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

COAL:
Meeting Future Energy Needs in an Economic and Environmentally Sound Manner

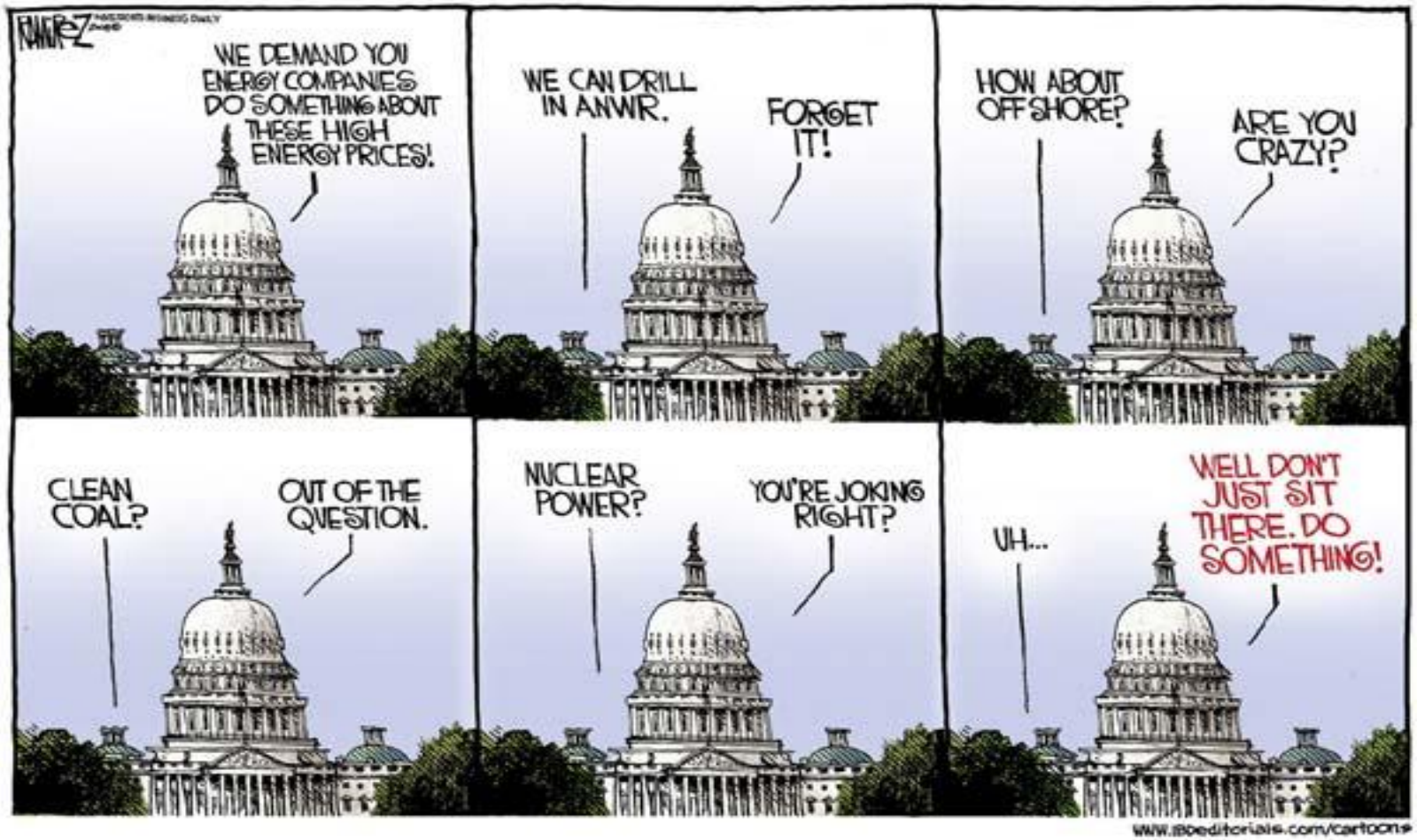
Environmental Science and Policy Seminar
Indiana University
School of Public and Environmental Affairs

March 5, 2009

Marty W. Irwin, Director
Indiana Center for Coal Technology Research

US Energy Policy

Don't just do something, sit there



US Energy Policy: 1) Encourage Consumption, 2) Discourage Production, 3) Make up the difference by buying from people who hate us.

Are we using to much Energy?

	Population	Energy	GDP	Energy/GDP 1000Btu/$
USA	6%	25%	33%	.758
ROW	94%	75%	67%	1.12

Do the Math

US population consumes 5.26 times the energy of the average person in the rest of the World;

But we produce 7.7 times the goods and services of the Rest Of the World.

The USA only 67% of the energy per unit of GDP as does the rest of the world.

We are the model of energy efficiency, (only **Japan** and **Lichtenstein** are better).

Per capita energy is of no value to measure, to reduce your per capita consumption you need only add population.

It is what you do with the energy that matters.

33% of the world has never used a telephone:

30% of China population have no electricity or indoor plumbing:

50% of the population of the world is on a subsistence economy:

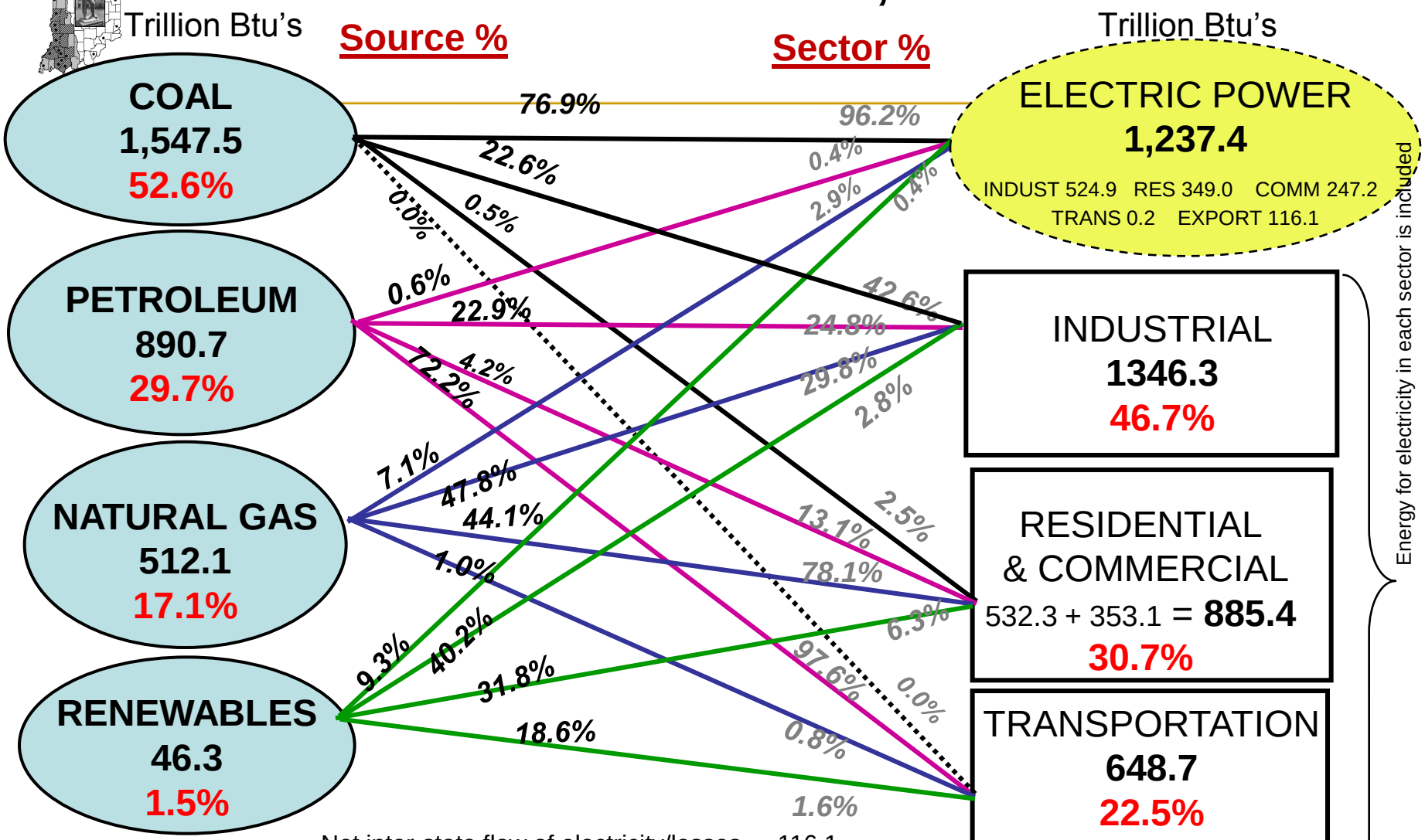
How do you compare the energy use of a Bushman in the Kalahari trying to feed his family with a Hoosier farmer who uses his 255 acres to feeds 150 people?

If the rest of the world consumed energy as efficiently as the USA

total World Wide Energy Consumption would be ***reduced by 25%***

- Shifting manufacturing overseas altered our energy intensity.

Indiana Primary Energy Consumption Source & Sector, 2006



Net inter-state flow of electricity/losses = -116.1

Indiana Total = 2.88 Quads (10^{15} Btu)

2,880,000,000,000,000 Btus (75% imported)

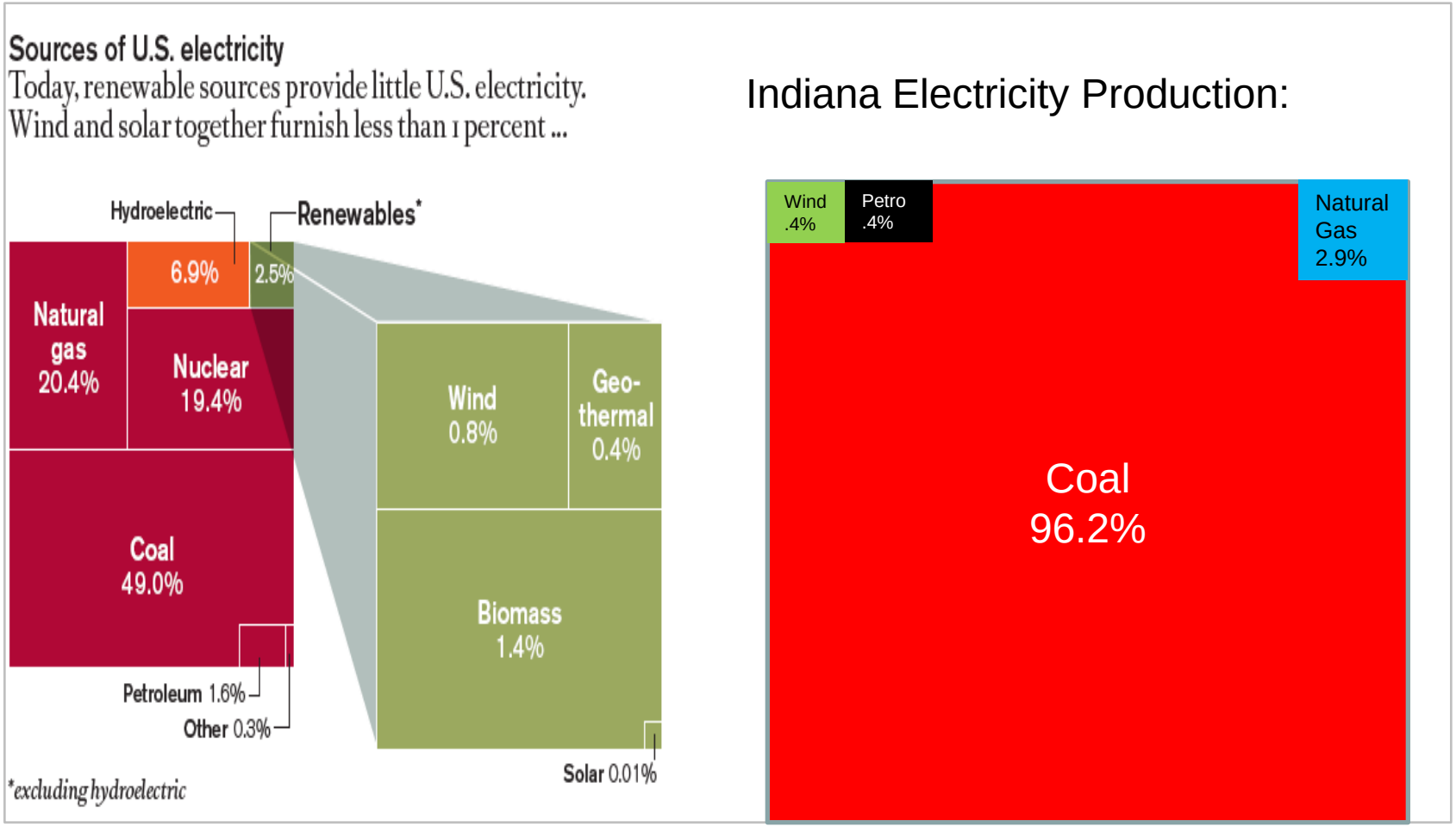
USA=101.6 Quads

32% Imported

http://www.eia.doe.gov/emeu/states/sep_use/total/pdf/use_in.pdf

http://www.eia.doe.gov/emeu/states/state.html?q_state_a=in&q_state=INDIANA

Coal, Nuclear, Natural Gas & Renewables as Sources of U.S. and Indiana Electricity Supplies



How Important is Manufacturing to Indiana? Manufacturing as % of Indiana's GDP

	1997 GDP	2006 GDP
Durable Goods	**18.1%**	**20.5%**
Non-Durable Goods	**10.2%**	**10.0%**
Total Manufacturing	**28.3%**	**30.5%**

- In 1997 Indiana's 18.1% durable goods as part of GDP was the highest in the nation. (2006 Indiana ranked 3rd).
- 2006 Total Manufacturing of 30.5% is highest in the nation.
- Your CO2 Footprint is large if you live in Indiana because we are a Manufacturing State: CO2 and Energy use measurements do not account for where the final product is consumed.

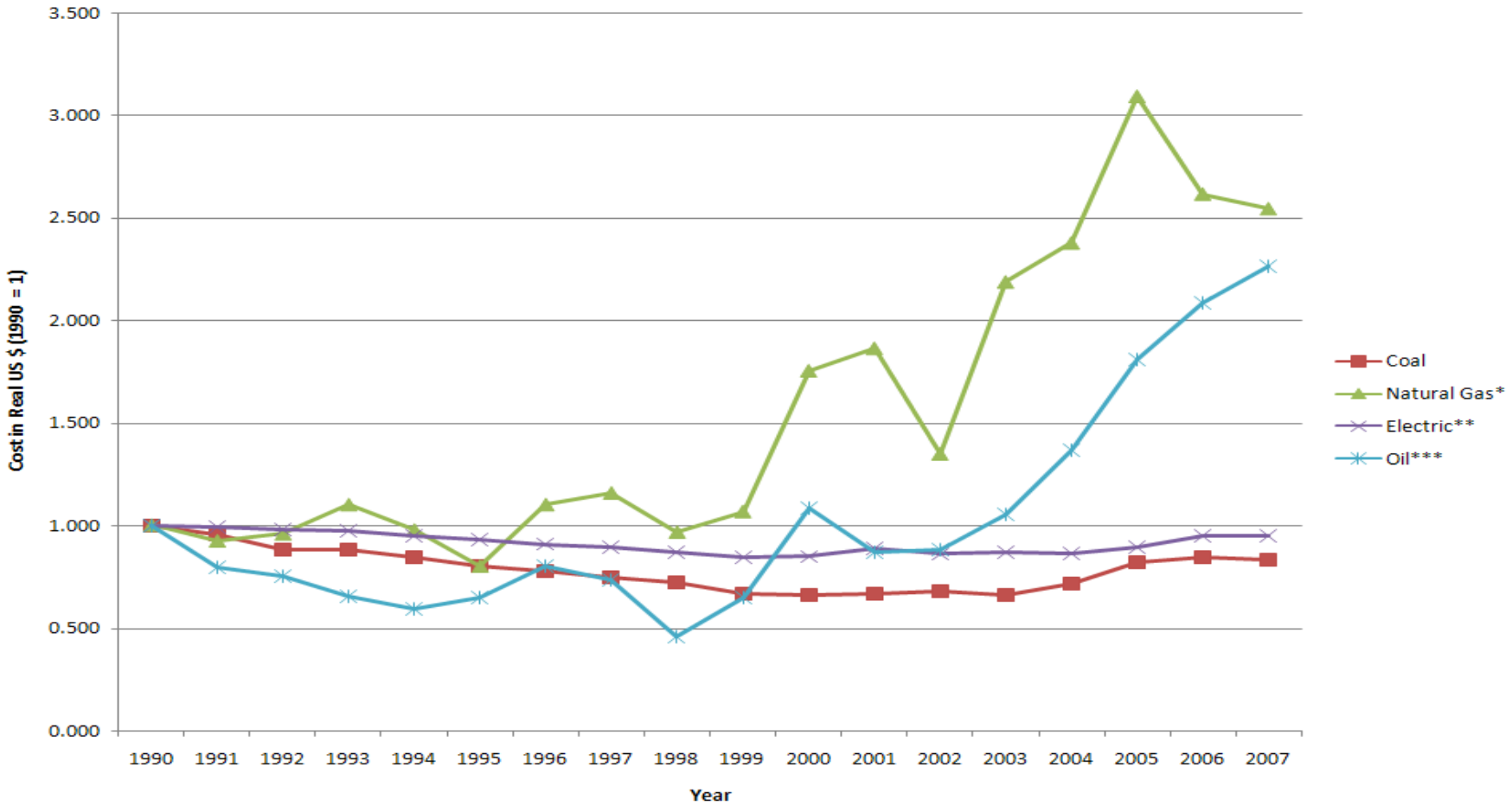
Indiana is a manufacturing state

Indiana's industrial sector provides about 1/3 of the state GDP & consumes nearly 1/2 of total energy

Indiana consumes 35.7% more energy than average due to manufacturing.

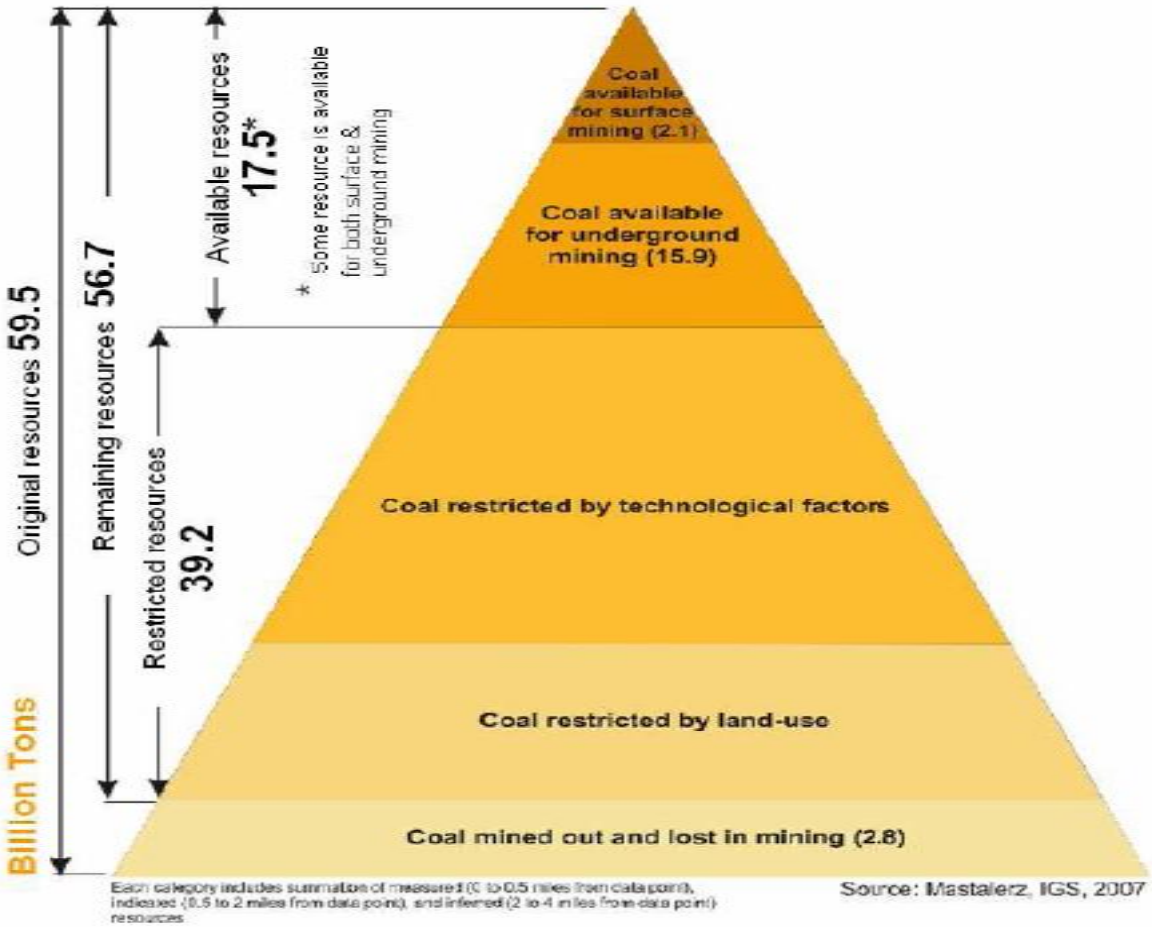
Source: Indiana Business Review, Spring 2008

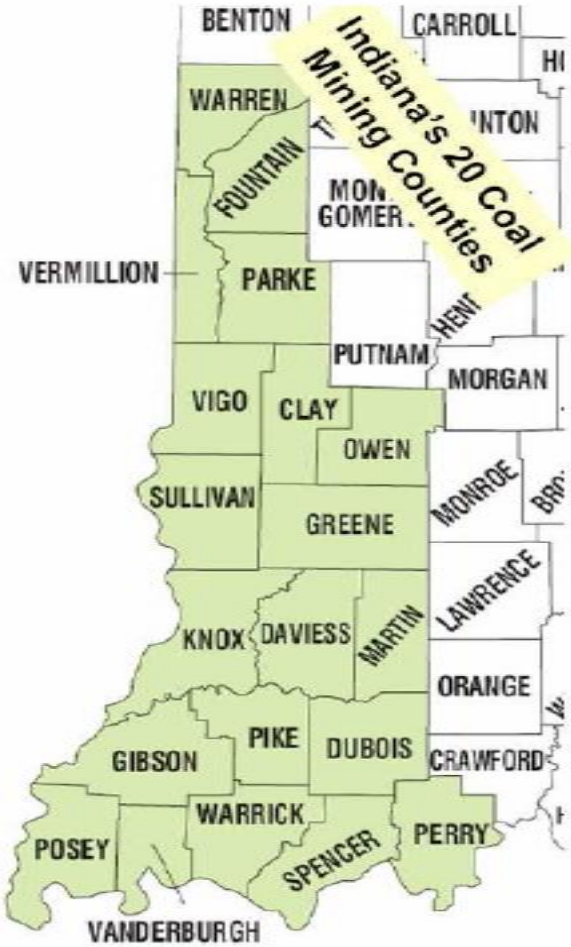
Real Cost of Energy In Indiana Electricity is Coal



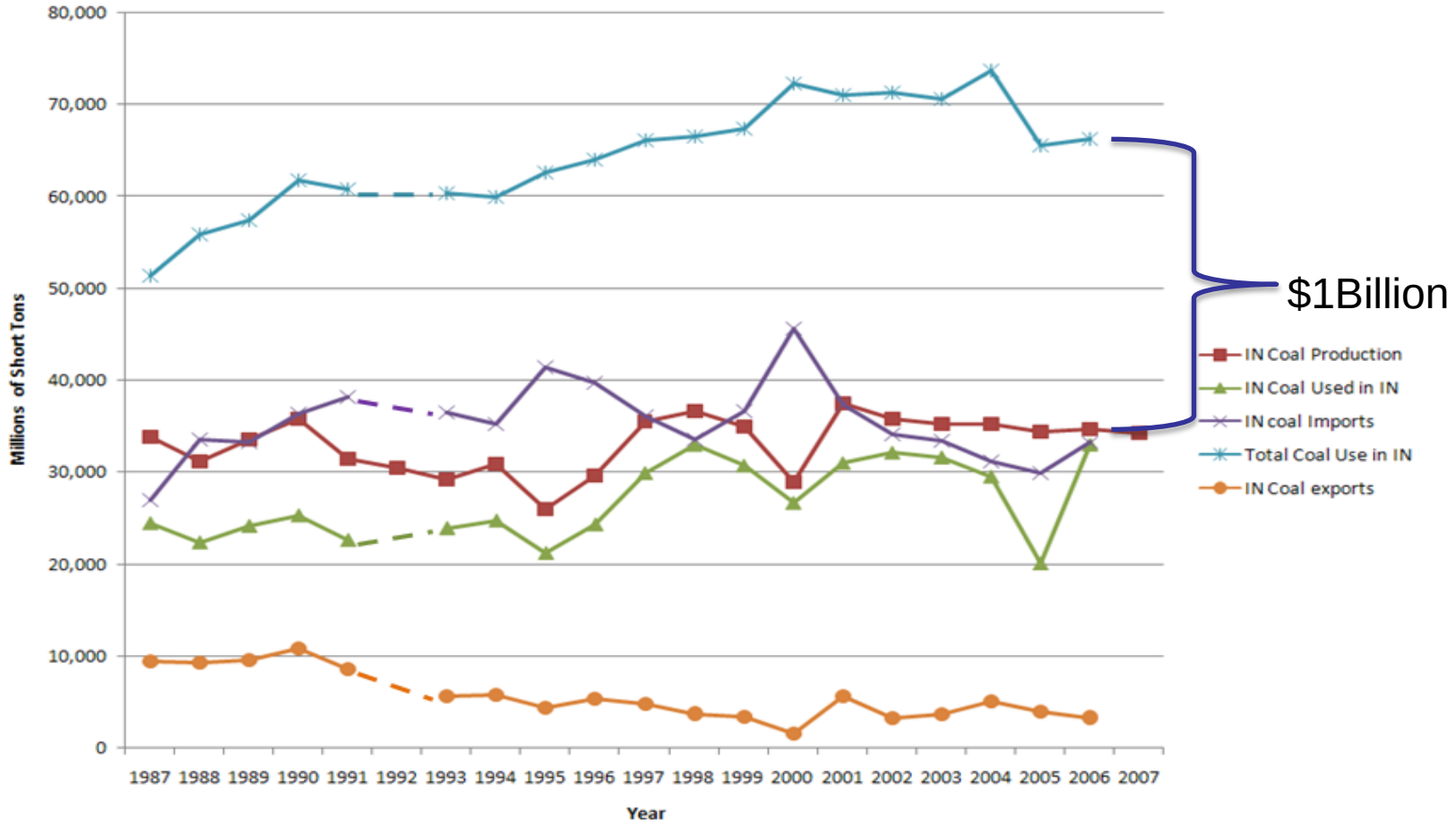
Why Coal?

Because for the next 30-40 years there is no Alternative that can meet this level of Demand for Energy.

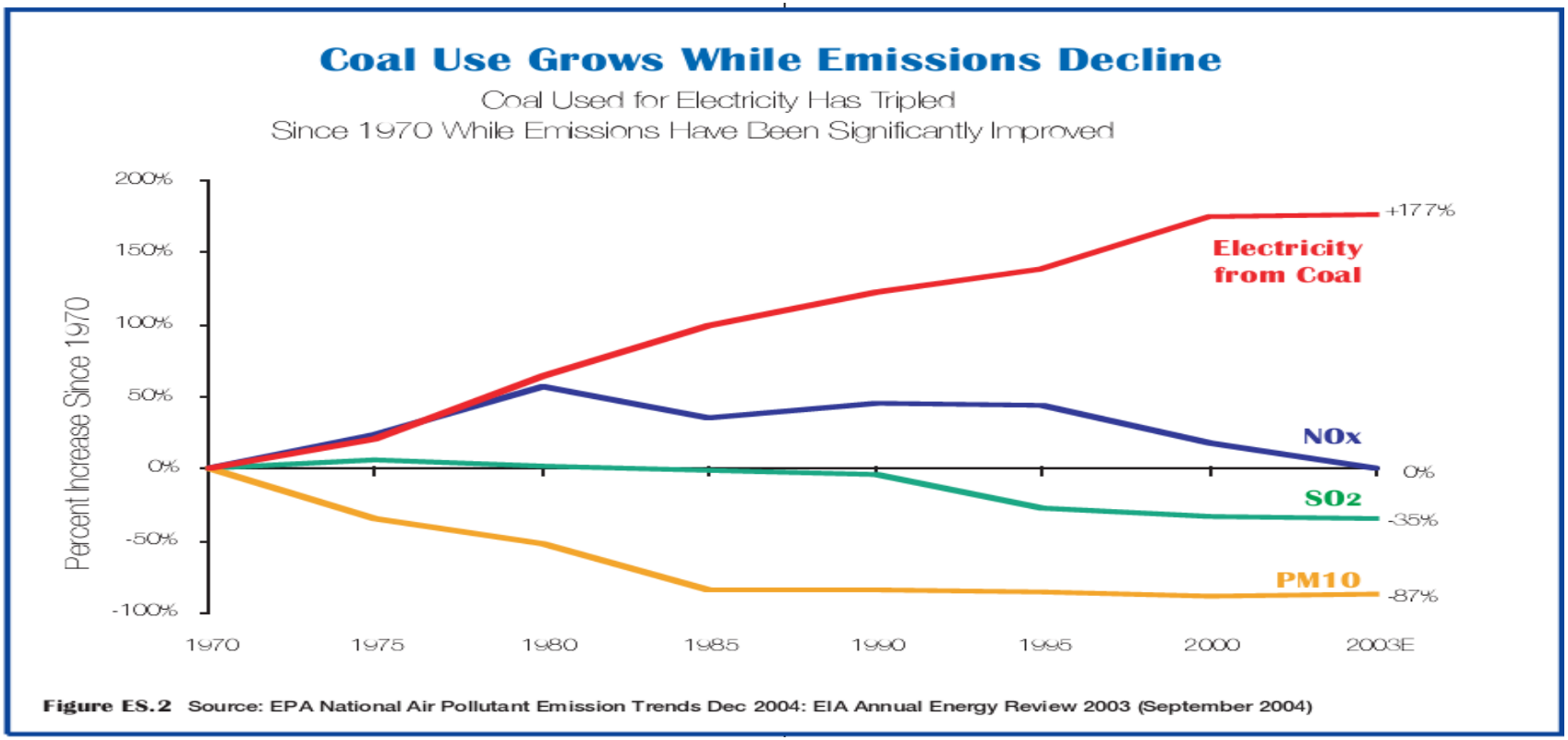




COAL USE TREND
Indiana coal consumption growing much faster than Indiana coal production



Coal is the Answer to the emissions problem. Increasing the use of electricity puts the emissions controls at the Utility.



<u>You rent pollution control when you buy electricity</u>
<u>Does CO2 work the same way?</u>

The average person today consumes *<u>2.2 times the ELECTRICTY</u>* as a person did in 1970 *<u>Not ENERGY But Electricity</u>*. One reason air quality has greatly improved.

2007 COAL IMPORTS: INDIANA

(Thousand short tons)

Wyoming: 15,764 Total
15,552 Electricity Generation
212 Industrial Plants

Colorado: 817 Total
817 Electricity Gen

Utah: 197 Total
197 Industrial

Illinois: 7,100 Total
6,003 Electricity Generation
1,097 Industrial Plants

Kentucky: 706 Total
108 Electricity Generation
598 Industrial Plants

Alabama: 483 Total
483 Coke

IN STATE PRODUCTION: 34,770 Total
29,807 Electricity Generation
1,812 Industrial Plants
166 Residential-Commercial

Pennsylvania: 1,298 Total
1,277 Electricity Generation
21 Coke Plants

Ohio: 1,341 Total
1,334 Electricity Generation
7 Industrial Plants

Virginia: 486 Total, Coke Plants

West Virginia: 7,946 Total
2,838 Electricity Generation
3,726 Coke Plants
1,382 Industrial Plants

Indiana Total Consumption

Electricity	59,664
Coke	4,716
Industrial	3,493

Indiana Exports
Total = 2,985

KY	1,779,	WI	361
AL	374,	IL	280
TN	97,	MS	78

Indiana Total Consumption = 67,873 Thousand short tons

Sources: FERC 423, http://www.eia.doe.gov/cneaf/electricity/page/ferc423.html
http://www.eia.doe.gov/cneaf/coal/page/coaldistrib/coal_distributions.html
http://www.indianacoal.com/

Evolution of the Coal Power Plant

Yet electricity per ton of coal continues to increase

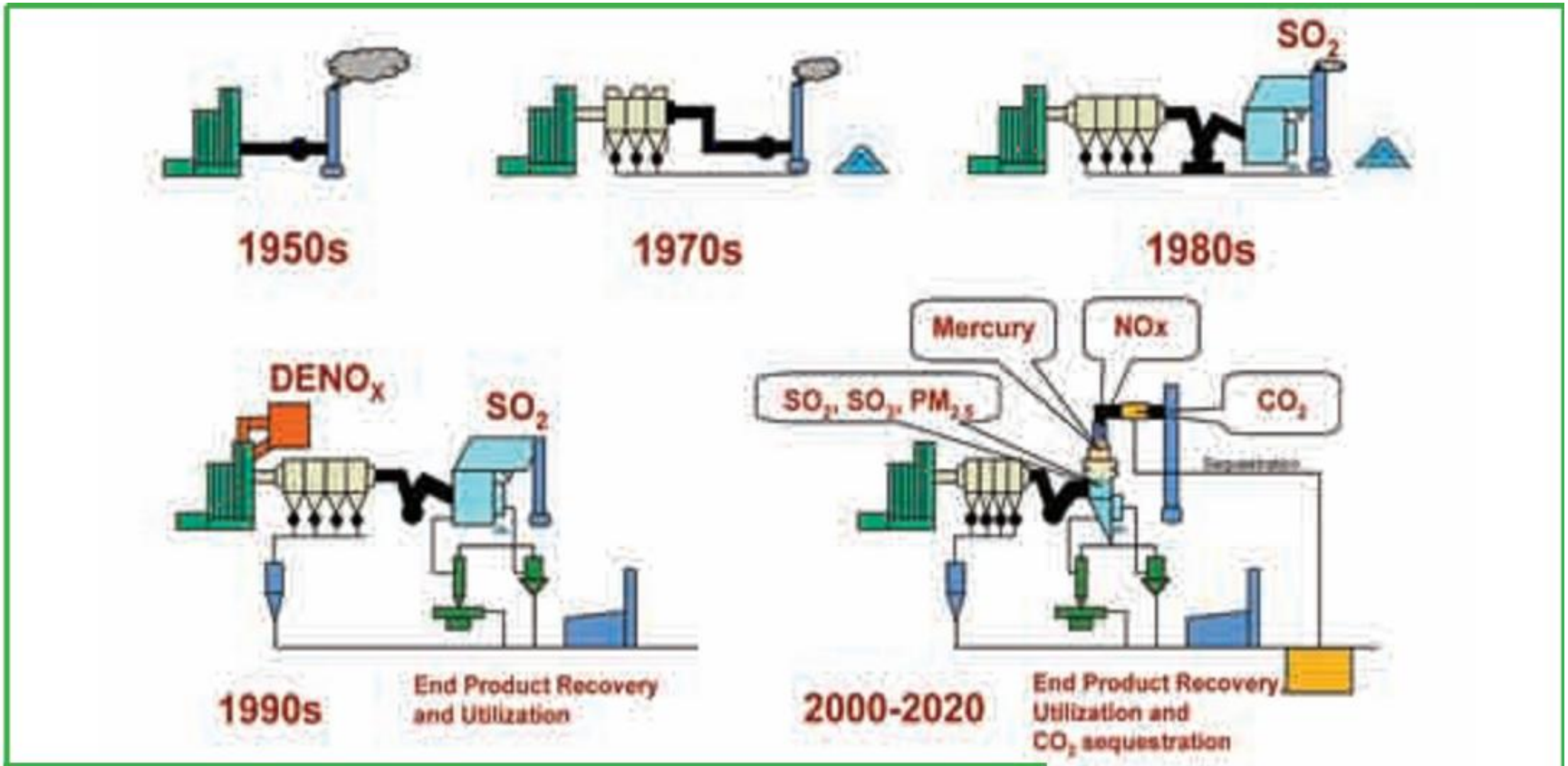
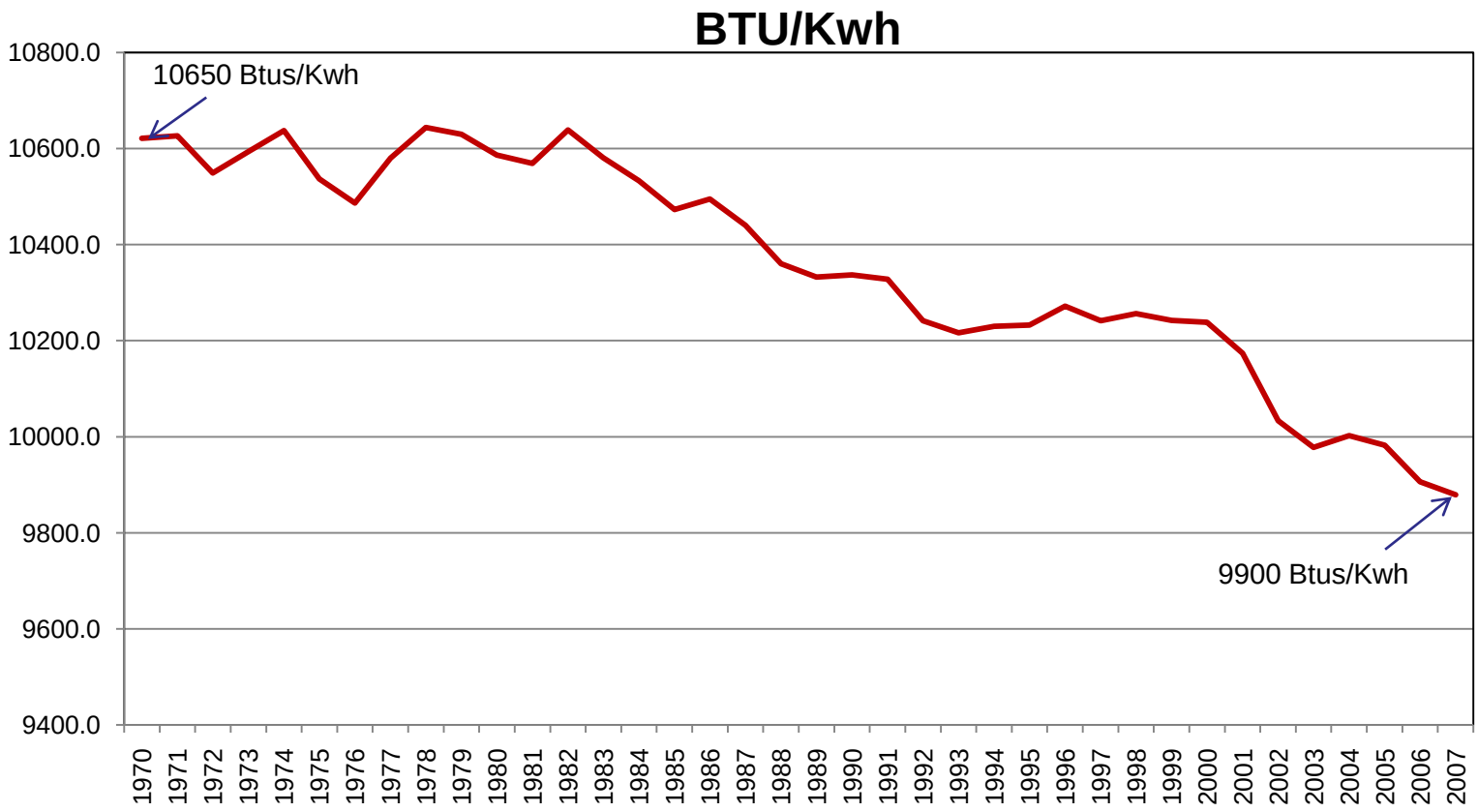


Figure ES-1

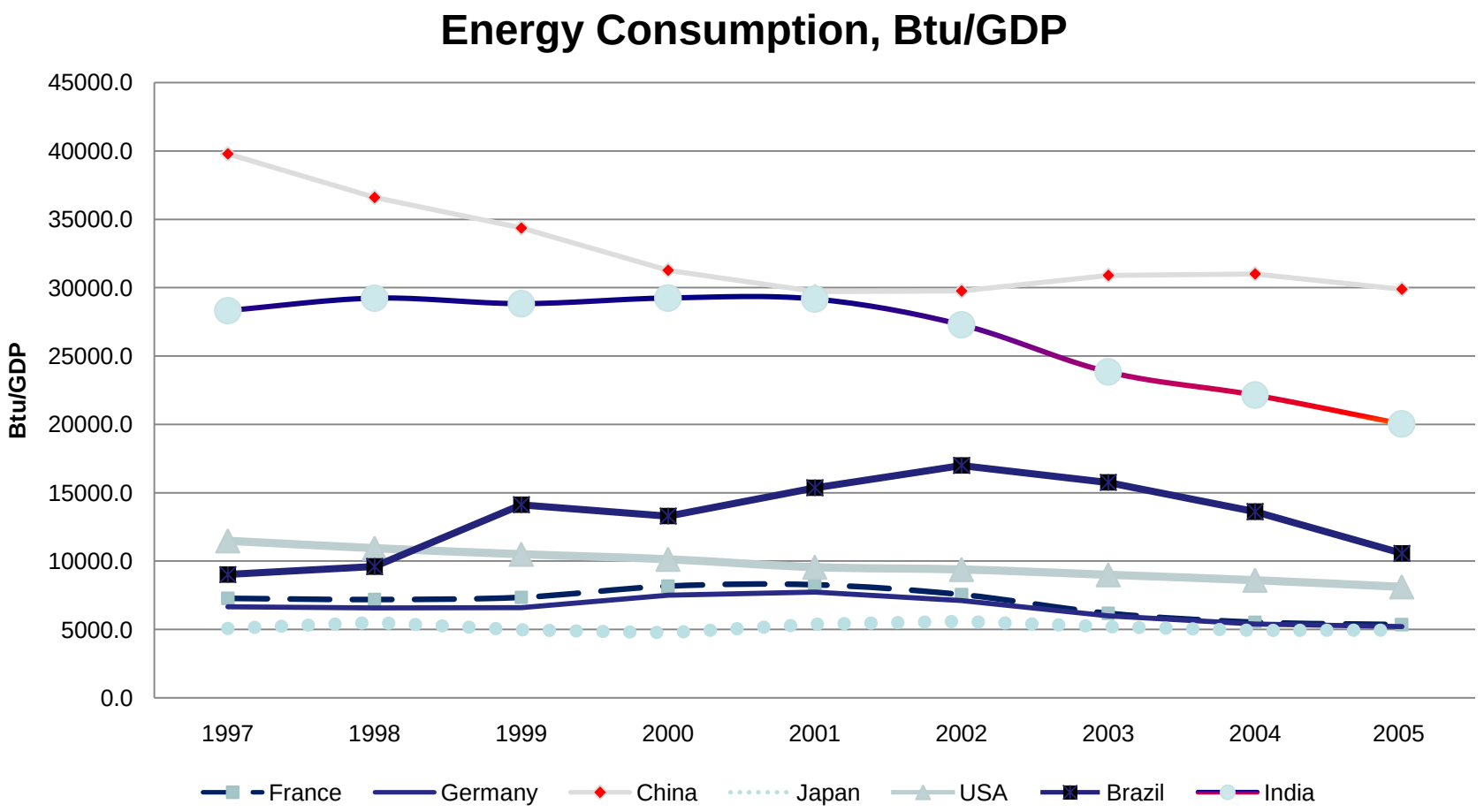
Evolution of Coal Fired Power Plant Emissions Capture[2]

The production of a KWh of electricity with the added environmental equipment and parasitic load takes *7.5% less* energy than it did 35 years ago



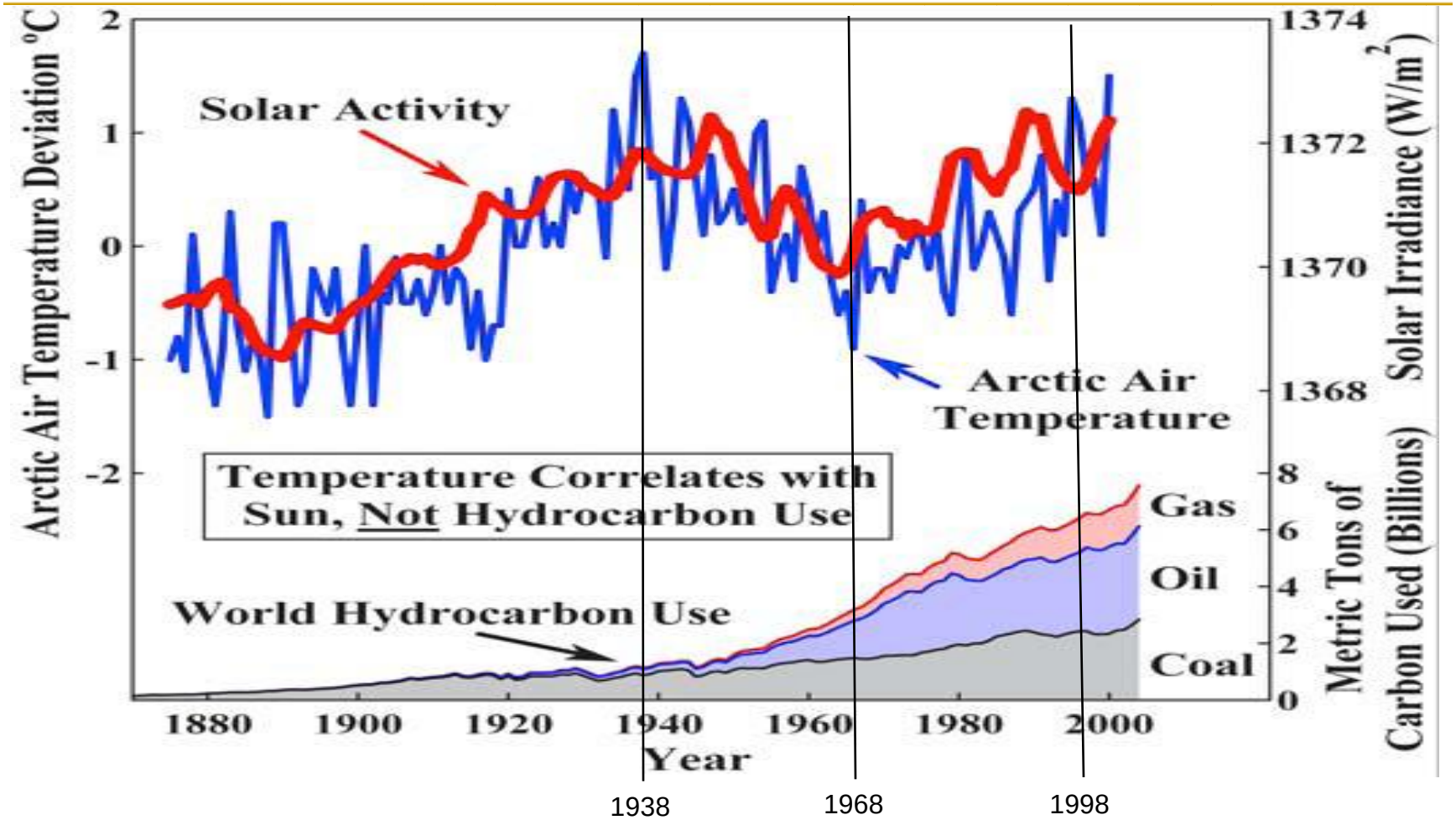
http://www.eia.doe.gov/emeu/states/state.html?q_state_a=in&q_state=INDIANA

US most energy efficient Country in the World



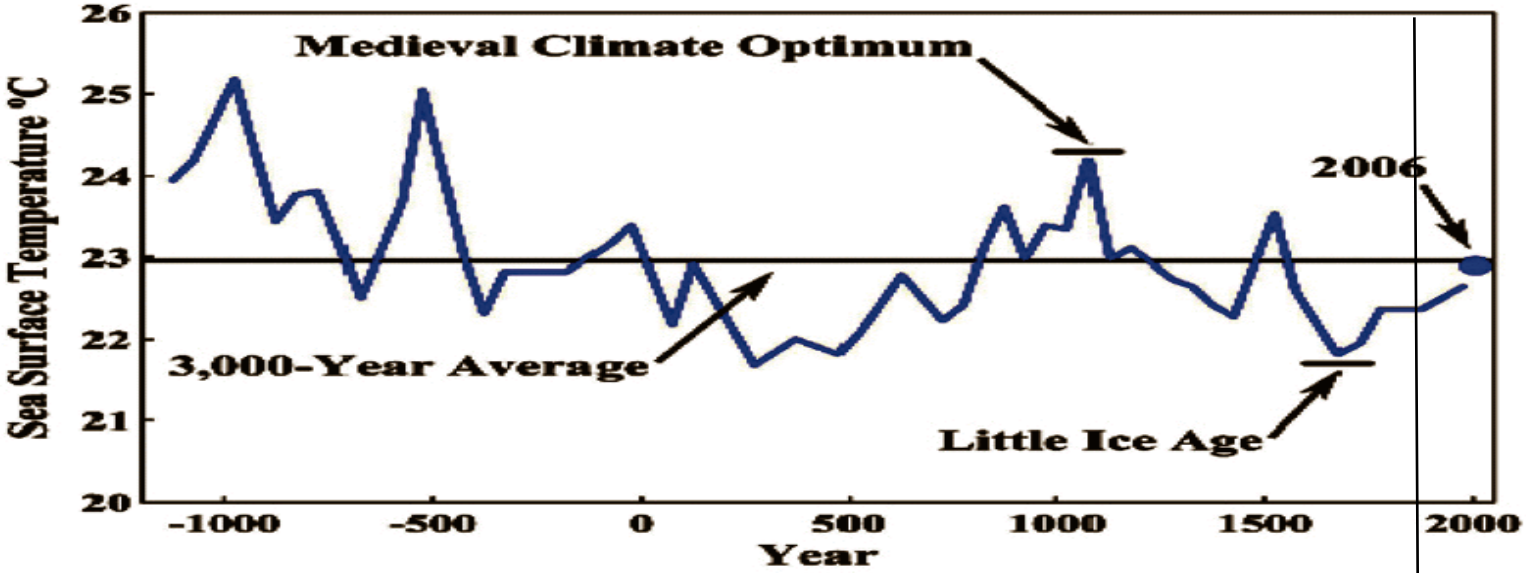
China consumes 3.7X the energy to produce 1$ GDP as does the US.
When we shifted manufacturing to China we shifted massive energy requirements also.

Sun, Temperature, CO_2 Correlations or Cause and Affect

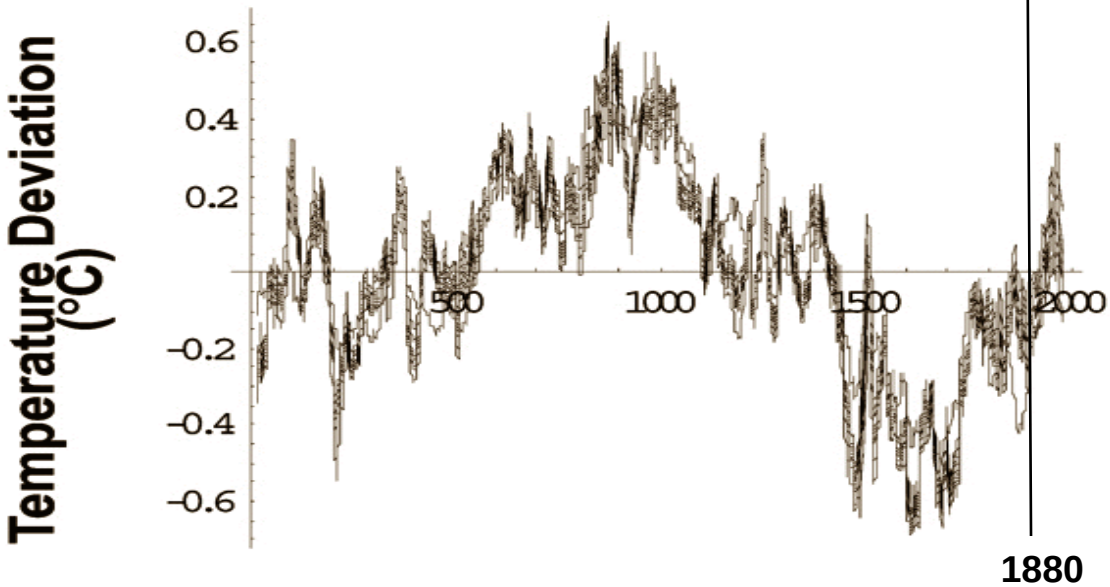


Source: Arthur B. Bobinson et al,, Journal of American Physicians and Surgeons (2007) 12, 79-90.

a.


Medieval Climate Optimum
2006
3,000-Year Average
Little Ice Age
Sea Surface Temperature °C
26
25
24
23
22
21
20
-1000
-500
0
500
1000
1500
2000
Year

b.


Temperature Deviation (°C)
0.6
0.4
0.2
-0.2
-0.4
-0.6
500
1000
1500
2000
1880

The Big CO2 Issue;
We Don't Know What We Think We Know

1) How Much CO2 is produced Naturally?
2) How Much CO2 is produced by Human Activity?
3) How Much CO2 is consumed by the Earth Naturally?
A) If #1 + #2 is > than #3 then CO2 Density will Increase.
B) If #1 + #2 is < than #3 then CO2 Density will Decrease.
C) If #1 is > #3 then CO2 Density will Increase regardless of what we do with Human Produced CO2
4) What is the Current Level of CO2 Density? Estimated at 380ppm, (ranges from <100ppm in upper Canada to > 500ppm in Amazon Rain Forest).
5) What is the Optimal Level of CO2 Density?
6) How Much Human Made CO2 Needs to be Reduced to Reach the Optimal Density Level? (Assuming that 3B is accurate).
7) What is the cost of reducing CO2 Human Made Emissions by 90% in by 2050? $ 1,354,000,000,000 .(McCain-Lieberman I Bill)
-
The problem with CO2 legislation: WE DO NOT KNOW THE ACTUAL VALUE OF ANY OF THE ABOVE!

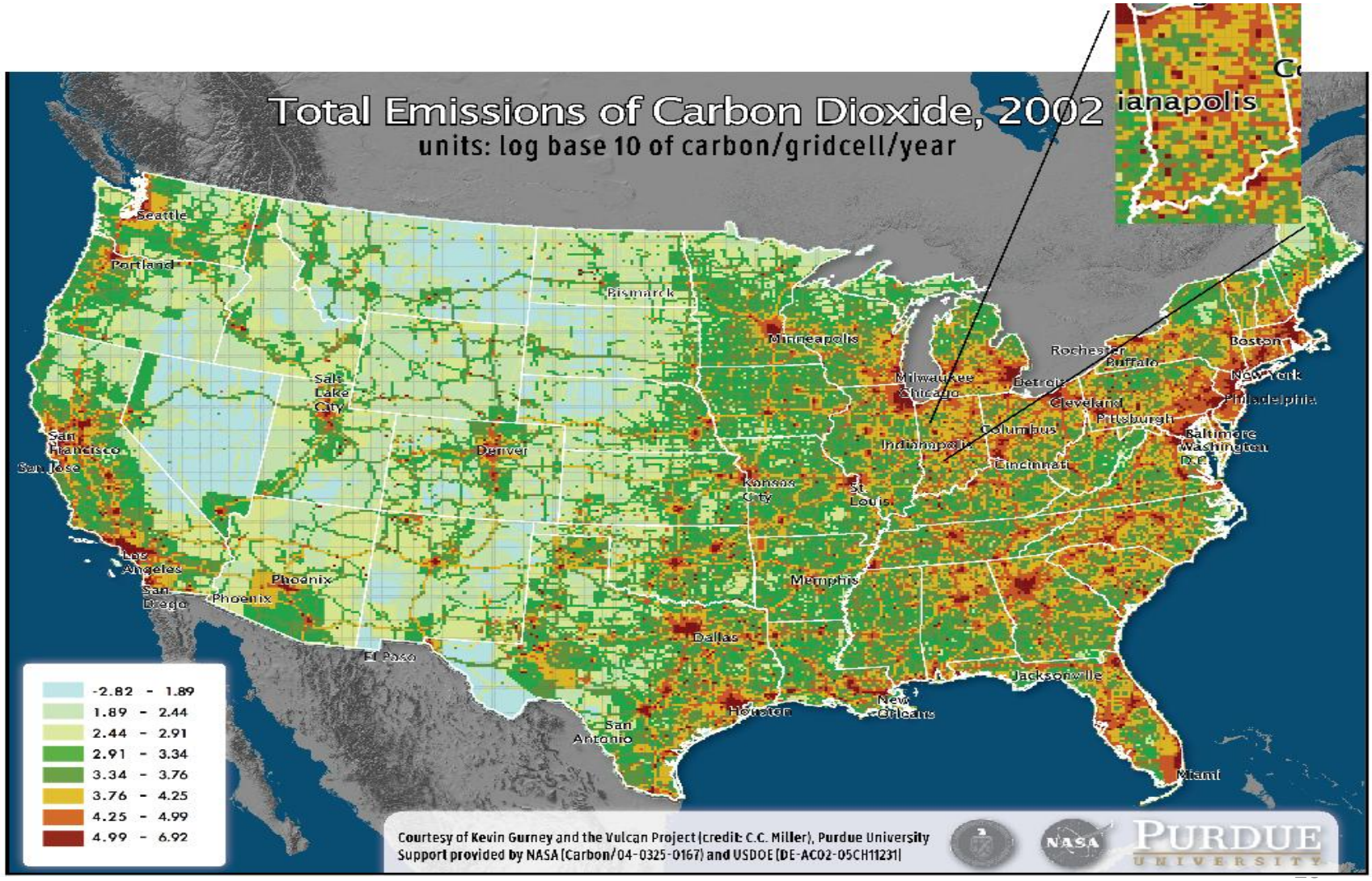
Indiana's Average CO2 & Power Production from 1 Ton of Coal

- **1 Ton of Coal produces 2.26 Tons CO2**
- **1 Ton of Coal produces 2.25 MWh Electricity**
- **1MWh of power ≈ 1 Ton of CO2 produced**

Average Indiana Household consumes 10 tons of coal in the form of electricity

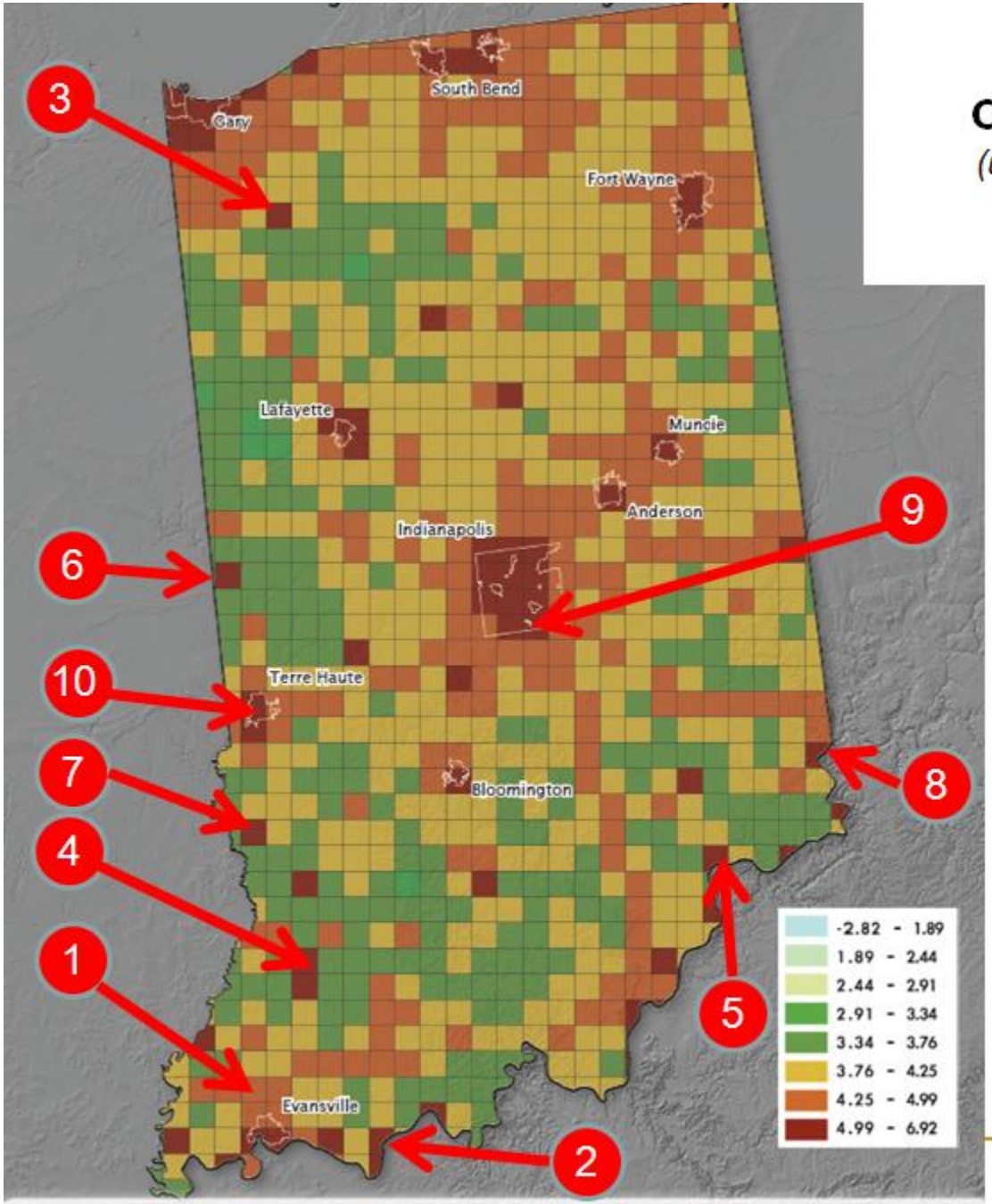
2 pounds CO_2 per KWh consumed

U.S. CO_2 Emissions and Density from Fossil Fuels



Total Emissions of Carbon Dioxide 2002

(units: log base 10 of carbon/gridcell/year)



Courtesy of Kevin Gurney and the Vulcan Project (credit: C.C. Miller), Purdue University
Support provided by NASA (Carbon/04-0325-0167) and USDOE (DE-AC02-05CH11231)

Indiana's Big 10 Power Stations:

1	Gibson	3,131 MW
2	Rockport	2,600
3	Schahfer	1,780
4	Petersburg	1,672
5	Clifty Creek	1,209
6	Cayuga	1,096
7	Merom	1,000
8	Tanners Ck	980
9	Harding St	924
10	Wabash River	918

Note: Impact of urban transportation

We must get the Science Right, or We will get the Policy Wrong.

Problem: We have a need for a lot more energy;
we produce stuff used elsewhere.
We have a lot of coal;
We have real issues with CO2 ;
Regardless of whether there is any legitimate environmental basis for the concerns or not.
We are shipping out $1 billion a year to buy coal from other states and bring it to Indiana;

What would resolve all of the issues?
Use Indiana's own coal in a way that would;

1) Retain energy capital,
2) Create jobs for Hoosiers,
3) Leave the environment cleaner than it is now,
4) Reduce the cost of the goods manufactured in the state (especially steel),
5) **Turn CO2 into a resource**

•**US Law REQUIRES all vehicles Built Sold and Used in the US to produce CO2**

Reduce CO2 by 80% from its 1990 levels by 2050

Obama campaign pledge

If we shut down the whole transportation system , every car, truck, train, plane and ship anything that flies or has wheels:

we reduce carbon dioxide by **14%**

If you shut down all industrial activity, all commercial activity ,all residential activity-shut off everything at home, school and work:

we reduce carbon dioxide by **68%**

The remaining 18% is the result of humans eating and exhaling.

Human energy consumption drops from 10KW to 2 KW per capita

David O'Reilly CEO Chevron

THE 3 BIG ISSUES

1) **The Scale of the Demand**
2) **The Scale of the Investment needed**
3) **The Scale of Time needed to produce Alternatives:**

It has taken 100 years to get the system we have now in place. How much time will it take to replace it with a bigger system?

These aren't "205 ways to easy ways to go Green"

There are massive investments in time effort and money needed to make reduced emission power.

Green Industry will be: *Steel, Aluminum, Copper, Nickel, Cobalt, Glass, Silicon (carbon fiber)*.

Every one of the United Nations Millennium Development Goals REQUIRE access to Electricity as a necessary prerequisite.

Energy use is going to rise, because there is an inexorable connection between energy use and well being**.**

TODAY	2050
Golden Billion	Golden 3 Billion
2 Billion Wannabes	3 Billion Wannabes
3 Billion Poverty	3 Billion new people born into poverty
Total World Population 6 Billion	Total World Population 9 billion

If the Golden Billion consume 75% of all energy, and Wannabes consume 20% of all energy, and those in poverty consumes 5%;
<u>by 2050 we will need 260% more energy than today.</u>

If we eliminate the Golden level then we will still need **125% more energy**.

Energy break even point may not be a significant consideration, It is the use of the energy that matters

Solar and Wind produce electricity without emissions or water.

Solar: Photovoltaic's use large amounts of Electricity to make devices that produce Electricity. (Energy transfer device?)

- Local use no transmission network needed.

Break Even: Never

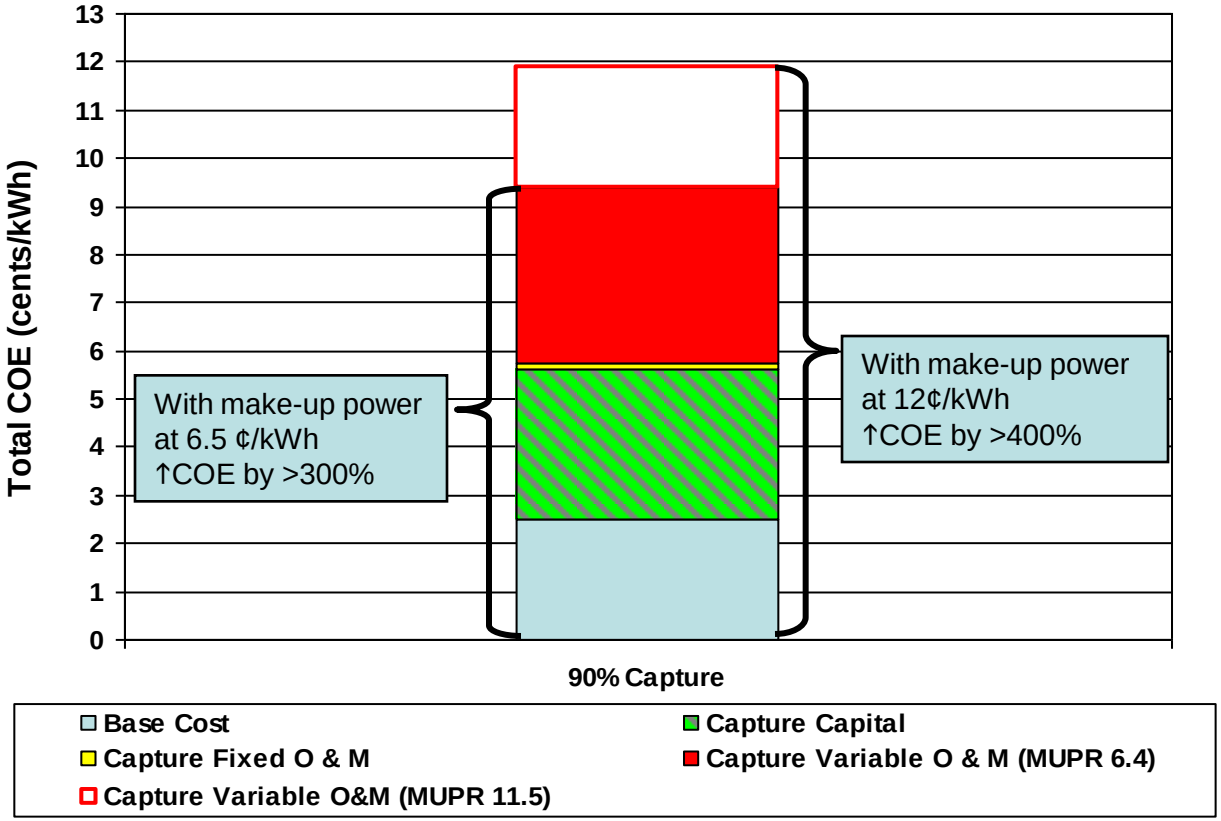
Wind: 2MW Turbine needs 6-8 tons of Cast Iron.

- 100 pounds of Copper,
- Heavy metal permanent magnets: Nickel, Cobalt, Iron
- Massive amounts of steel and aluminum for transmission towers and power lines
- **Break Even: 8-12 years** (makes electricity out of nothing)

Coal Fired Power Plant Break Even point ???

- Makes energy out of an otherwise worthless commodity, coal
- Coal in and of itself is of no value until you convert it to something else: heat or gas.

Economic Results
Of CO2 Removal and Sequestration



Base power plant cost for an existing plant obtained from Energy Velocity ranged from 2 to 3 cents/kWh.
6.5 ¢/kWh assumes make-up power from a new non-capture supercritical PC plant
12.0 ¢/kWh assumes make-up power from a new supercritical PC plant with 90% capture

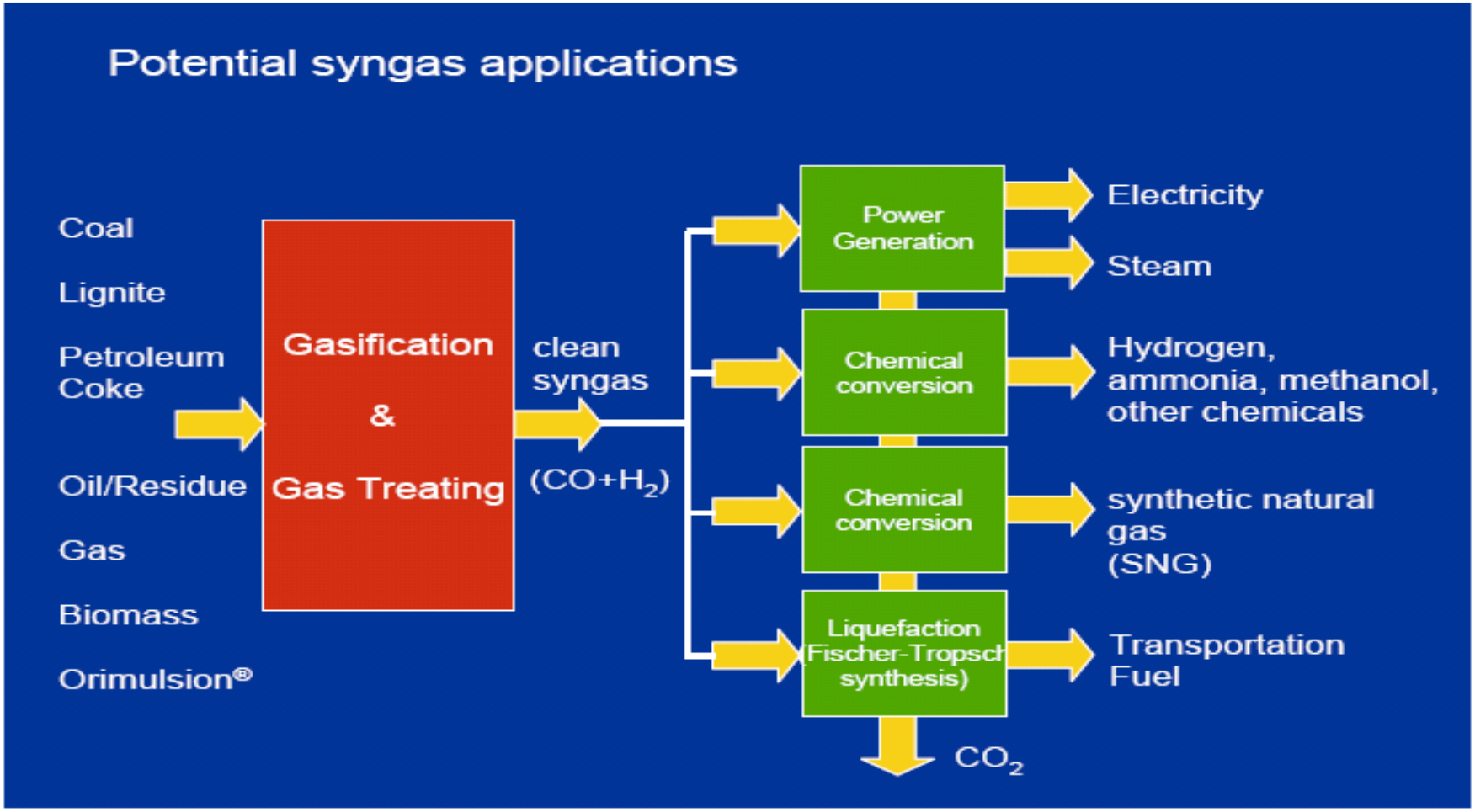
Source: Jared Ciferno, DOE NETL 401/110907

Energy cost are extremely regressive.

Wind versus Coal Employees

- Wind energy employees 85,000 in 2008.
- Coal industry employs over 1.4 million Americans.
- The wind industry generated 1.3 million megawatt-hours (Mwh) of electricity, while the coal industry generated 155 million Mwh.
- Wind energy produces **15.29 Mwh per Employee,**
- Coal energy produces **110.71 Mwh per Employee**
- What this figure actually demonstrates is how inefficient wind energy is compared with coal
- **Coal jobs are 7.24 times more efficient and productive than wind jobs.**

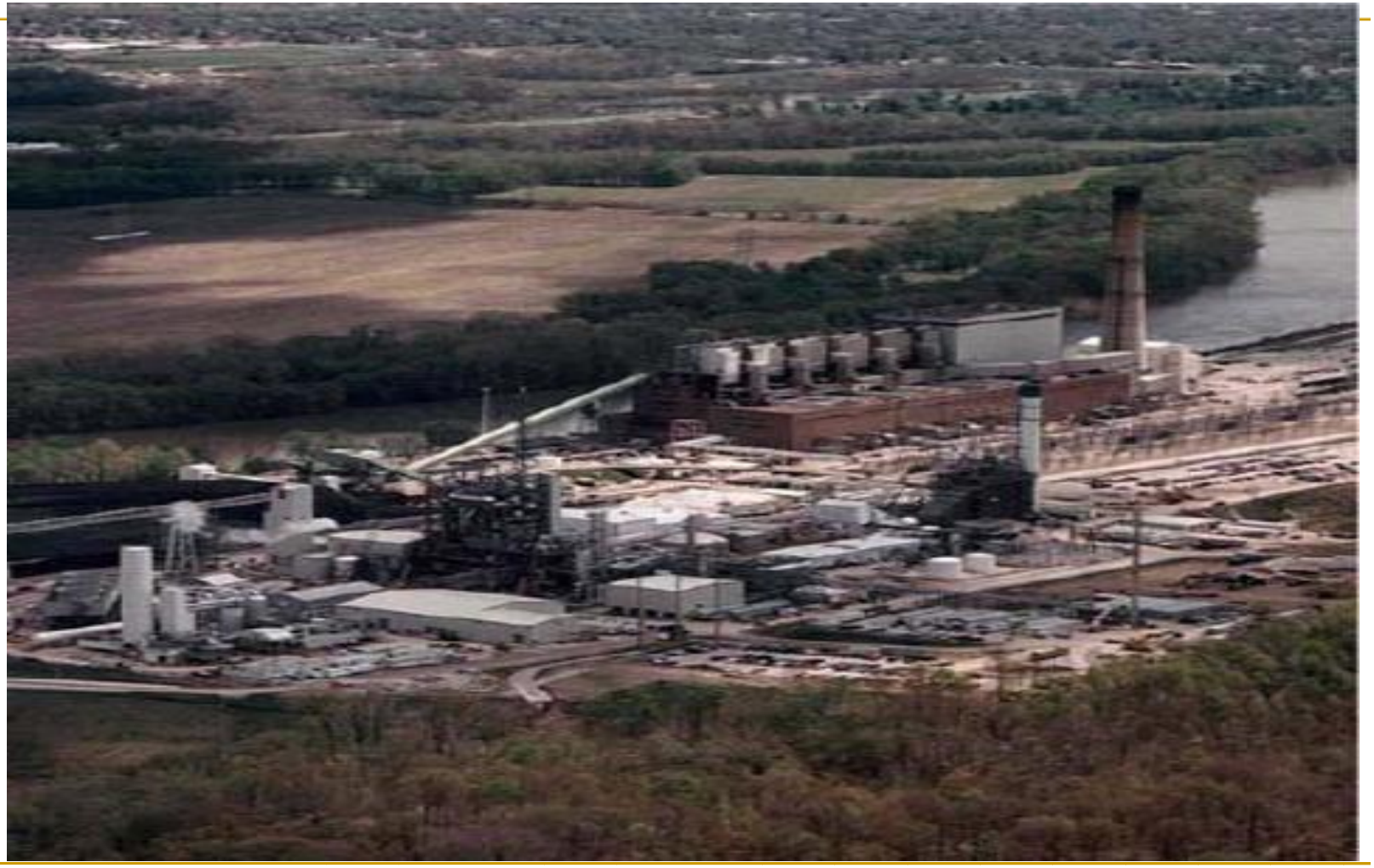
What choice do we have?
Change the way we produce power and energy



Wabash River

One of the Cleanest Coal Fired Power Plants in the World

Gasification operations require more space than the original power plant



Indiana's CO2 Storage

"The majority of estimates support the contention that sufficient capacity exists to store many 100's to many 1000's of GTons CO2, ***but this range is too large to inform sensible policy****." (MIT study)*

Indiana produces nearly 320 Million tons of CO2 annually of which **150 MTons (47%) come from utilities.** The U.S. produces about 6.0 Billion Tons of CO2 annually of which 2.5 BTons (42%) comes from utilities

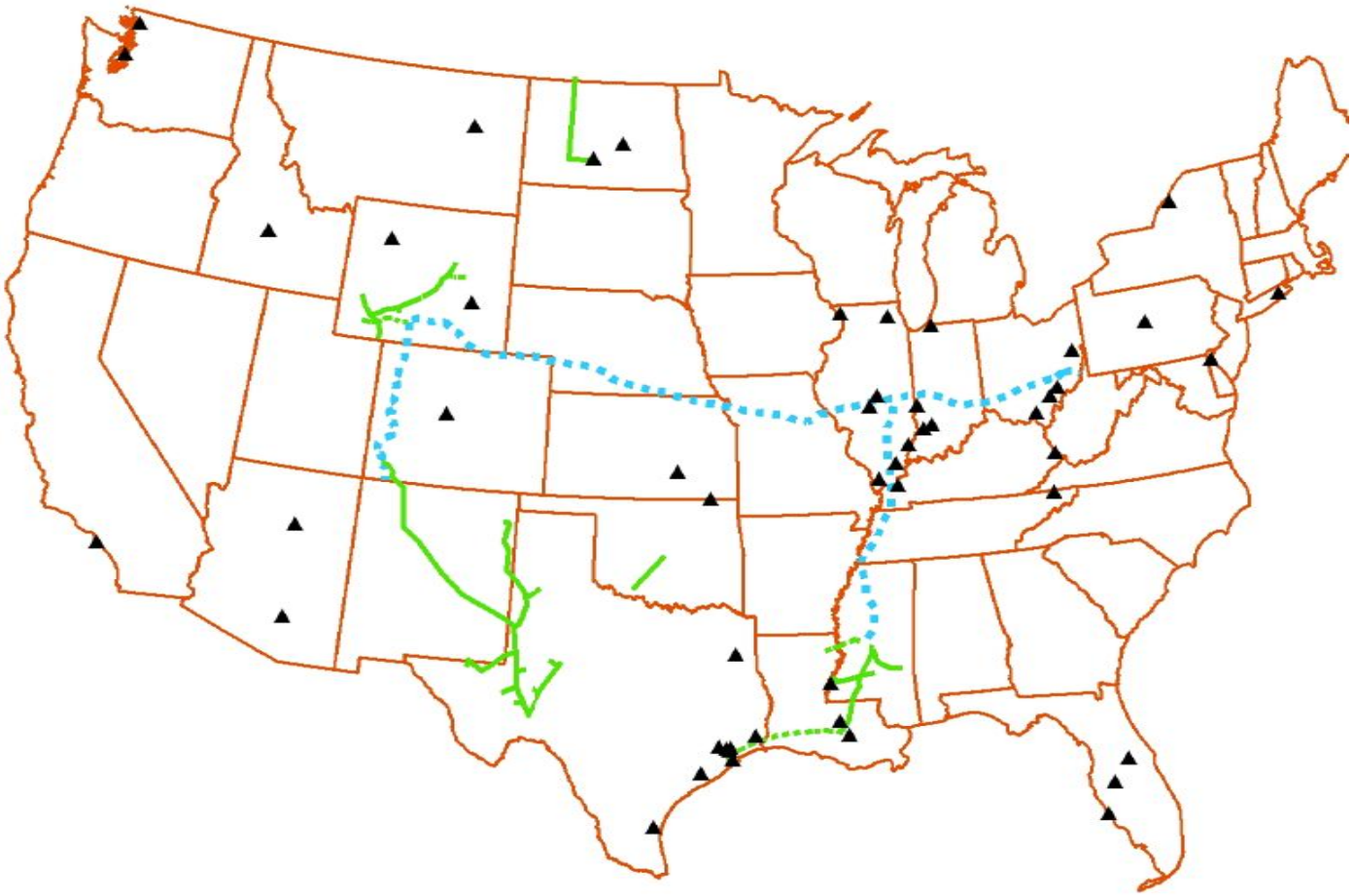
Initial estimates from the Indiana Geological Survey indicate that there are 38.0 BTons of CO2 storage capacity under Indiana's Mt Simon Sandstone & 7.8 BTons under the New Albany Shale

Sources: "The Future of Coal", An Interdisciplinary MIT Study, 2007"Challenges of U.S. Energy Goals Determinism, Stewardship, Technology", The Richard G. Lugar Symposium for Tomorrow's Leaders, 2006

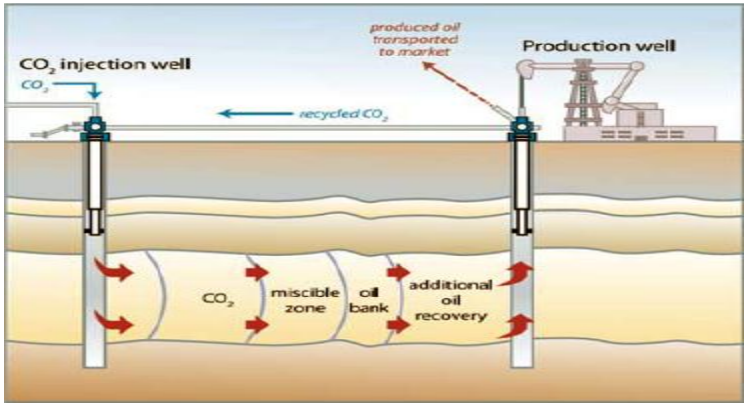
Midwest Geological Sequestration Consortium (MGSC)

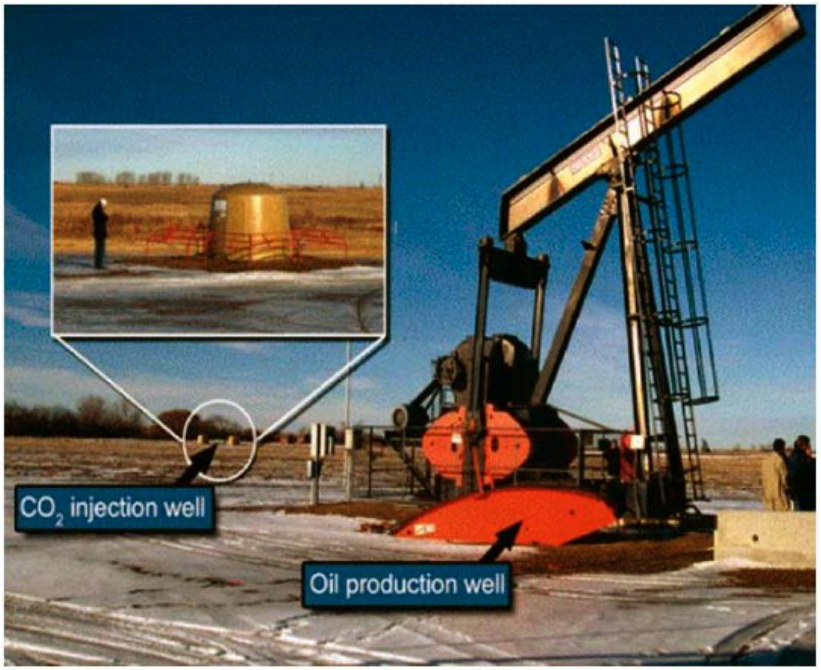
New Albany Shale
Injection of CO2 into the organic shale may result in CO2 absorption & possibly the enhanced production of CH4, (**Shale Gas**) just as in coal beds (**Coal Bed Methane, CBM)**

Extensions and Existing CO2 Pipelines in Relation to Gasification Projects



CO2 Sequestration For EOR and CAPTURE





Small amounts of CO2 dissolve in the oil, increasing the bulk volume & decreasing the viscosity, so facilitating flow

Average of 13% of the original oil in place, OOIP, is produced from **Enhanced Oil Recovery, EOR**

Sources: "Carbon Dioxide Capture and Storage", Intergovernmental Panel on Climate Change, WMO, UNEP, 2005

Coal Wind Hybrid Configuration

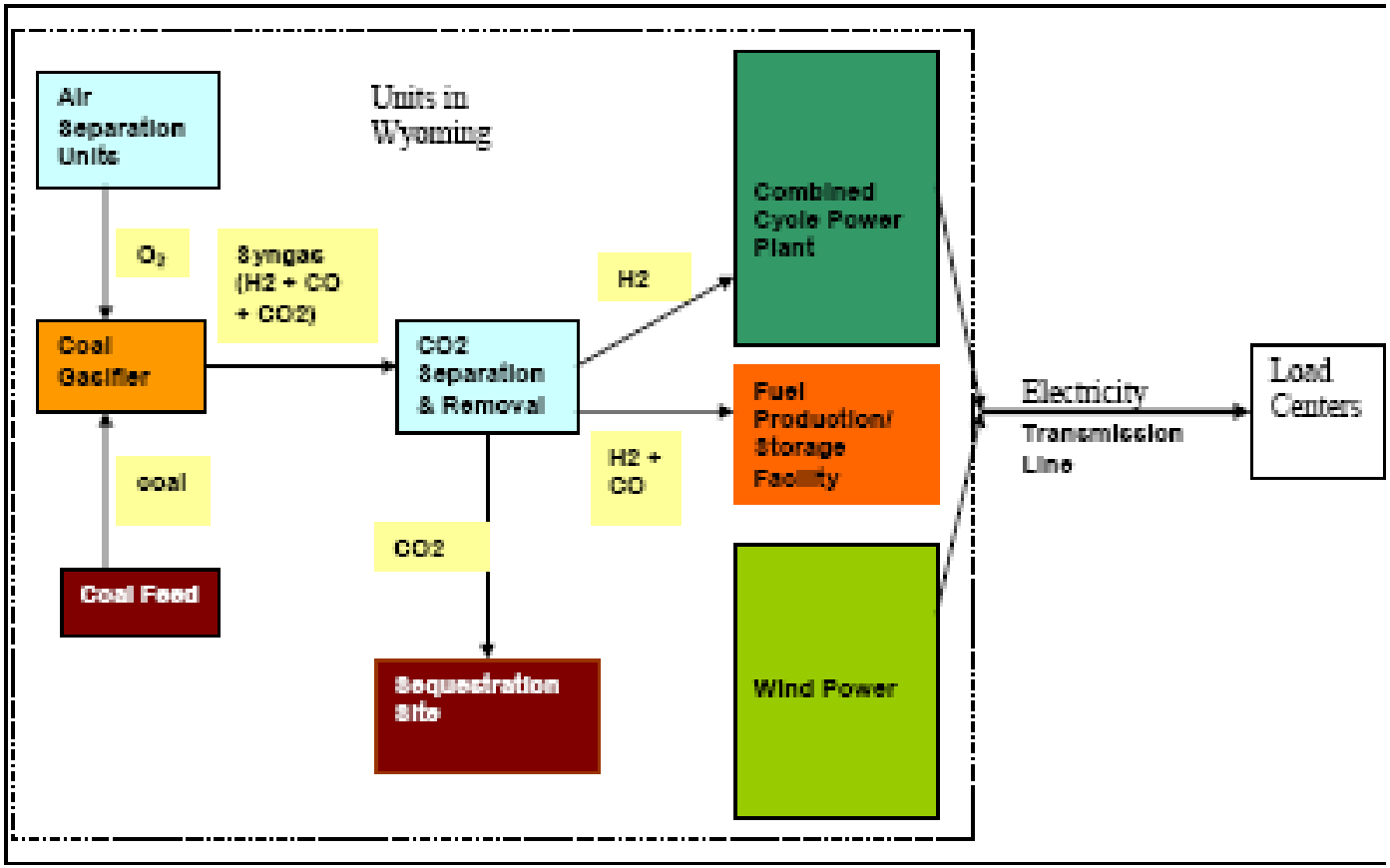
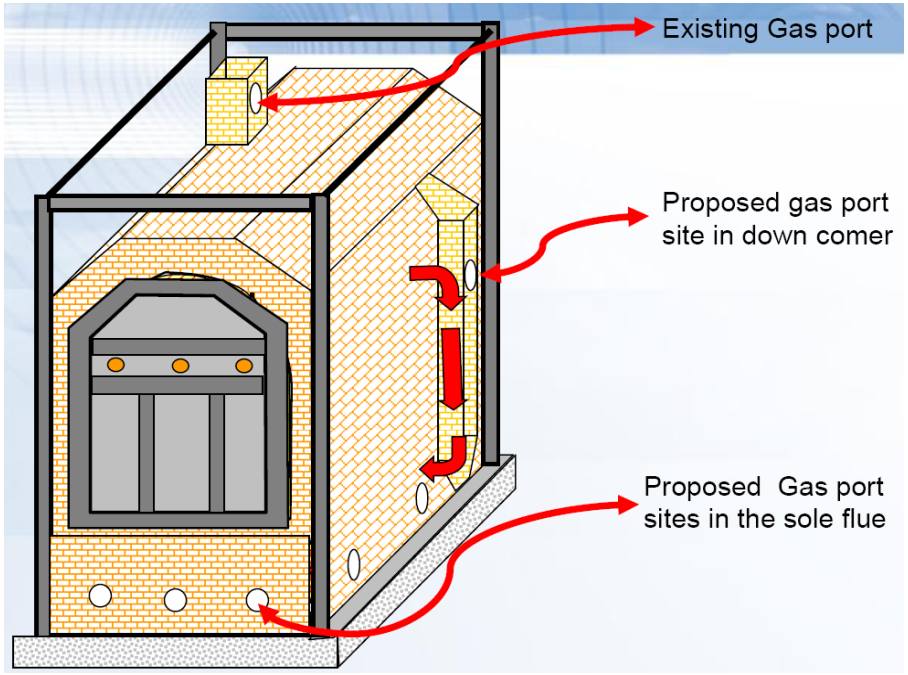


Figure 1. Advanced-Coal Wind Hybrid: Basic Configuration

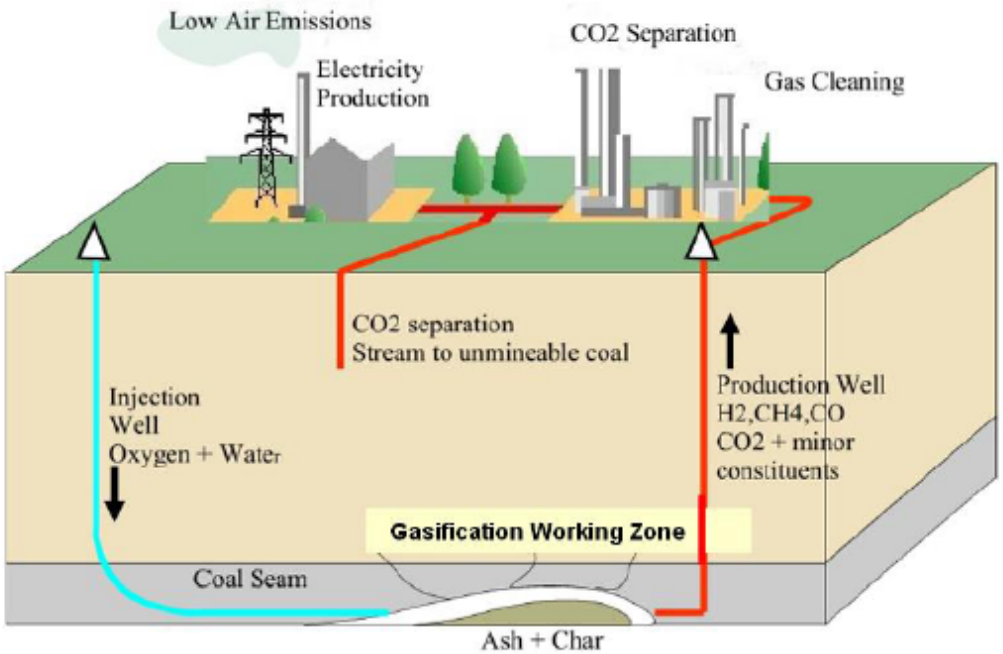
Coking Coal from Indiana Coal

How to replace about half of the 6 million + tons imported metallurgical coal with Indiana coal, Greatly reducing the air emissions from the 400+ coke ovens operating in the northwest region and produce lower cost coke.



http://www.purdue.edu/dp/energy/CCTR/byTopic.php

A UCG Production Facility



Air is injected into the cavity, water enters from surrounding rock & partial combustion with gasification take place at the coal seam face following ignition. The resulting high pressure syngas stream is returned to the surface, where the gas is separated & contaminants are removed

"Best Practices in Underground Coal Gasification", E.Burton, J.Friedman, R. Upadhye, Lawrence Livermore Nat. Lab., DOE Contract No. W-7405-Eng-48

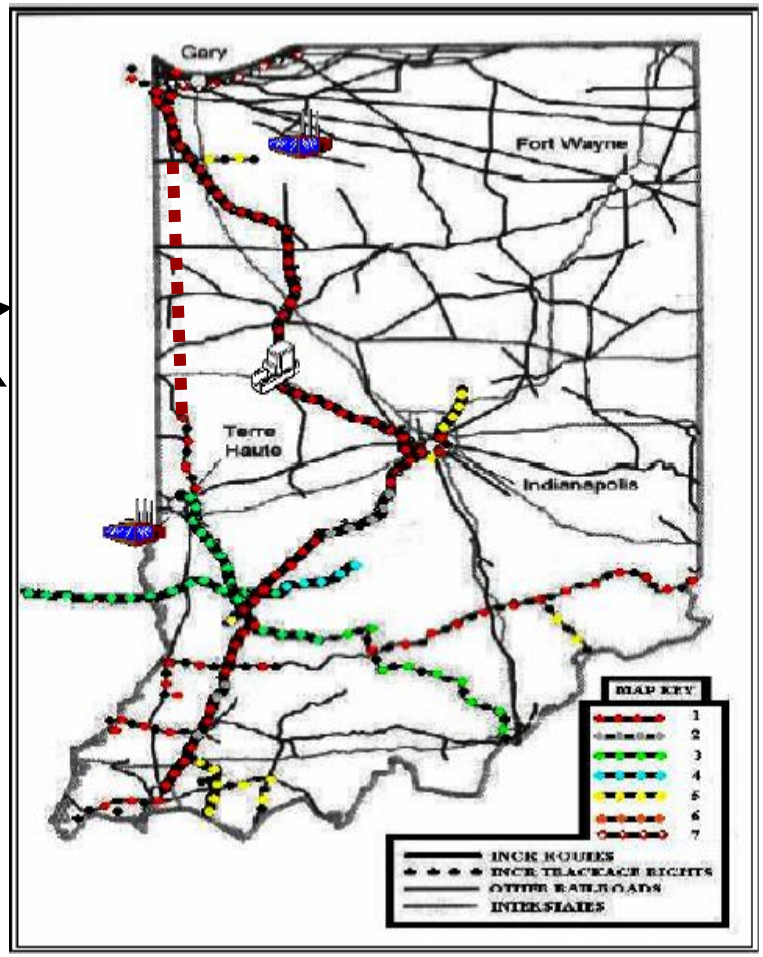
Produced in-depth scenarios involving new rail infrastructures to reduce the exportation of Energy Capital

Infrastructure changes including the “missing Links” will enable Indiana coal to be moved north but by-passing Terre Haute, Indianapolis and Chicago

Allows for the access of Indiana coal to the northwest region.

Connects Indiana’s North and South Ports via rail.

Increase Indiana coal export market potential



Newport Chemical Depot Reuse Plan

Best Infrastructure in the US

- 2 345 & 3 230Kv power line connections
- Water
- Natural Gas pipeline
- Railroad

US needs a gasification test center

- Plasma
- Biomass
- Cellulose

– Wind Power supplemental grid power system:

  Ready user for all syngas produced: Cayuga

– CO2 Capture Technology

– Need an infrastructure planning center to reduce time and cost of implementing new technologies.

Coal Gasification Economic Impact
Edwardsport/Crane/ IN Gas, Inc.
What's in it for us?

The overall economic impact of Adding **5.8* Million Tons of coal** is over **$345.6 Million per year**

483 mining jobs

1933 ancillary jobs

Producing:

Edwardsport	**800**	**MW of Power** (690 MW net)
IGS	**40**	**Bcf** (8% of total State demand)
Crane	**4500-6000**	**Bpd/FT fuel liquids + (25mW)**

***Edwardsport:**	**1.8 Million Tons**
Crane:	**1.0 Million Tons**
Indiana Gasification, Inc:	**3.0 Million Tons**

Southwest/Northwest Indiana Economic Development Plan

Future Idea Areas

Indiana Coal Production Potential:

A) Indiana coal to make coke:

reducing cost of steel production, reducing air emissions in the region	2.1 million tons
NiSource coal replacement potential	6.8 million tons
TOTAL Indiana Coal Potential	8.9 million tons

Producing 8.9 million tons of coal adds:

742 direct mine workers*

2967 Ancillary workers * employment to South West IN

Total added annual economic activity in South West Indiana	$530.3 million*
Estimated cost of the Indiana/Illinois order rail line	$ 50.0 million

B) Newport Military Base transfer to Indiana/Purdue University:

1. Biomass to Energy test site
2. **Coal Wind Hybrid Configuration site**
3. Provide syngas to Cayuga making it more usable during peak demand times

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. Center for Coal Technology Research, Purdue University, 2004, page 20.

Correlation versus Causality

World Series	Winner	Gulf Coast Hurricane	
Oct. 2004	Boston	Katrina Sept 2005	
Oct. 2005	Not Boston	None	
Oct. 2006	Not Boston	None	
Oct. 2007	Boston	Ike	Sept. 2008

When Boston wins World Series a Hurricane will hit the Gulf Coast before the next World Series is played.

Correlation Coefficient between Boston winning World Series and a Hurricane hitting the Gulf coast over the last 4 years ***100%***

Causality? Ask a Yankee Fan.

Evaluate every suggestion
Trust but verify

Clean Wind Energy?

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

We welcome visits

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