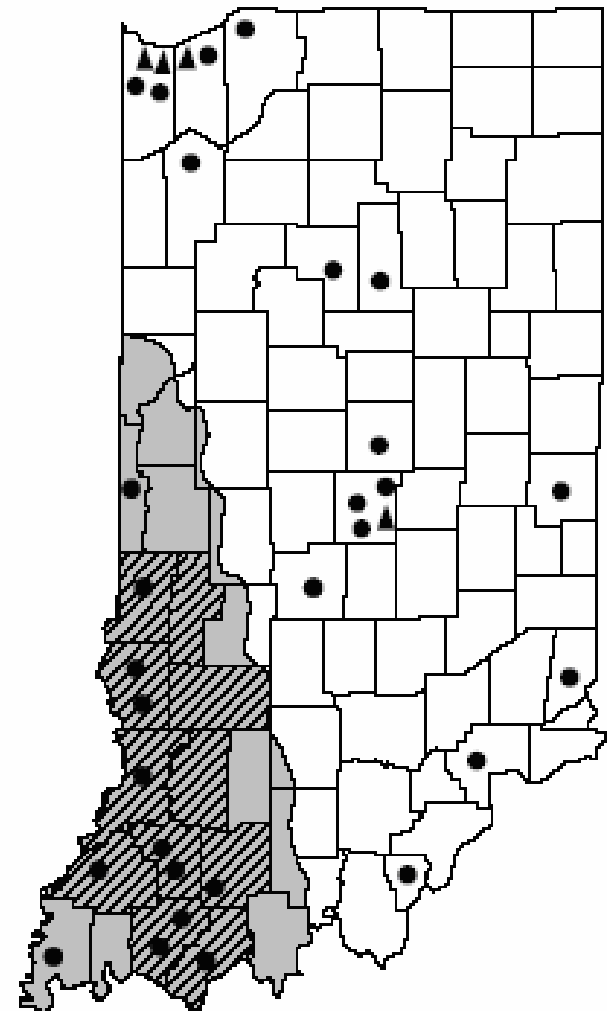


EXPANDING THE UTILIZATION OF INDIANA COALS

Brian H. Bowen, Forrest D. Holland
F.T. Sparrow, Ronald L. Rardin
Douglas J. Gotham, Zuwei Yu, Anthony F. Black

Indianapolis
August 18, 2004

Center for Coal Technology Research
PURDUE UNIVERSITY
Potter Engineering Center, 500 Central Drive, Room 270
West Lafayette, Indiana 47907



CCTR

Indiana Center for Coal Technology Research

- July 2002: The CCTR is established, Indiana Senate Enrolled Act No. 29, July 2002.
- July 2003: House Enrolled Act No. 1166, creates CCTR Advisory Panel and provision for public education.
- June 2004: CCTR Advisory Panel appointed.
- August 18, 2004: First CCTR Workshop.
- Fall 2004/Spring 2005: Four Consultation Workshops are being planned.

What are the Surrounding States Doing?

Illinois

- ***Coal Research Program*** – granted over \$60 million in last two decades, through Illinois Clean Coal Institute at SIU.
- ***Coal Demonstration Program*** – state's \$120 million has attracted over \$200 million in federal funds, over \$450 million in private and public cost-sharing.

Ohio

- ***Coal Research Grant Program*** – through Ohio Coal Development Office – almost \$4 million to fund 19 projects in 2000.
- ***Ohio Coal Research Consortium*** – over \$1 million/year at six universities.

What are the Surrounding States Doing?

Kentucky

- ***Center for Applied Energy Research*** at University of Kentucky – started in 1972 as ***Kentucky Coal Utilization Research Program***.
- Total funding authorization was \$50 million.
- Governor's current budget provides \$4 million for coal-bed methane production, \$3 million for clean coal combustion.

CCTR BACKGROUND PAPERS

Recommended at June 2002 Workshop that two background papers be commissioned

- (1) Background Paper # 1: (August 18, 2004)
Indiana Coal Reserves and Characteristics
- (2) Background Paper # 2: (August 18, 2004)
Demand for Indiana Coal

CCTR PRIORITIES

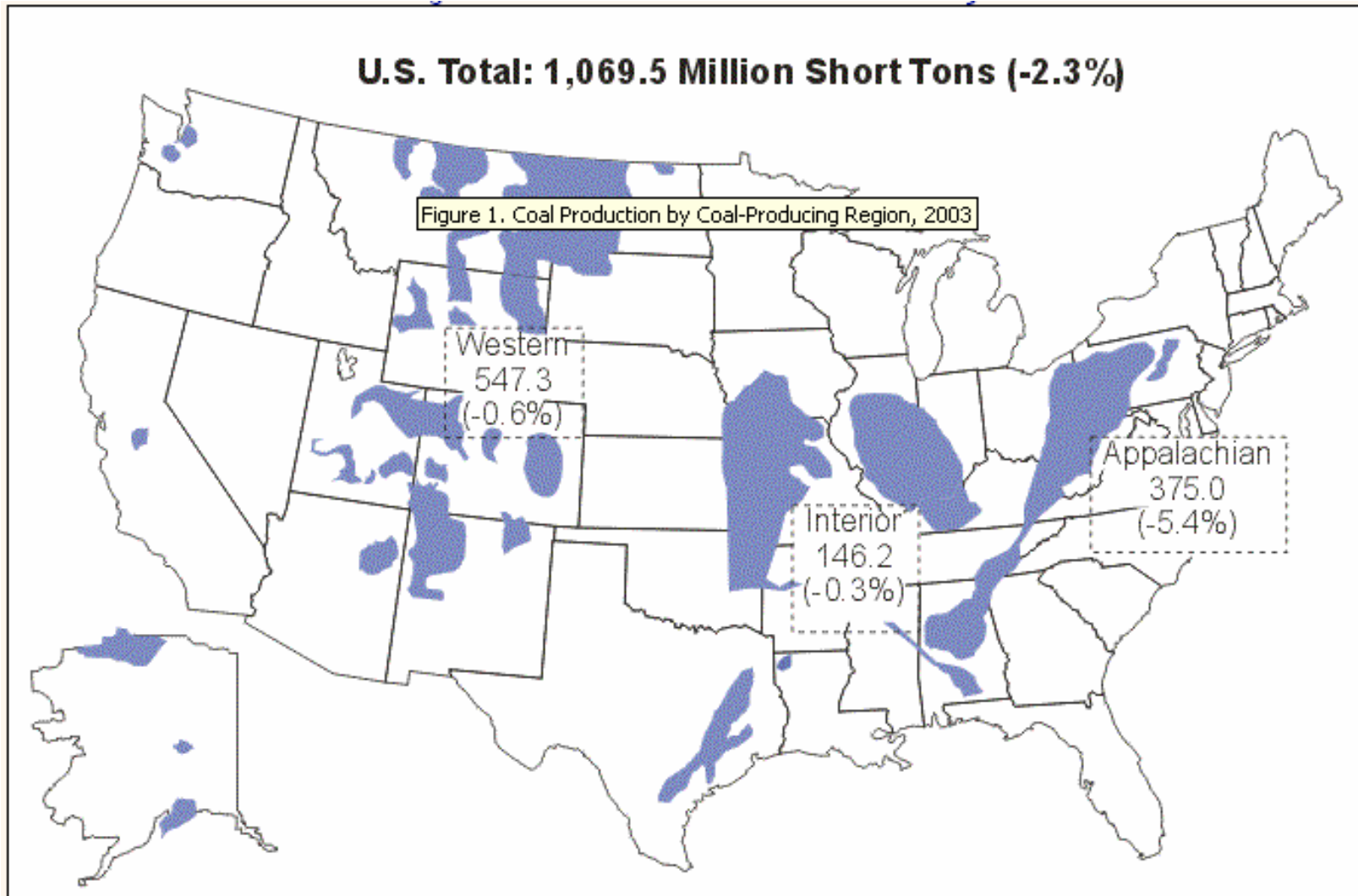
August 18, 2004

Next step this afternoon: **Three Break-Out Sessions**

CCTR to commission, via the RFP route, three papers to be used for the four workshops being planned for this fall and winter. Each paper is to evaluate current knowledge, and identify barriers to progress, in: (i) Indiana Coal Demand, (ii) Indiana Coal Supply, and (iii) Indiana Coals and the Environment. To suggest a research agenda.

The objective for all three sessions today is the same; to put together a tentative list of the major issues, barriers, and opportunities in each of the three areas which will define the scope of work spelled out in the RFP for each of the three papers.

COAL PRODUCTION BY COAL-PRODUCING REGION, 2003 (10⁶ tons & Percent Change from 2002)



Source: <http://www.eia.doe.gov/cneaf/coal/page/special/fig1.html>

COAL RESERVES IN THE U.S. AND INDIANA

- Current U.S. recoverable reserves are 498 billion tons, enough to last for over 450 years.
- Indiana recoverable reserves are 9.6 billion tons, enough to last for over 250 years (producing 35 million tons per year).
- Indiana has more energy underground in the form of coal reserves than the U.S. does in the form of oil and gas reserves.

INDIANA COAL FACTS - 2002

- Indiana mines are part of the Interior Coal-Producing Region, Illinois Coal Basin.
- Economic impact: \$675 million.
- Employment impact: >14 thousand people.
- Strong link: coal with low cost electricity.
- Coal is a significant contributor to the economy of the state.

CONCLUSION

- Coal will be a larger force in the U.S. and Indiana economy than it is now
- How can we secure a role for Indiana coals in this future without compromising our environment?

APPLIED R&D PROGRAMS FOR COAL

Helping to strengthen the economy of Indiana:

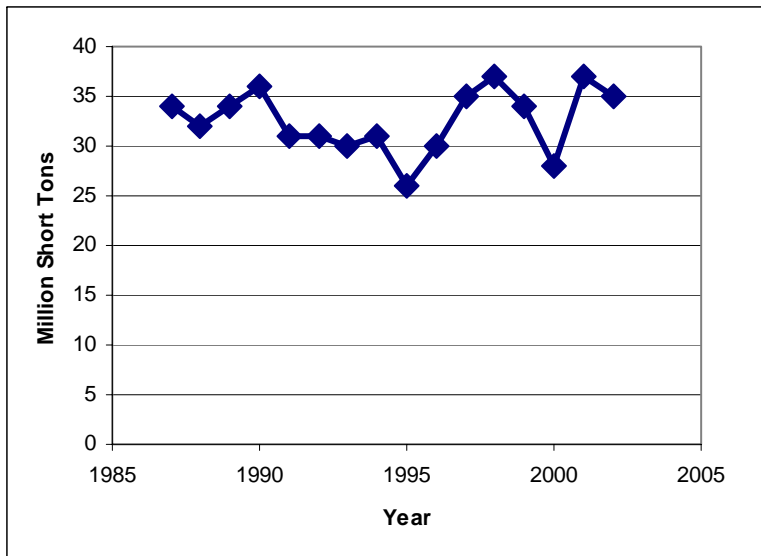
BY: Assisting in the development of strategic long-term coal related proposals

THROUGH: Appropriate policies, most cost effective new technology investments, reduced transportation costs, regional cooperation

WITH: Increases in Indiana's coal production

WHILE: Having concern for health and environment

INDIANA COAL PRODUCTION



Production of 35 million tons of coal in 2002

Indiana coal has high heat content and high sulfur content

78% of production is from surface mining. Is there a gradual return to underground mining? At present Indiana has highest percentage of surface mining in the Midwest (next highest is Ohio with 49%)

INDIANA COAL TRADING


Indiana **is a major importer** of coal

- Consumption 66 million tons in 2002
- Imports 34 million tons
- Exports 3 million tons

Where do coal imports come from and where do coal exports go to?

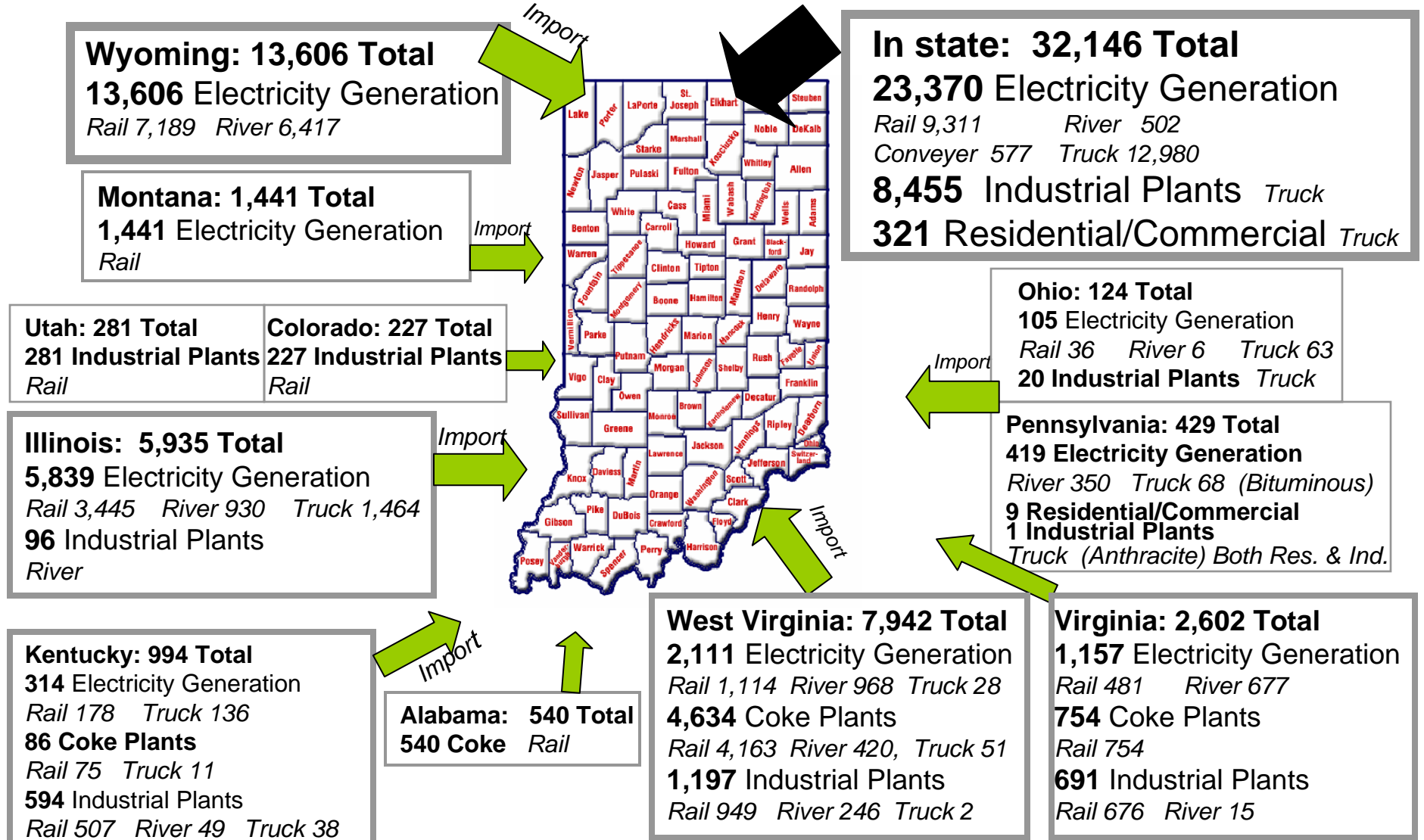
This network of trade flows **needs to be understood** for future planning.

INDIANA COAL TRADE FACTS AND RESPONSE

- Complex flow of coal supplies
- Indiana imports $\frac{1}{2}$ of its total coal needs
- Wyoming is biggest supplier of out-of-state coal
- Majority of coal imports are for electricity generation
 - Strategy for **import substitution**?
 - Strategy for **increase in exports**? 
 - Coal directly*
 - Coal by wire*
 - Investment strategy for **increased mine production**?

INDIANA COAL IMPORTS - 2002

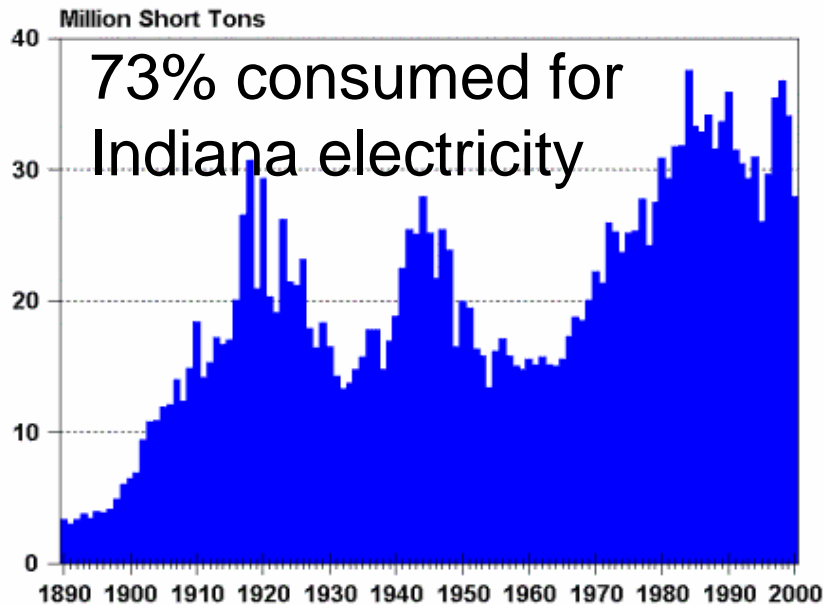
State Consumption Total of 66,269 Thousand short tons & methods of transportation



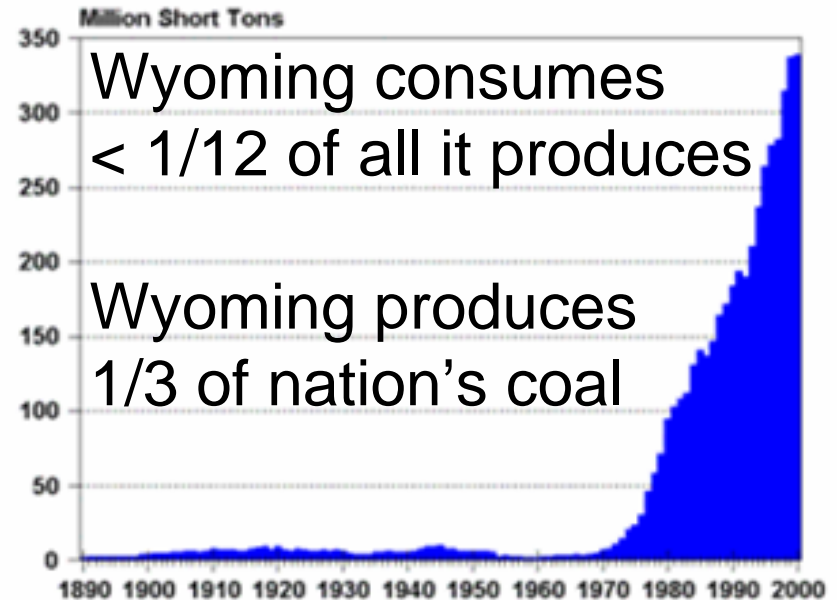
State Totals: 48,643 Electricity Generation
6,014 Coke Plants, 11,281 Industrial Plants, 331 Resid/Com

LOW SULFUR IMPORTS TO INDIANA

Indiana Production Profile



Wyoming Production Profile



Major imports of Wyoming's low sulfur coal have dramatically affected Indiana's coal trade situation as result of more stringent environmental standards.

2002 WYOMING EXPORTS TO MIDWEST

Wyoming consumes only 28.5 million tons and exports to Midwest (million tons):

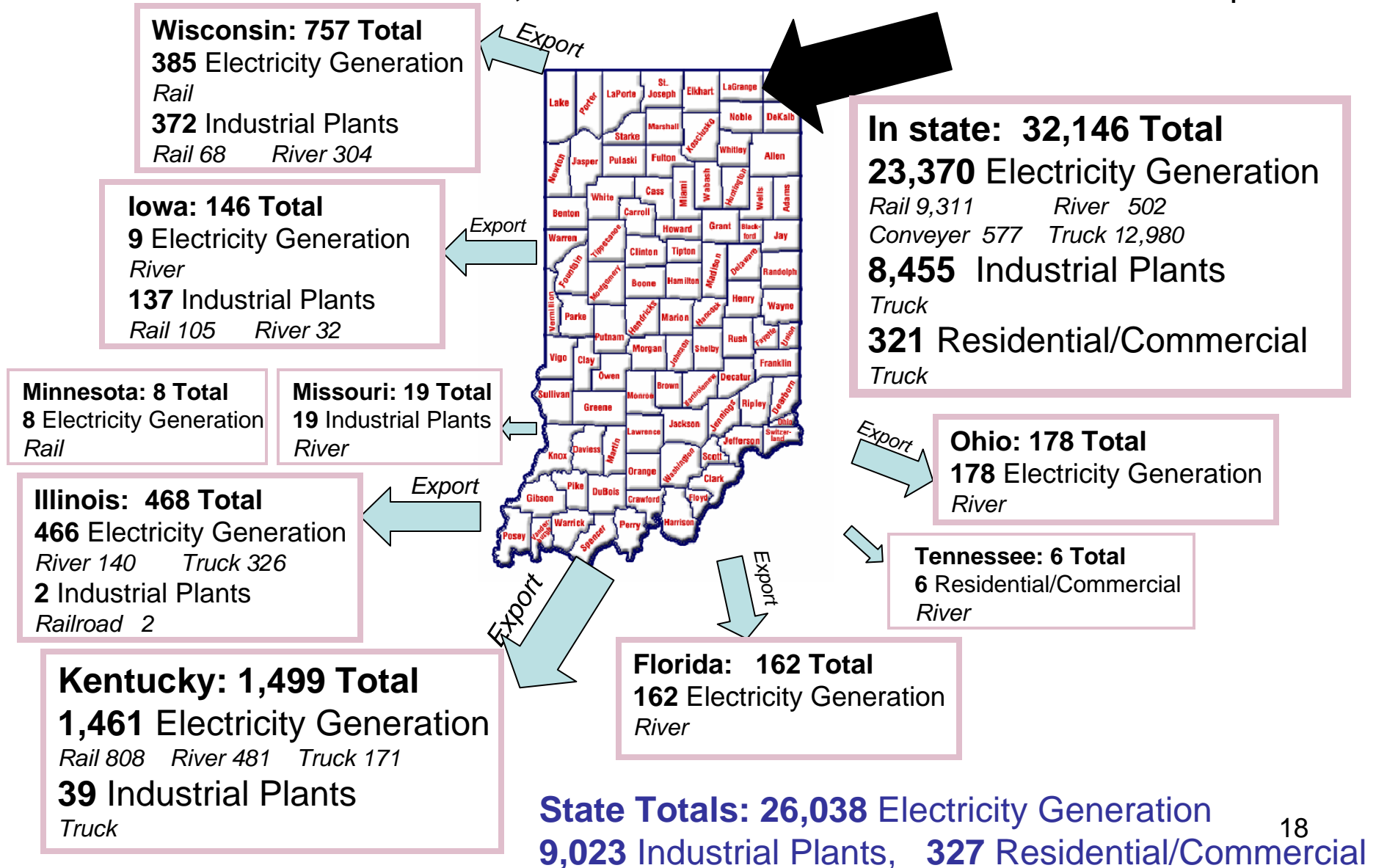
IL - 7.0, **IN - 13.6**, KY - 1.7, OH - 9.6,
MI - 13.1, WI - 20.0, and many other states

Midwest total imports of WY coal is 65 million tons

How can Indiana increase coal production and substitute for WY Midwest exports?

INDIANA COAL EXPORTS - 2002

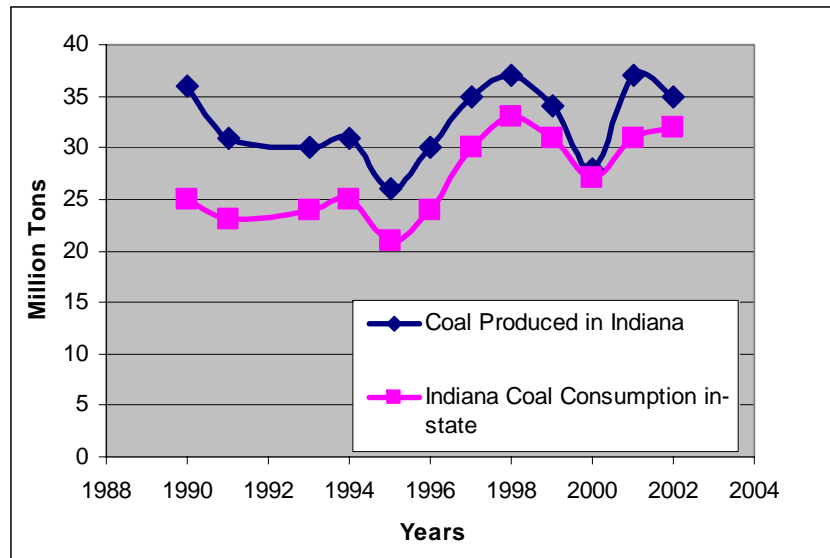
State Production Total of 35,391 Thousand short tons & methods of transportation



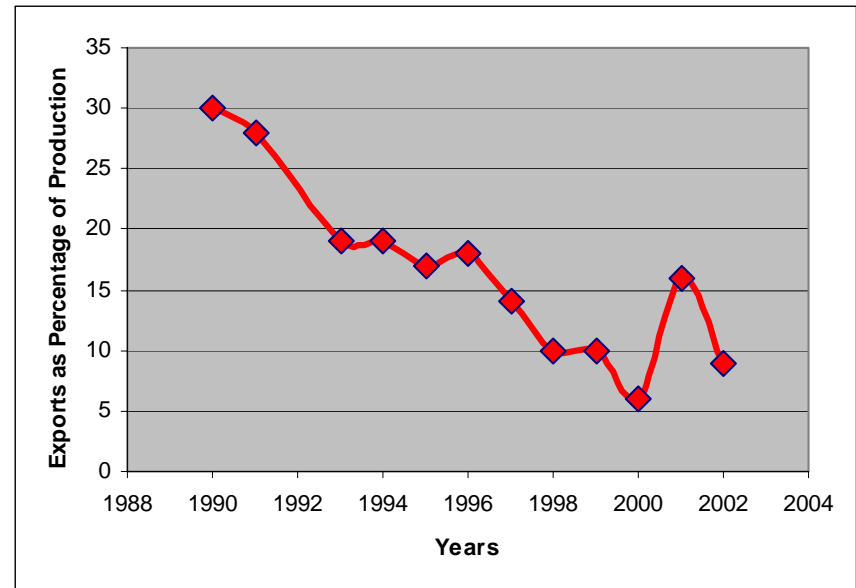
Source: http://www.eia.doe.gov/cneaf/coal/page/coaldistrib/o_in.html

INDIANA COAL EXPORTS

Indiana Coal Production and Consumption



Decline in Indiana Coal Exports

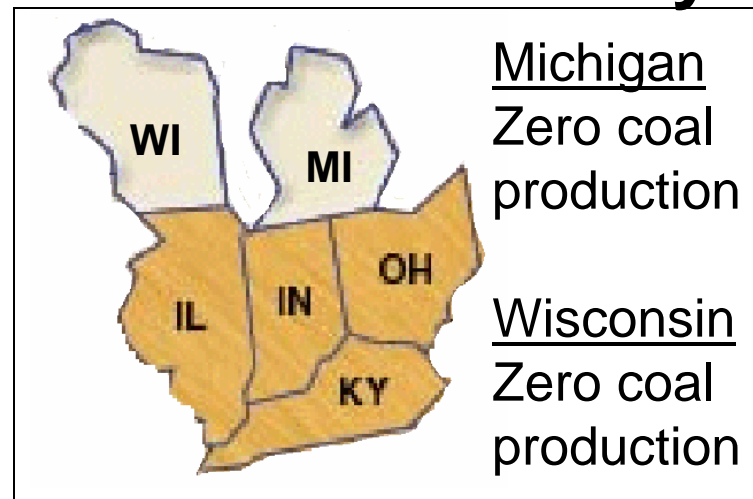


What has caused the decline in Indiana's coal trade and what response is to be made to this?

COAL CONSUMPTION IN NEIGHBORING STATES

2002 Consumption and Production for Electricity

	Consumption (10 ⁶ tons)	Production (10 ⁶ tons)
IL	12.6	5.0
IN	43.8	21.5
KY	30.7	17.8
OH	29.4	11.3
MI	32.1	0.0
WI	22.8	0.0

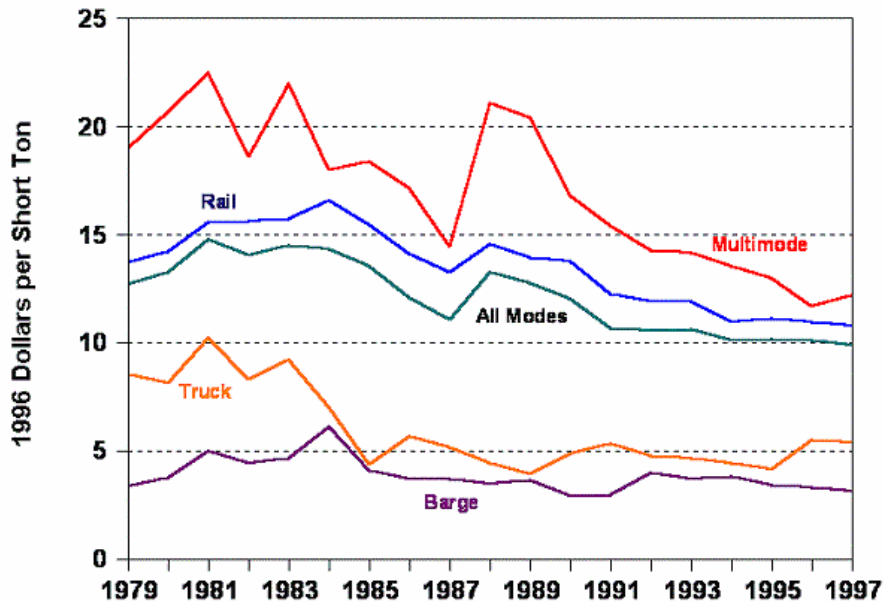


These 6 states produce 56 million tons of coal for generating in-state electricity but consume 171 million tons for electricity – massive imports into Midwest

COAL AND MIDWEST ELECTRICITY SUPPLIES

- The neighboring states to IN are very dependent on coal for power generation, less so for IL (35%).
- IN generates highest proportion using coal (94% of MWh). Next comes KY and OH (90%).
- IL, MI & WI have $\frac{1}{4}$ of power generation from nuclear stations (OH 7%).
- Heaviest dependence on natural gas is in IL (26%).

TRANSPORTATION & INVESTMENT



Notes: Multimode includes shipments that use any combination of rail, truck, barge, and collier transportation. Import records are excluded.

- Coal transportation rates were coming down, now uncertain, and are still costly (\$13/ton from WY).
- Mine prices of WY coals are low.

- Low sulfur content of imported WY coal and long contractual agreements (low sulfur & high transport costs or high sulfur & low transport cost).
- Long-term investments in new technology or short-term transportation operational costs.
- Tough decisions to make.

REGIONAL TRADE CONCLUSION

- Midwest imports have been increasing and exports decreasing.
- Can Indiana increase it's share of this 100 million tons of regional imports?
- Can Indiana significantly increase its exports to MI and WI?

COOPERATION WITH NEIGHBORS

- The Midwest states are all very dependent on coal imports from the Western Region and Indiana exports suffer
- Similarly to the electricity network of the region and the creation of MISO can there be a similar regional level of cooperation with coal technology development?
- A regional approach could have important consequences for the location of the FutureGen project?

FUTURE PRODUCTION AND TRADE

What are the key issues to be tackled through the CCTR for helping increase Indiana's coal production:

Approach: To be solely for the interest of Indiana and irrespective of the Midwest neighbors or full cooperation with neighbors? (Buy IN or Buy IL Basin?)

Investments: How to be most cost effective for:

- (1) Mines, (2) Power Plants,
- (3) Transportation of coal to plants

New Technology: What are the options available and what are their comparative costs?

EXPANDING INDIANA COAL USE BY THE IRON AND STEEL INDUSTRY

- Currently, very little Indiana coals utilized by the industry.
- Two opportunities – in coke blends and blast furnace injection.
- Two studies – IGS Report 64, DOE Clean Coal Technology Report.
- **Coke blends:** Indiana coals limited by strength, moisture problems – nonetheless, “Indiana coal could be successfully incorporated in amounts up to 45% of the blend” – potential between 2 to 3-½ million tons/year.

EXPANDING INDIANA COAL USE BY THE IRON AND STEEL INDUSTRY

- ***Blast furnace injection:*** could replace up to 40% of coke charge; in competition with gas. Coals with high combustibility, high coke/coal replacement ratios, low sulfur preferred.
- ***Total potential:*** 4 ½ to 5 ½ million tons/year.
- ***Problem:*** best Indiana coals for both uses are Brazil formation, with limited reserves.

INDIANA'S GENERATING STATIONS

- The majority of Indiana's coal, 73% in 2002, went to power stations (23.4 of the 32.1 million tons of in-state coal and 48.6 million tons of Indiana's total coal consumption).
- The ten largest Indiana power stations all use coal and represent 74% of Indiana's utility station power.
- Where do the coal supplies for these major installations come from? What are the emissions from these largest stations?

INDIANA'S TEN LARGEST POWER STATIONS

Plant	Operating Company	Net Summer Capability (MW)
1. Gibson	PSI Energy Inc	3,131
2. Rockport	Indiana Michigan Power Co	2,600
3. R M Schahfer	Northern Indiana Pub Serv Co	1,780
4. Petersburg	Indianapolis Power & Light Co	1,672
5. Clifty Creek	Indiana-Kentucky Electric Corp	1,209
6. Cayuga	PSI Energy Inc	1,096
7. Merom	Hoosier Energy R E C Inc	1,000
8. Tanners Creek	Indiana Michigan Power Co	980
9. Elmer W Stout	Indianapolis Power & Light Co	924
10. Wabash River	PSI Energy Inc	918

COAL IMPORTS TO INDIANA'S LARGEST POWER STATIONS

Indiana Coal Imports in 2000 to 10 Largest Power Stations

(Thousands of short tons)

Schahfer 1,780MW
WY 3,127 thousand tons, 15%
IL 1,151 5%
WV 502 2%
VA 12

Cayuga, 1,096MW
IL 356 thousand tons

Gibson 3,232MW
IL 1,600 thousand tons, 7%

Rockport 2,600MW
WY 7,747 thousand tons, 36%
KY 792
WV 436



Total coal imports to Indiana's
10 largest power stations
in 2000:
21,625 thousand short tons

Percentage of Imports

Wyoming 65.0%
Illinois 14.6%
W. Virginia 11.0%
Kentucky 5.1%
Virginia 3.0%
Ohio 0.9%
Pennsylvania 0.4%

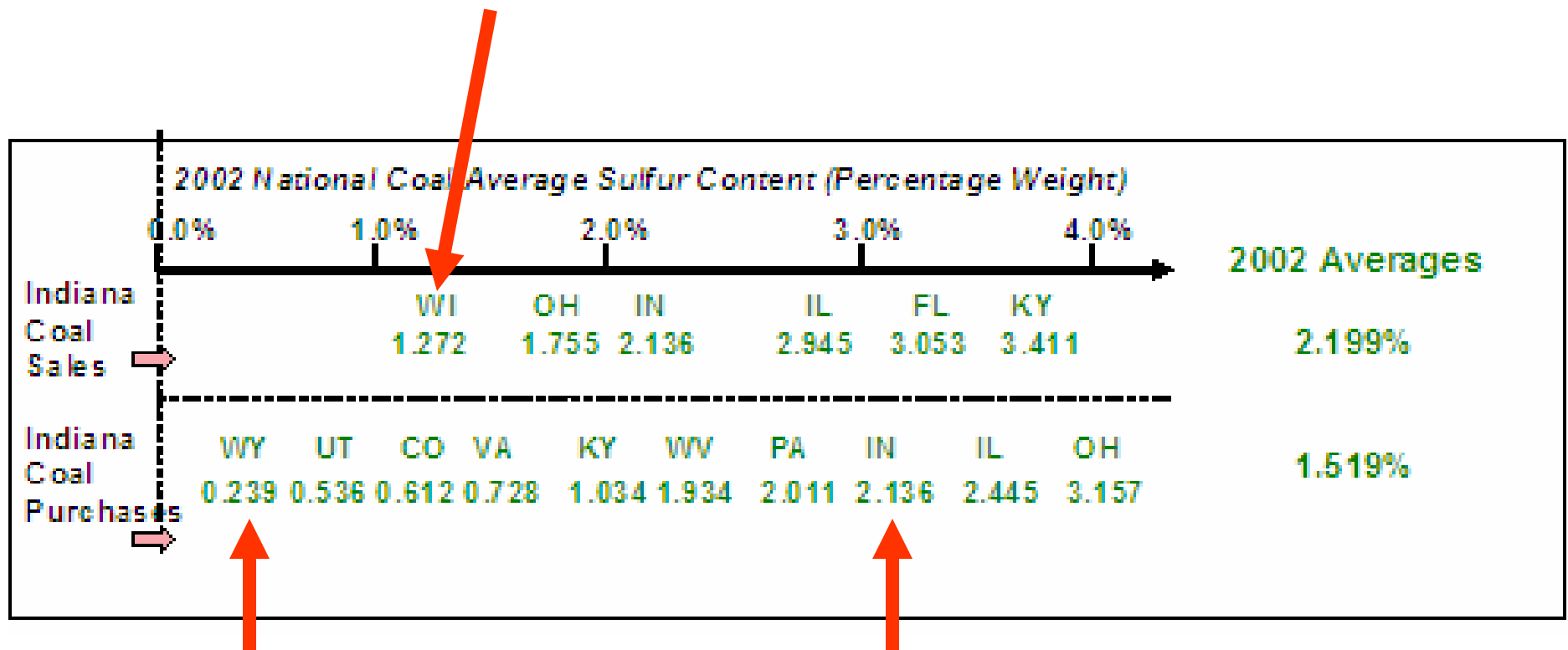
Tanners Creek 980MW
WV 1,416 thousand tons, 7%
KY 284
WY 101
PA 81
IL 48

Clifty Creek 1,209MW
WY 3,041 thousand tons, 14%
VA 683
OH 156
WV 29
KY 28

- Power stations, Peterburg, Merom, EW Stout, & Wabash River use 100% Indiana coal
- Power stations, Rockport, RM Schahfer, & Clifty Creek use 0% Indiana coal (major Wyoming coal importers)

COAL AND SULFUR EMISSIONS

- There is 9 times as much sulfur in the Indiana coal compared with the Wyoming coal imports
- How much lower sulfur coal is to be found in Indiana?



SO₂ AND INDIANA POWER STATIONS

- Indiana total SO₂ emission, 786,000 Tons.
- Three of Indiana's large power stations emit 45% of this SO₂ total emission.
- Although Indiana is such a big importer of low sulfur coals it is still 4th in the nation of highest SO₂ emitting states.

HOW TO DECIDE WHICH COAL?

- The decision process for coal selection and contracting agreements need to be well understood.
- SUFG forecasts Indiana needing 5,870MW of new base load plant by 2021. What technology should be chosen?
- Peabody Coal has announced it's intention to build 3000MW of new coal fired stations (in IL and KY). Latest pollution control equipment is paid for from the saving in transportation costs.

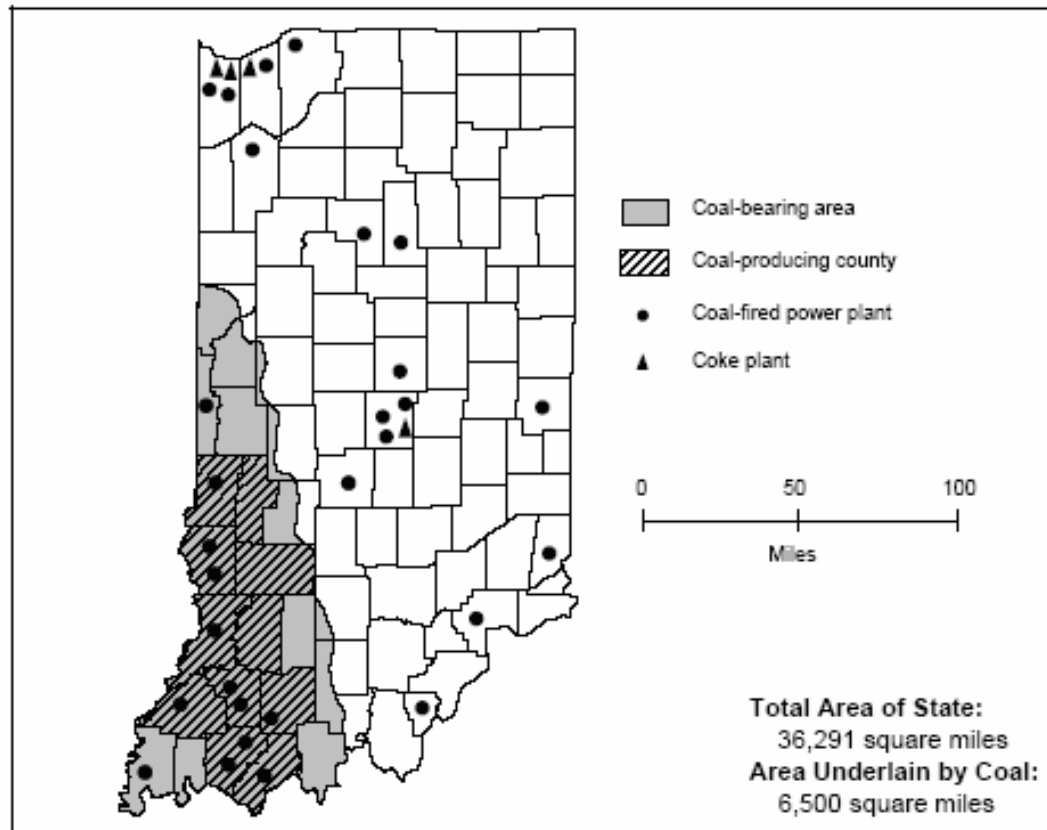
INDIANA OUTPUT AND EMPLOYMENT MEASURES

	Total	Coal Mining	Share
Gross State Product (million 2001\$)	189919	301	0.16
Establishments (2002)	151573	50	0.03
Employment (2002)	2832553	2836	0.10
Annual Wages (2002\$/person)	32603	55205	169.32

Source: Bureau of Economic Analysis, and Bureau of Labor Statistics.

- Relatively small portion of Indiana's economy.
- Less than one percent of GSP, employers, and employment.
- Average wages well above statewide average.

LOCATIONS OF INDIANA'S COAL MINES AND COAL-FIRED POWER PLANTS



Source: Energy Information Administration/State Coal Profiles

- Concentrated in southwestern portion of Indiana.
- Largest production in Gibson, Pike, Knox, Vigo, and Greene Counties.
- Economic impacts, especially employment, concentrated.

U.S. COAL PRODUCTION DIRECT REQUIREMENTS PER DOLLAR DELIVERED

Sector	Share
Agriculture, Forestry, and Fishing	0.0009
Mining	0.1005
Construction	0.0034
Manufacturing	0.1669
Transportation and Utilities	0.1548
Wholesale and Retail Trade	0.0446
Services	0.0404
Value Added	0.4886
Total	1.0000

- Production requirements: the economic activity used in coal production.
- U.S. national averages. Similar data not publicly available for Indiana.
- Value added is portion of output that goes to wages, taxes, and return on investment.

Source: Bureau of Economic Analysis, National Input Output Accounts.

INDIANA RIMS II MULTIPLIERS

(1) The total dollar change in output that occurs in all industries for each additional dollar of output delivered to final demand by the industry.

(2) The total dollar change in earnings of households employed by all industries for each additional dollar of output delivered to final demand by the industry.

(3) The total change in number of jobs that occurs in all industries for each additional 1 million dollars of output delivered to final demand by the industry.

(4) The total dollar change in earnings of households employed by all industries for each additional dollar of earnings paid directly to households employed by the industry.

(5) The total change in number of jobs in all industries for each additional job in the industry.

NOTE. Multipliers are based on the 1999 Annual Input–Output Table for the Nation

Coal Mining
(1) 2.2435
(2) 0.5653
(3) 13.4217
(4) 2.3437
(5) 5.0512

Source: Bureau of Economic Analysis.

INDIANA RIMS II MULTIPLIERS (cont.)

- Derived using a tool called Input-Output analysis.
- Based on data similar to that shown on previous overhead for all industries in an economy.
- Explicitly accounts for the interaction between various components of an economy.
- Multipliers are used to summarize the economic impact of change in economic activity.

INDIANA RIMS II MULTIPLIERS (cont)

- Economic impact of coal production is larger than direct measure of GSP (value added) and employment.
- Applying the multipliers yields estimates:

\$675 million economic activity

14,325 jobs

- Indiana coal mining has economic impact beyond those directly attributed to mining.

ESTIMATES OF INDIANA ECONOMIC IMPACT OF ONE MILLION TON INCREASE IN COAL PRODUCTION

Item	Units	Value
Coal Production	Short Tons	1,000,000
Heat Content	Btu/lb	10,625
Heat Content	10 ⁶ Btu	21,250,000
Coal Price	\$/10 ⁶ Btu	1.25
Coal Cost	\$ million	26.56
Total Economic Impact	\$ million	59.59
Coal Mining Jobs	Persons	158.34
All Other Jobs	Persons	641.49
Total Jobs	Persons	799.83
Total Household Income	\$ million	33.69

- Assumptions used and multipliers result in estimates of economic impact, employment, and household income.
- Quantity and price assumptions are key to estimates. 40

COAL-FIRED SHARE OF ELECTRICITY GENERATION (%) AND AVERAGE RETAIL ELECTRICITY PRICE (cents/kWh), INDIANA AND SURROUNDING STATES

State	Coal Share (%)	Electricity Price (cents/kWh)
Illinois	46.1	6.97
Indiana	93.7	5.34
Kentucky	90.4	4.26
Ohio	90.4	6.66
Michigan	56.5	6.92

Source: Energy Information Agency, State Electricity Profiles, 2002

- Indiana enjoys some of the lowest priced electricity in the nation.
- Low electricity prices due in large part to coal-fired electricity generation.

COAL-FIRED SHARE OF ELECTRICITY GENERATION (%) AND AVERAGE RETAIL ELECTRICITY PRICE (cents/kWh), INDIANA AND SURROUNDING STATES

- Economic impact of coal production larger than estimates on previous overheads due to the unmeasured impact of electricity prices.
- A more detailed study of the relationship between coal, electricity, and economic activity may be desirable.

COAL BY WIRE

- Indiana electric utilities currently export about 850 MW under firm capacity agreements.
- Additional 1,200 MW exported from Clifty Creek plant.
- Depending upon load patterns and availability of generation units, Indiana may be net electricity importer or exporter.
- EIA and SUFG project substantial need for base load electric generation resources over next 15 to 20 years.

ESTIMATES OF INDIANA ECONOMIC IMPACT OF 500 MW COAL-FIRED ELECTRIC GENERATION

Item	Units	Value
Capacity	MW	500
Capacity Factor	%	75
Generation	MWh	3,285,000
Heat Rate	Btu/kWh	9,500
Heat Content	10 ⁶ Btu	31,207,500
Coal Price	\$/10 ⁶ Btu	1.25
Coal Cost	\$ million	39.01
Total Economic Impact	\$ million	87.52
Coal Mining Jobs	Persons	232.54
All Other Jobs	Persons	942.08
Total Jobs	Persons	1,174.62
Total Household Income	\$ million	49.47

- Conventional pulverized coal-fired plant assumed.
- Input-Output multiplier based estimates.

HYPERTHEMETICAL EXAMPLE OF DELIVERED COAL COST AND ELECTRICITY FUEL COST

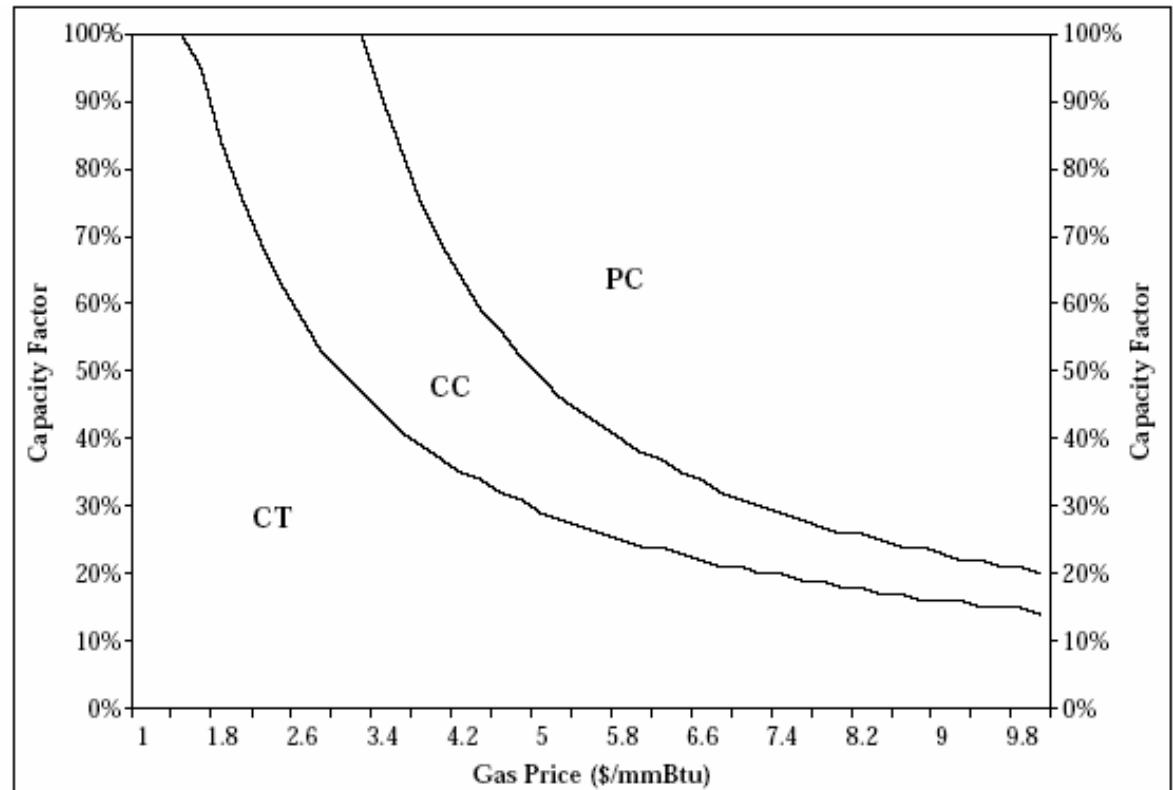
Coal Cost, $\$/10^6$ Btu, 1.00; Transport Cost, $\$/\text{Ton-Mile}$, 0.010;		Heat Content, Btu/lb, 10625 Heat Rate, Btu/kWh, 9500	
Miles	$\$/\text{Ton}$	$\$/10^6$ Btu	$\$/\text{MWh}$
0	21.25	1.00	9.50
100	22.25	1.05	9.95
200	23.25	1.09	10.39
300	24.25	1.14	10.84
400	25.25	1.19	11.29
500	26.25	1.24	11.74
600	27.25	1.28	12.18
700	28.25	1.33	12.63
800	29.25	1.38	13.08
900	30.25	1.42	13.52
1000	31.25	1.47	13.97

HYPERTHEORETICAL EXAMPLE OF DELIVERED COAL COST AND ELECTRICITY FUEL COST

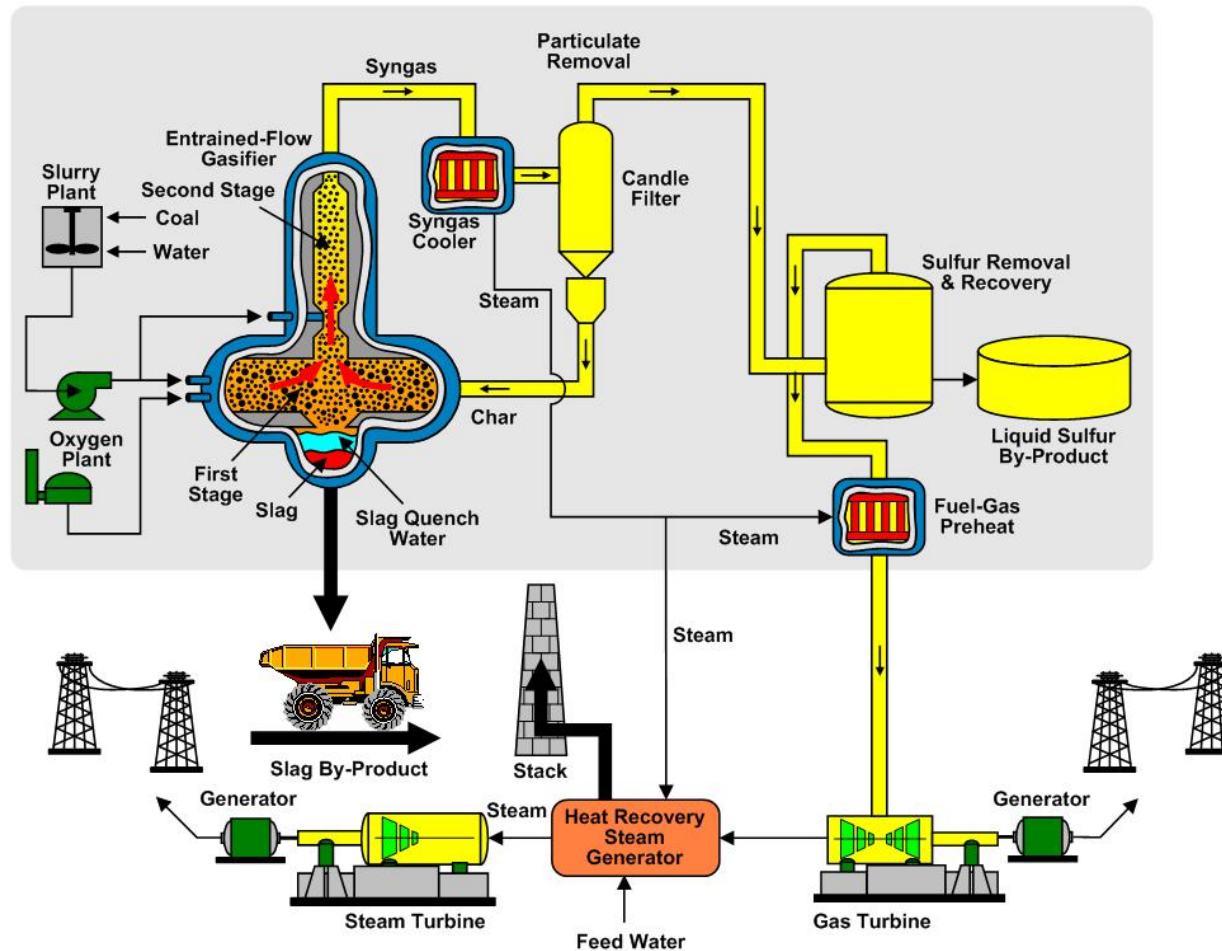
- Trade-off between transporting coal to generation plant near load versus electricity transmission to load from distant plant.
- Simple analysis illustrates concept.
- Real world much more complicated:
 - coal transport mode and availability
 - electricity transmission cost and availability

FUTURE COMPETING TECHNOLOGIES FOR POWER GENERATION

- Power generation from coal becomes more competitive as the capacity factor increases
- It appears likely that future base load needs in Indiana (6000 MW by 2021) will come from coal based plants while the peaking and cycling demands will be met by gas fired turbines and combined cycle plants



FUTURE COAL-BASED POWER GENERATION TECHNOLOGIES



How extensive a role is IGCC technology to have in Indiana and the Midwest?

FUTURE COAL-BASED POWER GENERATION TECHNOLOGIES

- Requirements for future coal-based power plants include
 - High Efficiency
 - Low Emissions (including CO₂)
 - Versatility
- Competing technologies include
 - Pulverized Coal Steam Turbine
 - Integrated Coal Gasification Combined Cycle (IGCC)
 - Flue Gas Recycle
- The IGCC process best fits the criteria for future plants, exhibiting a high efficiency, low emissions with the possibility of economical CO₂ capture, and versatility to produce power, syngas, or hydrogen. The sulfur is captured in a form that provides an additional economic advantage.

PERFORMANCE COMPARISON OF MAJOR COMPETING IGCC TECHNOLOGIES

Process	Shell (Hot Gas Clean Up)	Texaco (Quench Cooling)	E-Gas (Hot Gas Clean Up)	Kellogg Transport (Air Blown)
Gas Turbine Power (MW)	272.4	272.7	272.6	272.6
Steam Turbine Power (MW)	187.5	152.3	171.1	162.6
Misc./Aux Power (MW)	47.7	42.0	43.3	-20.0
Total Plant Power (MW)	412.2	382.9	400.4	415.4
Efficiency, HHV (%)	48.0	39.7	47.6	49.8
Total Capital Requirement, (\$1000)	564,963	500,599	538,933	484,062
\$/kW	1,370	1,307	1,346	1,165
Net Operating Costs (\$1000)	42,562	48,411	41,888	45,388
Cost of Electricity (cents/kWh)	4.07	4.25	4.04	3.81

SUMMARY OF ISSUES RAISED IN THE WHITE PAPER

- Complete list of questions in the handout.
- **Basic Issue:** How can Indiana increase the use of Indiana coal through a state needs-directed R&D program? To do this, should we form a partnership with other Illinois basin coal producing states?
- **In the short run:** How can we obtain a higher fraction of the 100 million tons/year now imported into Midwest markets? To do this, how can we increase the economic advantage of using IBC rather than PRB coals?
- **In the long run:** How can we help make the Midwest the “clean coal technology (CCT) capital of the world”?
 - By encouraging the use of CCT to satisfy the Midwest’s emerging needs for new generation capacity.

CONTACTS

F.T. Sparrow, Ronald L. Rardin, Brian H. Bowen
PURDUE ENERGY MODELING RESEARCH GROUPS
PURDUE UNIVERSITY
Ph: 765-494-7043, Em: fts@ecn.purdue.edu