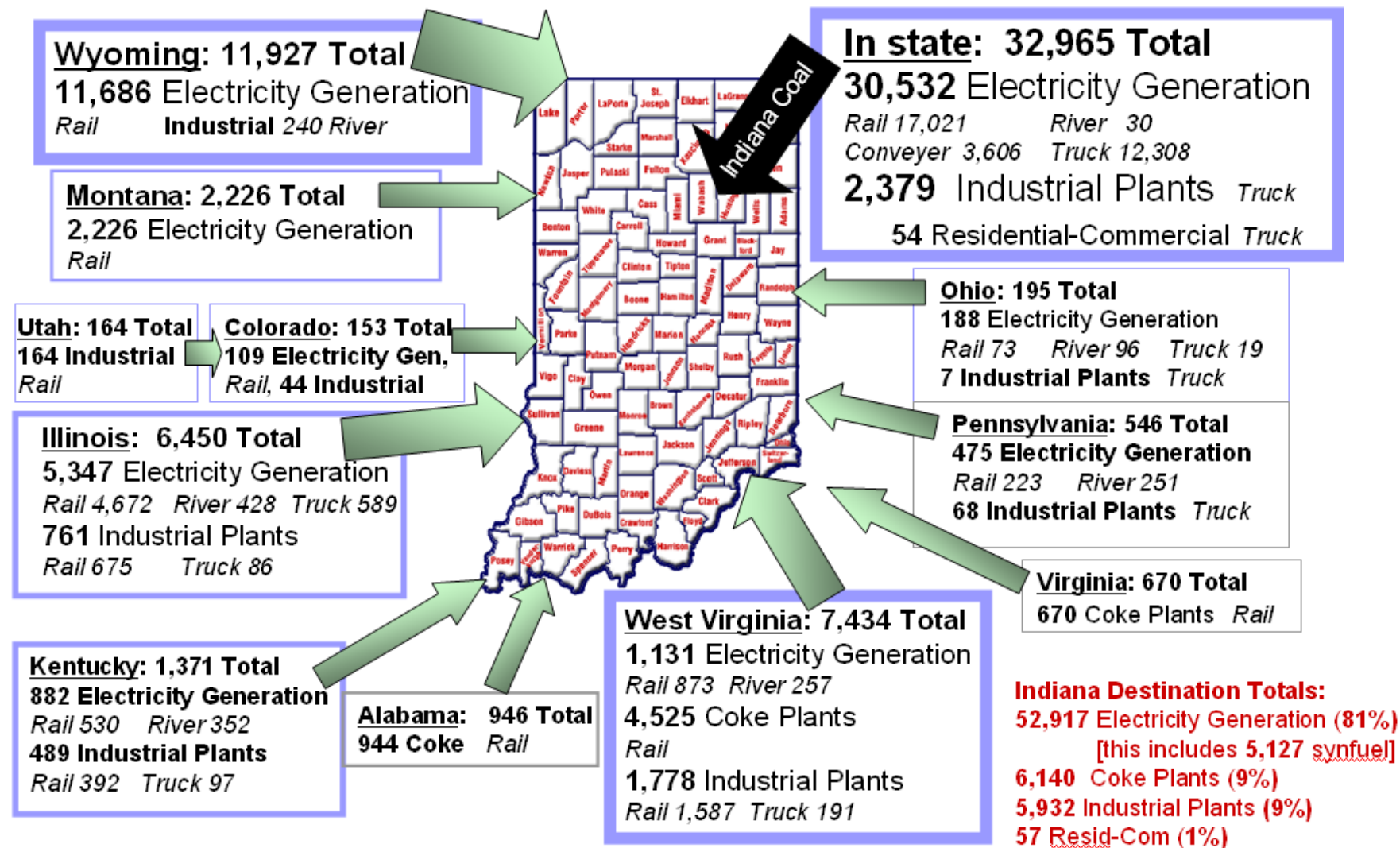




2006 Coal Destination: Indiana

69 MTons Consumption, 35 MTons Production

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





Uncertainty on CO₂ Legislation & Coal-Fired Power Plant Emissions

2006 Indiana Utilities, Amounts Emitted

	Thousand Metric Tons	Ibs/MWh	Examples of Control
SO ₂	758.0	12.8	Wet & dry FGD processes
NO ₂	202.0	3.4	Staging, low-NO _x burners, SCR, SNCR
CO ₂	121,950.0	2,060.0	Amine scrubbers

Source: http://www.eia.doe.gov/cneaf/electricity/st_profiles/indiana.html

INDIANA EMISSIONS

	2002 (Thousand Metric Tons)		
	SO ₂	NO _x	CO ₂
Utilities	901	279	148,000
Transportation	19	318	64,348
Other	93	119	109,391
Total	1,013	716	321,739

Indiana Power Plants produce 148 MTons of CO₂/ year



Emissions & Legislative Uncertainty

Uncertainty is key policy word for CO₂. Planners & investors are in limbo. The magnitude of the **costs for carbon management will be huge**

Currently there is no CO₂ regulation. Considerable debate on CO₂ trading, tax, capture & storage in coming years, but for how long?

CO₂ 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



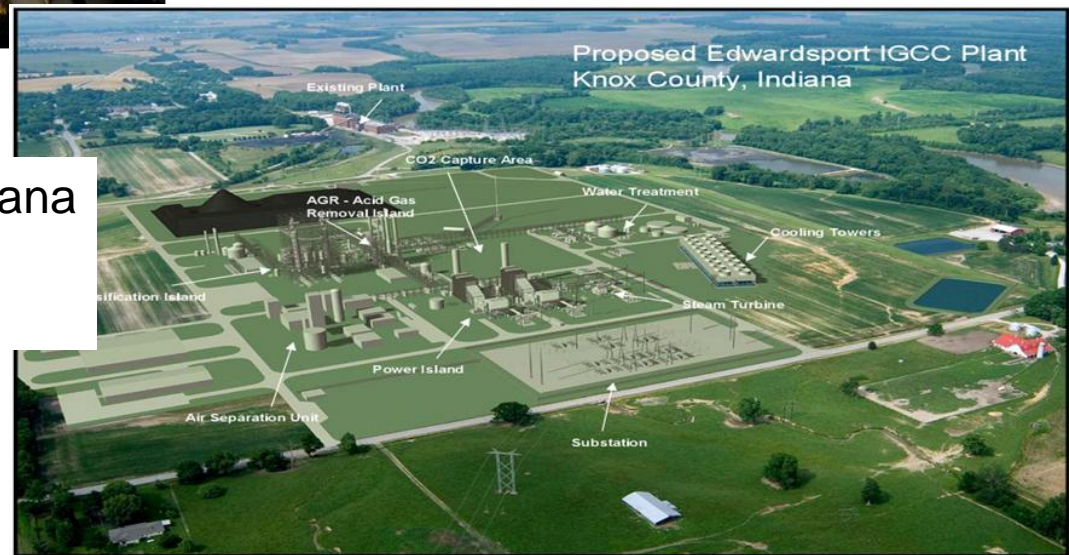
1995 Fully operational Wabash IGCC,
Terre Haute, Indiana
2007 Only two IGCC plants exist in the U.S.

*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 IGCC
20% CO₂ capture
study



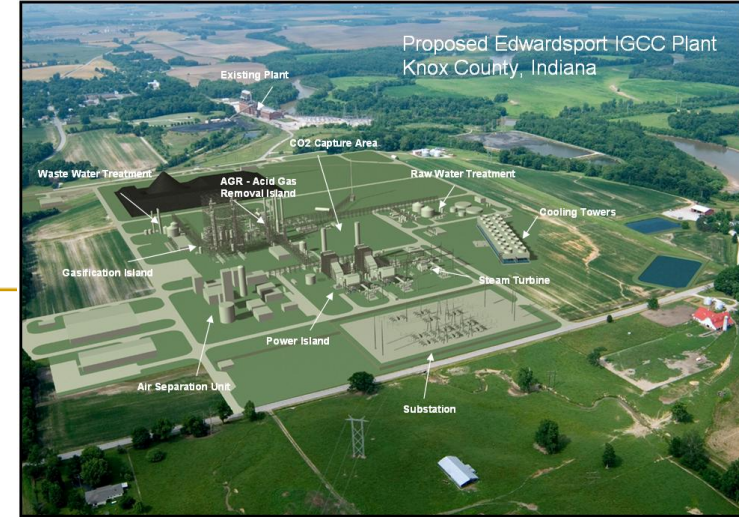


Edwardsport IGCC

Planned 630 MW for 2012

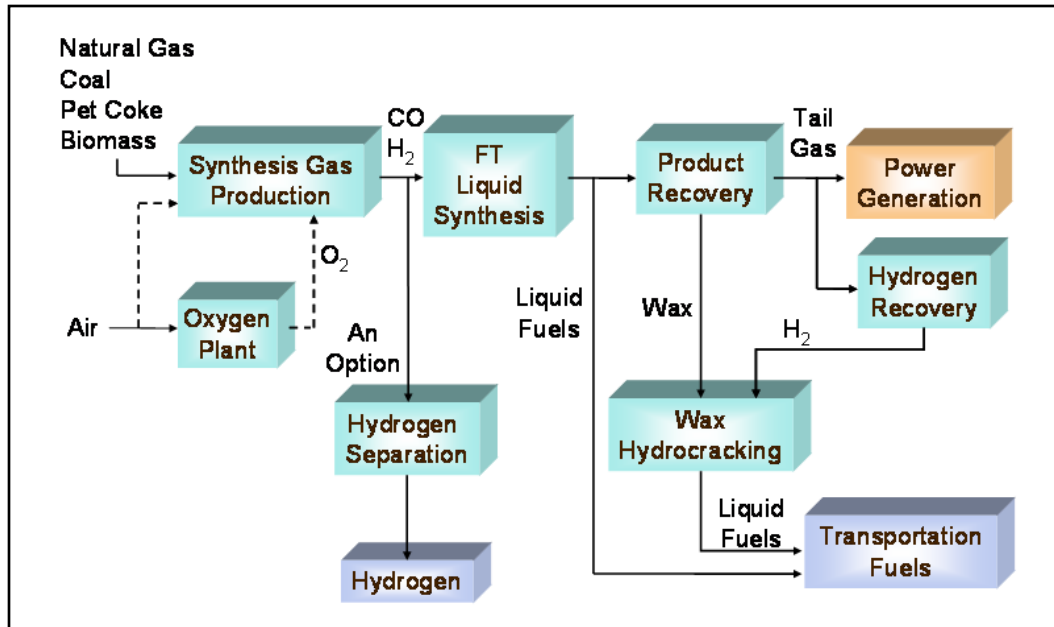
The only **IGCC** that has both **air permits** & **regulatory** authority to be built

- 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**





Coal Gasification & CTL for DOD



Synfuels: 1-2 barrels of liquid fuel from 1 Ton 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

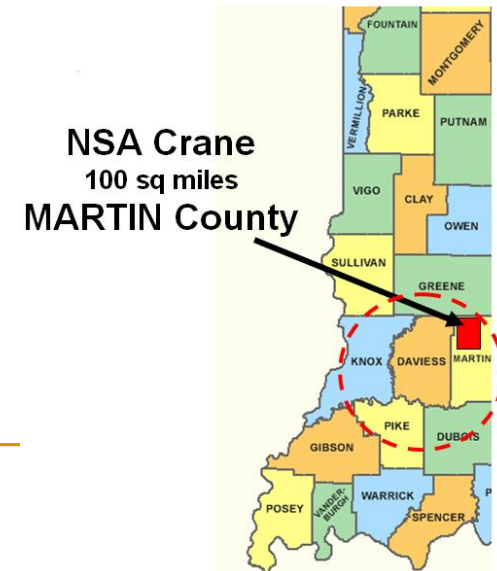


Criteria for Indiana's NSA Crane Naval Base Gasification & Coal-To-Liquids

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*





SAIC & Crane

Science Applications International Corporation



Type Public (NYSE: SAI[®])

Founded 1969

Headquarters La Jolla, California, USA

Key people Ken Dahlberg (CEO)
Dr. J. R. Beyster (Founder)

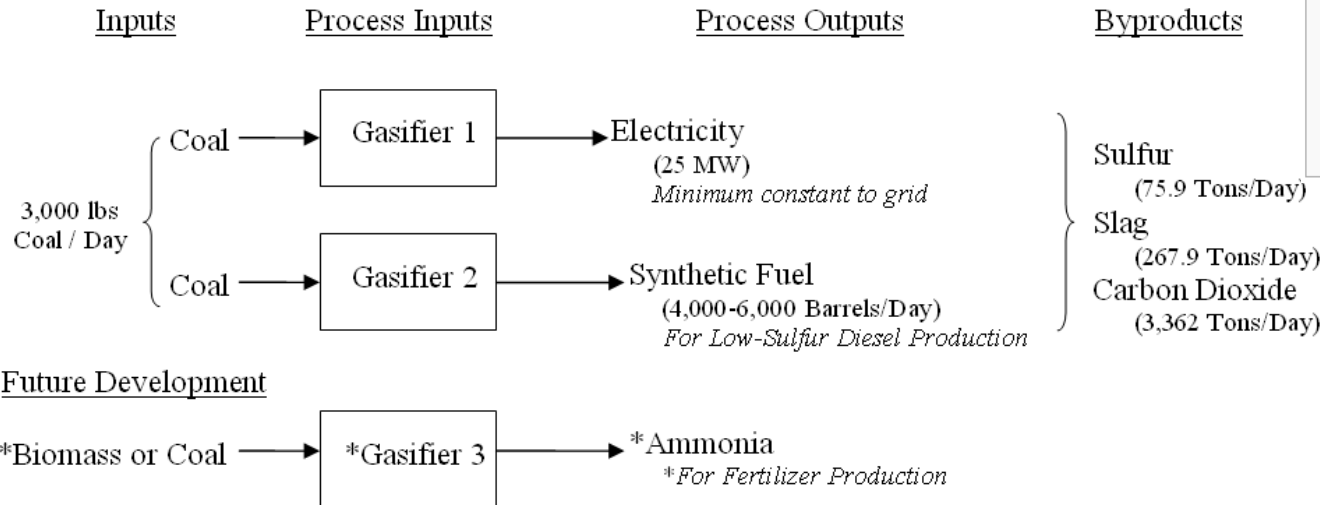
Industry Defense contractor

Employees 44000

Website www.saic.com

CCTR sponsored project with Crane Military base

Simplified Coal Gasification Facility Design



* - Proposed 3rd Gasifier-for future development

The **key to the system** will be the capture of CO₂ for sale to industry
 At this size facility CO₂ could be captured, technologically viable
 A **good test case** for how to scale up CO₂ technology



SW Indiana Coal Gasification Plant

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

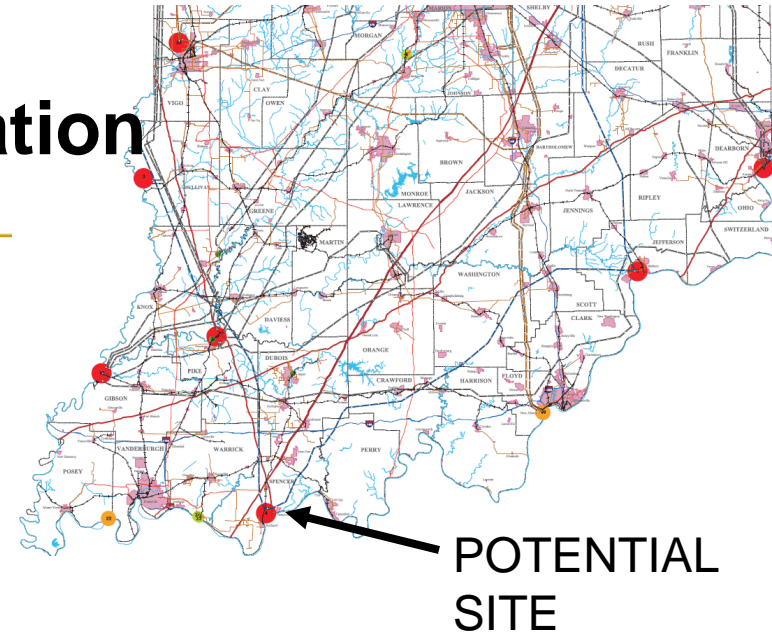
The plant will use **GE Energy's gasification technology**

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 CO₂ Pipelines & Sequestration

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 CO₂ for the proposed CO₂ pipeline (Indiana, Illinois, Ohio)



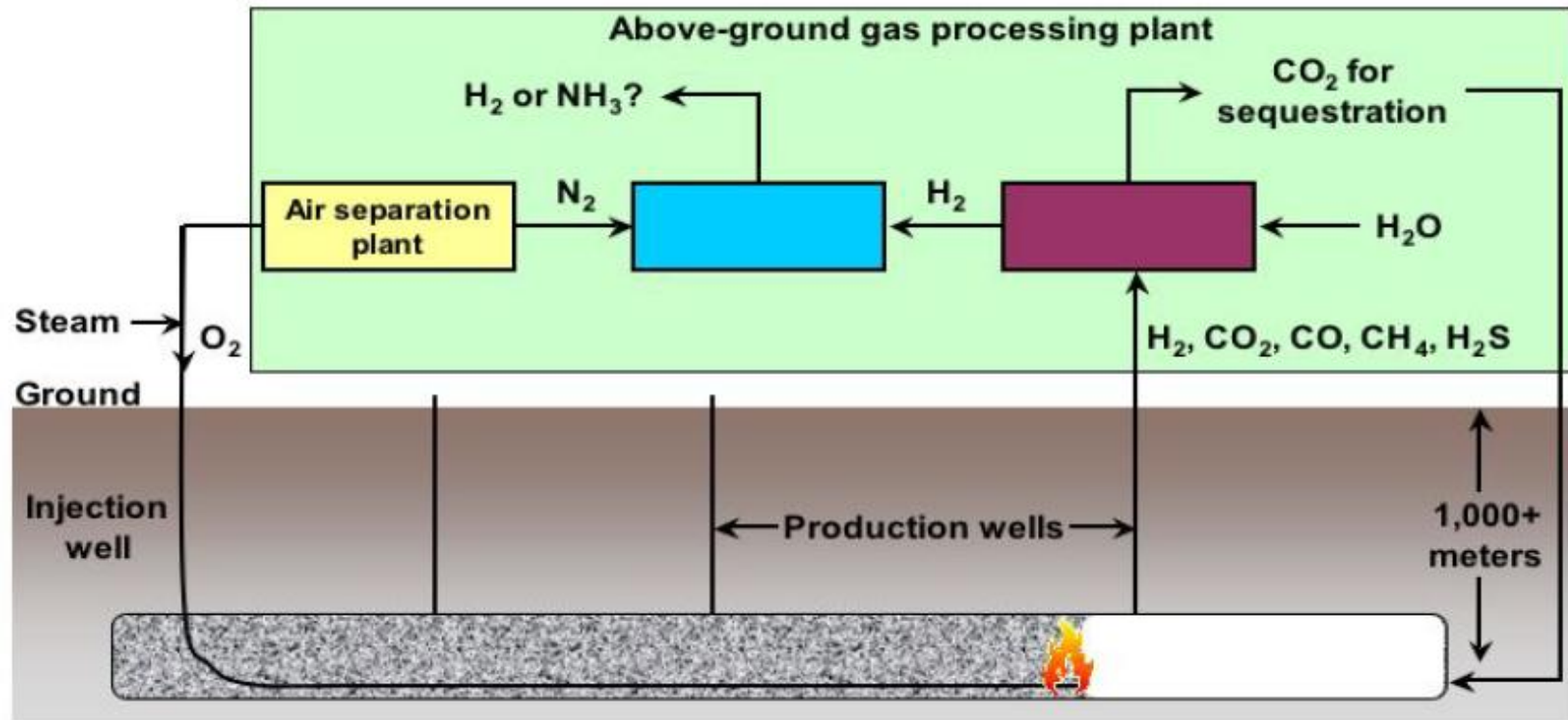
Midwest Geological Sequestration Consortium MGSC - Phase III Project Awarded

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?**
-

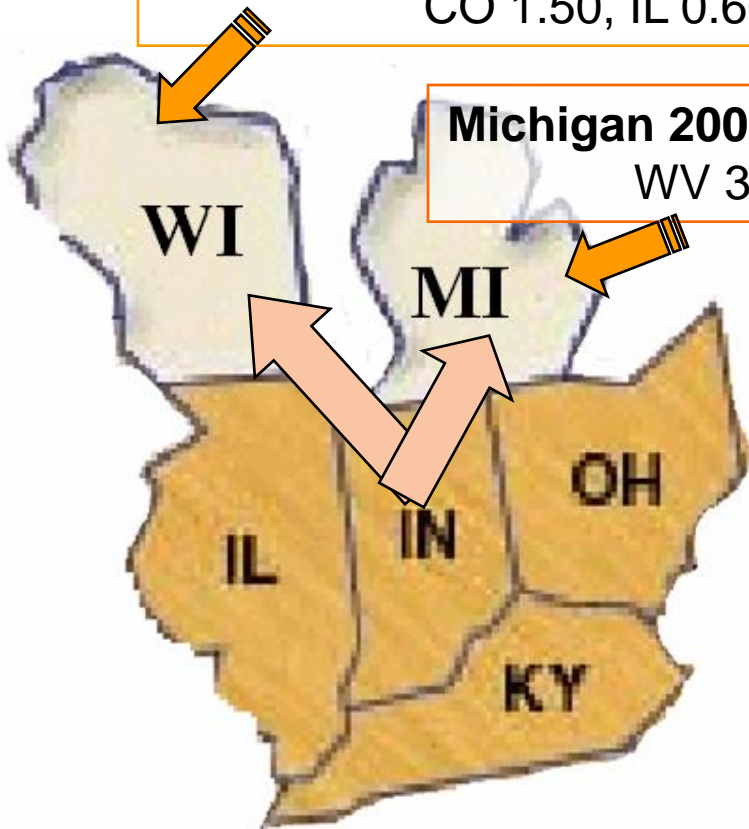


Midwest Coal Production & Consumption

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



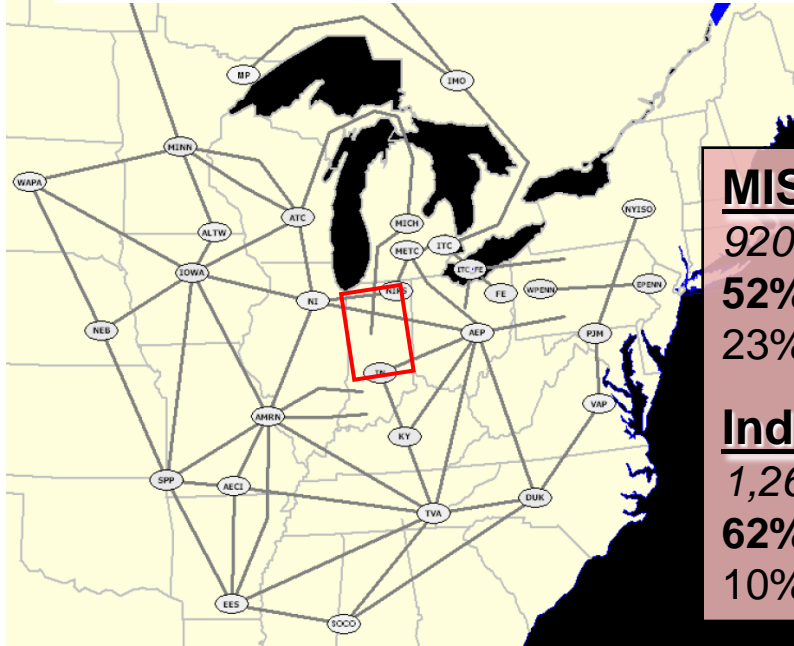
	2004 Coal Consumed (MTons)	2005 Coal Production (MTons)	2004 Electricity Net Flow * (GWh)
Indiana	73.7	34.5	-42.0
Michigan	38.5	0.0	-6.6
Wisconsin	26.7	0.0	+33.3

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



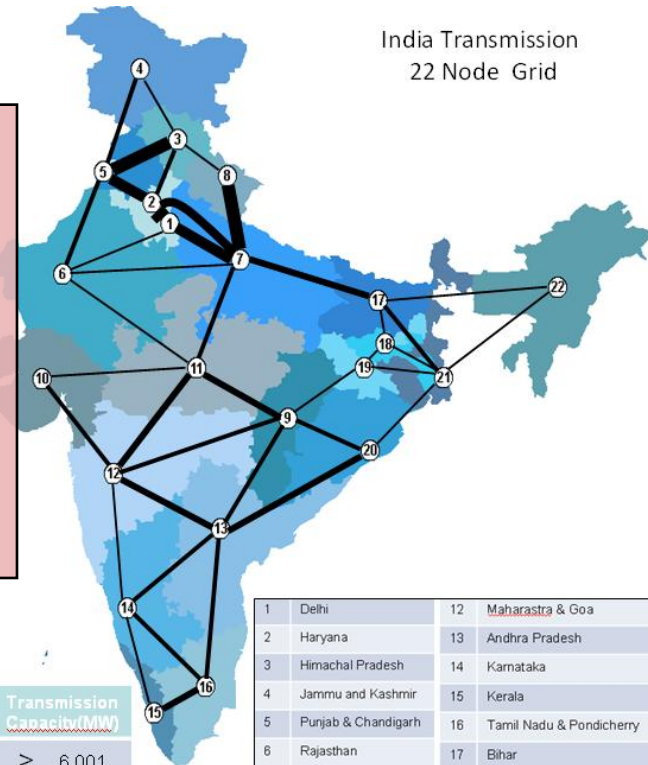
Midwest Transmission & Generation & MISO Footprint in 15 states

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



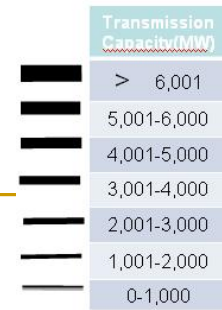
MISO 156 GW
 920,000 sq miles
 52% Coal, 1% Hydro
 23% Gas, 8% Nuc

India 150 GW
 1,268,000 sq miles
 62% Coal, 27% Hydro
 10% Gas, 3% Nuc



1 Delhi	12 Maharashtra & Goa
2 Haryana	13 Andhra Pradesh
3 Himachal Pradesh	14 Karnataka
4 Jammu and Kashmir	15 Kerala
5 Punjab & Chandigarh	16 Tamil Nadu & Pondicherry
6 Rajasthan	17 Bihar
7 Uttar Pradesh	18 Damodar Valley Corporation
8 Uttaranchal	19 Jharkhand
9 Chhattisgarh	20 Orissa
10 Gujarat & DD - DNH	21 West Bengal & Sikkim
11 Madhya Pradesh	22 All North East

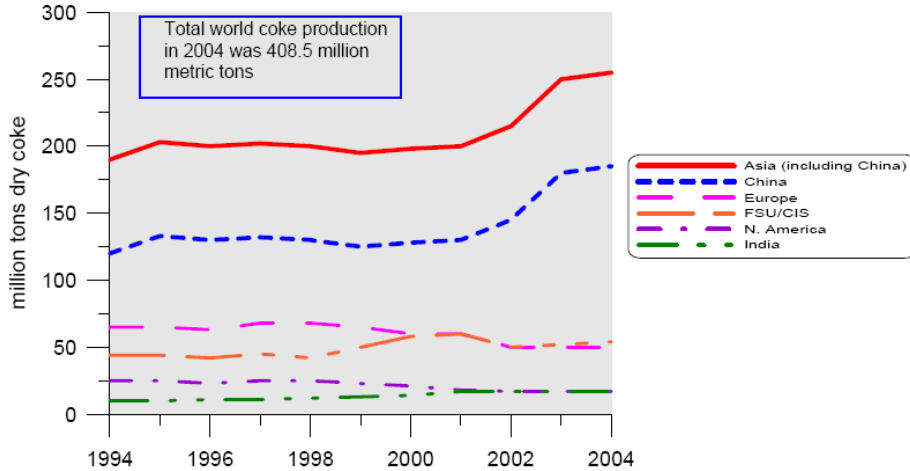
Challenges facing Midwest ISO:
 Transmission Corridor West to East?
 Future capacity expansions, wind, coal, etc?



Note: This illustrated grid was derived from Transmission Maps (kV) published by various Regional Power Committees

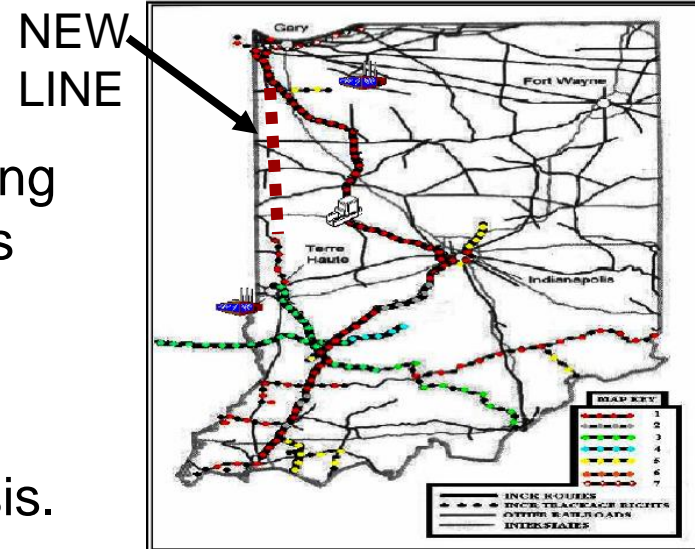


Coke & Coal By Rail



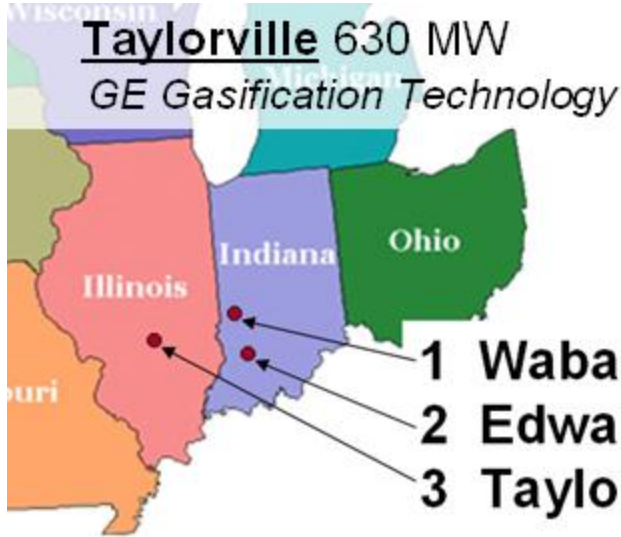
World Coke Production: 2005 forecasts indicate that the US would produce 11.5 MTons of coke, but required 17.0 MTons for blast furnace, foundry, and related uses. **At present no IN coal is being used.**

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



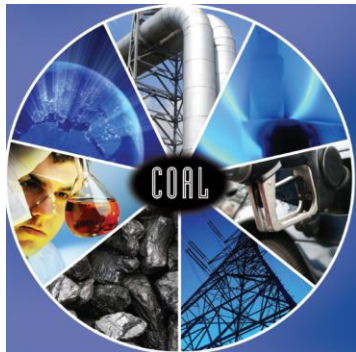
Global Energy's Lima Project On Track to Become Third U.S. IGCC Plant - Sequestration Plans to Follow **Ohio** (*Under construction*)

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

TEC, Taylorville Energy Center, Illinois

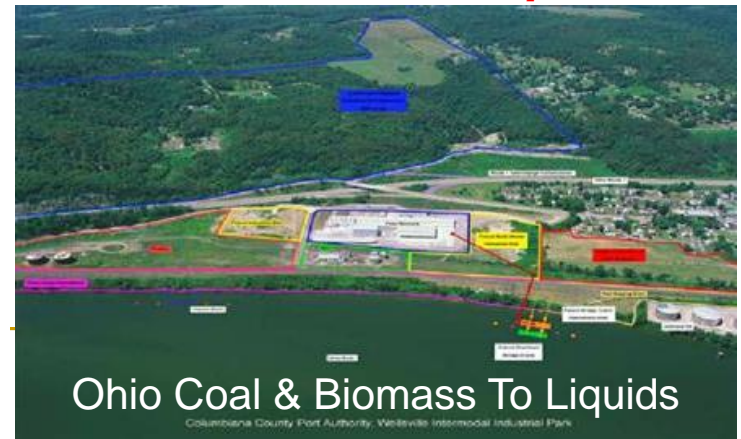
Baard Energy CBTL Project

- 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





Coal Gasification in Illinois & Ohio

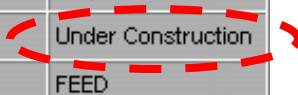
Under Construction & Proposed

American Clean Coal Fuels (ACCF)	CTL	Illinois	Proposed
Cardinal Energy Project	IGCC	Illinois	Proposed
Clean Coal Power Phase 1	IGCC	Illinois	Proposed
Drummond Co. (Birmingham, AL)	CTL	Illinois	Proposed
Peabody Energy / Arlight Capital	SNG	Illinois	Proposed
Power Holdings of Illinois LLC <small>UPDATED</small>	Coal-to-SNG	Illinois	Pre-FEED
Rentech Energy Midwest Corp. (REMC) <small>UPDATED</small>	Fertilizer/CTL	Illinois	Shelved
Taylorville Energy Center <small>UPDATED</small>	IGCC/SNG	Illinois	Feasibility Study
Secure Energy Inc.	SNG	Illinois	FEED
Southern Illinois University-Carbondale (SIUC) IGCC <small>UPDATED</small>	IGCC	Illinois	Feasibility Study

ILLINOIS

Air Force	IGCC	Ohio	Proposed
American Clean Coal Fuels (ACCF)	IGCC/CTL	Ohio	Proposed
Americal Electric Power's Ohio Power	IGCC	Ohio	Proposed
Baard Generation 1 project	IGCC/CTL	Ohio	Proposed
Baard Generation 2 project	IGCC/CTL	Ohio	Proposed
CME Energy	IGCC	Ohio	Unidentified
FirstEnergy / Consol	IGCC	Ohio	Proposed
Lima Energy Co. / Cincinnati (Global Energy)	IGCC	Ohio	Under Construction
Ohio River Clean Fuels <small>UPDATED</small>	CTL	Ohio	FEED

OHIO





Coal Gasification in Kentucky & India

Operational, Under Construction, Planned & Proposed

KENTUCKY		IGCC	Kentucky	Proposed
Appalachian Power		IGCC	Kentucky	Proposed
Cash Creek Generation <small>UPDATED</small>		IGCC	Kentucky	FEED
FFI's CTL project <small>UPDATED</small>		Coal-to-Diesel	Kentucky	Planned
Peabody Energy <small>UPDATED</small>		CTL	Kentucky	Planned

BP & Reliant Industries Ltd. UCG projects <small>UPDATED</small>		UCG	Proposed
Energy Quest's Indian IGCC Projects <small>UPDATED</small>		IGCC	Conceptual Design
GAIL/Coal India Coal-to-Fertilizer Project <small>UF</small>		Coal-to-Ammonia	Feasibility Study
Gujarat UCG Project Well <small>UPDATED</small>		UCG	Feasibility Study
Linc/Shi-Vani's UCG Project		UCG	Planned
Oil India Ltd. (OIL)'s CTL Project <small>UPDATED</small>		CTL	Feasibility Study
Paradip Gasification H2/Power Plant <small>UPDAT</small>		Petcoke-to-Hydrogen	Under construction
Reliance Industries' CTL Project <small>UPDATED</small>		CTL	Feasibility Study
RIL's Integrated Coke Gasification Project		IGCC	Planned
RIL's Petcoke Gasification Project		Petcoke-to-Fuel	Pre-FEED
Sanghi IGCC Plant		IGCC	Operational
Sasol's Indian CTL Project		CTL	Proposed
Singareni UCG Project		UCG	Pre-FEED



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

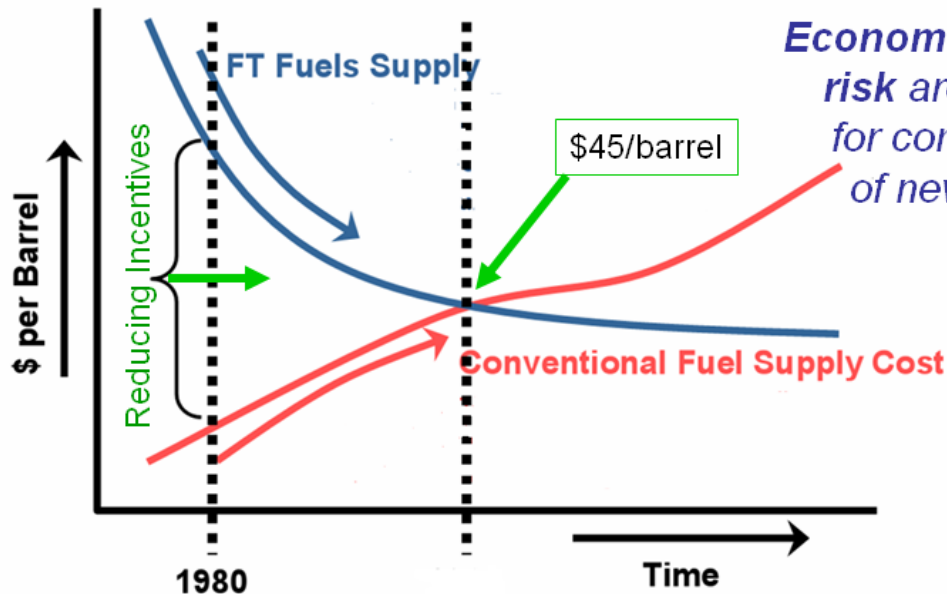


southern states energy board





Conventional & Future Liquid Fuel Use Coal Investments for India & Indiana



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

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