Scoping Study

Development of Coking/Coal Gasification Concept to Use Indiana Coal for the Production of Metallurgical Coke and Bulk Electric Power

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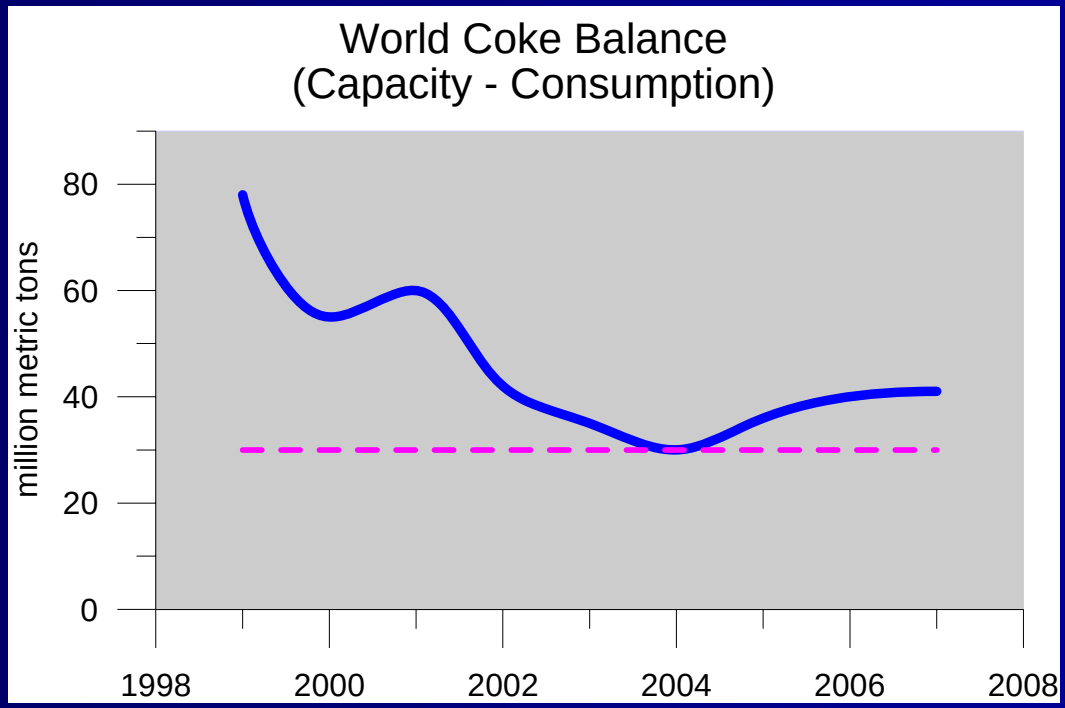
Coke is an absolutely essential part of iron making and foundry processes

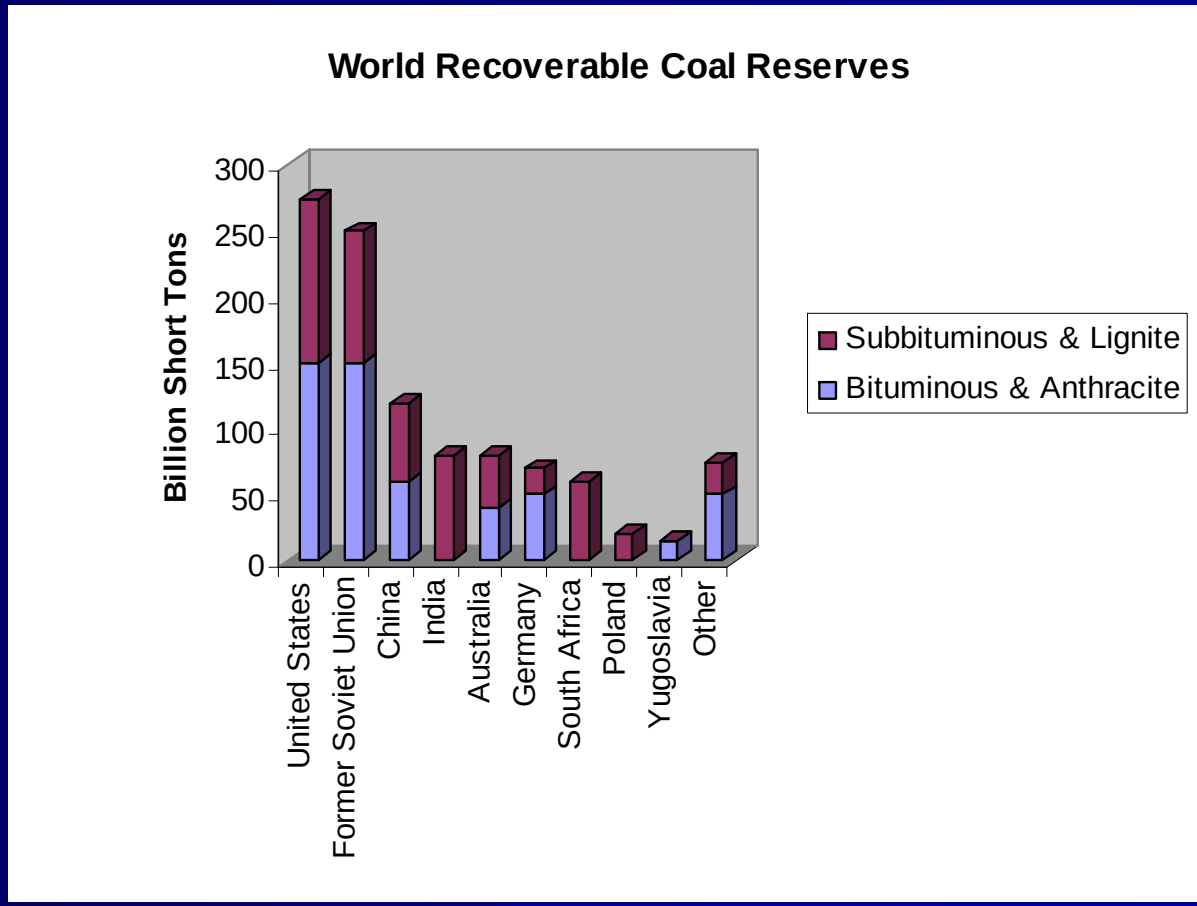
- Currently there is a shortfall of 5.50 million tons of coke per year in the United States.
- Shortfall is being filled by imports, mainly from China and, to a lesser extent, from Japan.
- The result is high volatility in coke prices and a general trend to dramatic price increases.
  - Coke FOB to a Chinese port in January 2004 was priced at $60/ton, but rose to $420/ton in March 2004 and in September 2004 was $220/ton.

Coke Supply and Demand



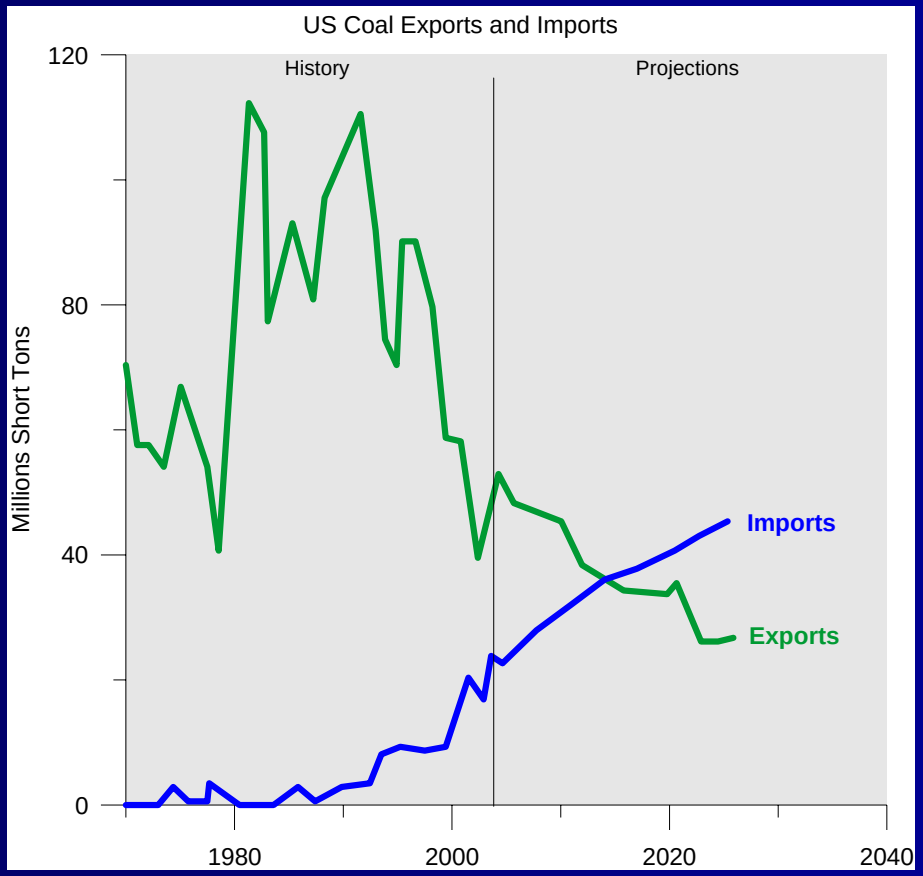
Source: Ludkovsky, G., “Coke Overview at Mittal Steel – Issues and Opportunities”, 3rd China International Coking Technology and Coke Market Congress 2005, Beijing, China, Sept. 2005.

Coal Reserves



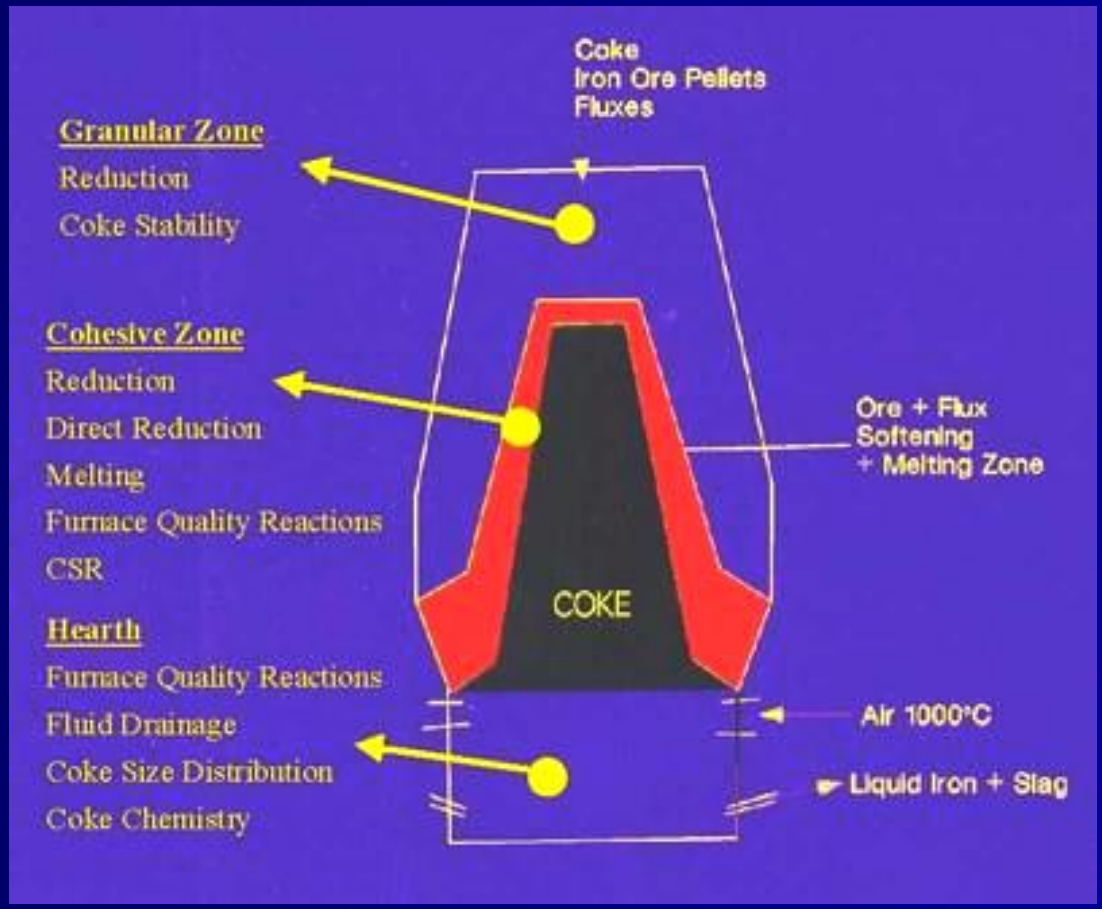
Source: Energy Information Administration / International Energy Outlook 2004

US Coal Exports and Imports



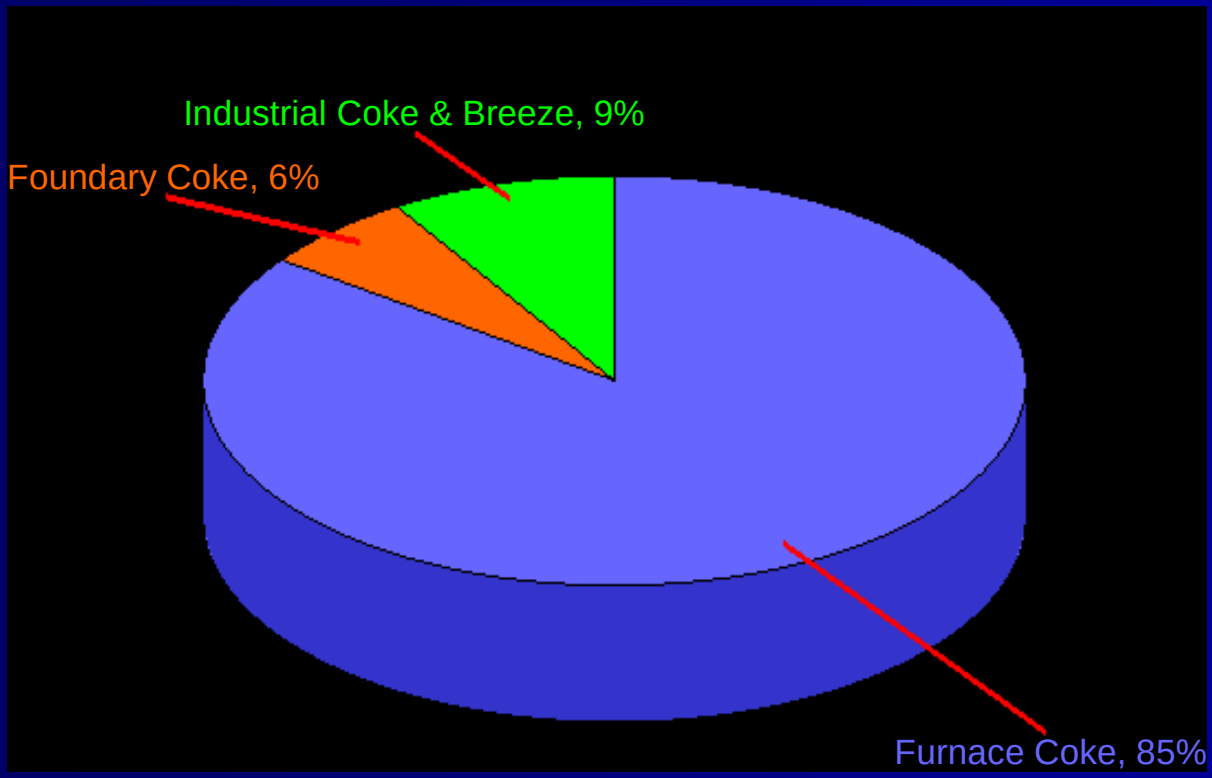
Source: Energy Information Administration / International Energy Outlook 2004

Zones of a blast furnace



Source:Valia, H., "Coke Production for Blast Furnace Ironmaking",AISI

Coke Type

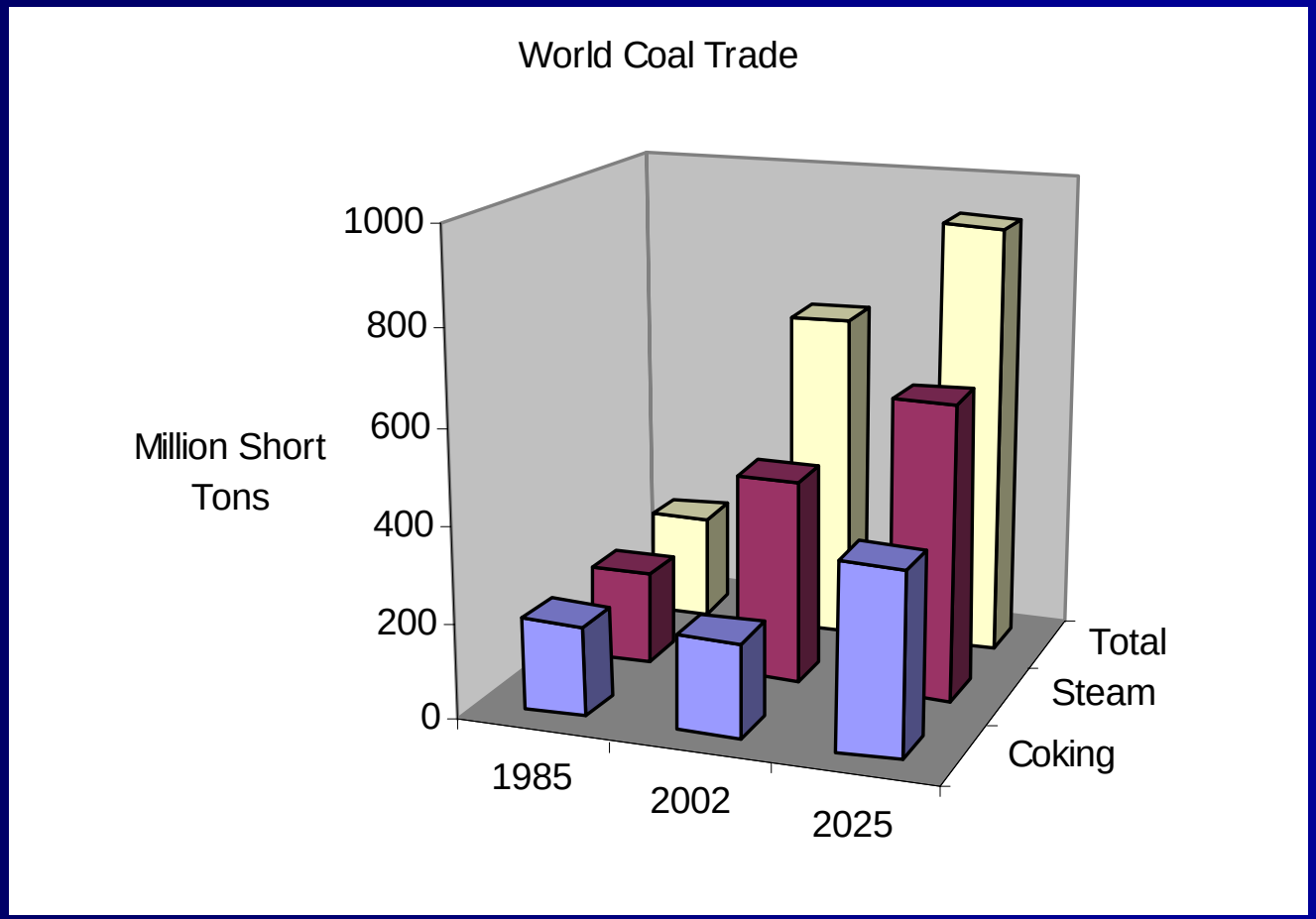


Source:
Economic Impact Analysis of Final Coke Ovens NESHAP - Final Report,
US Environmental Protection Agency, EPA 452/R-02-008, 2002

Coke Usage is Increasing

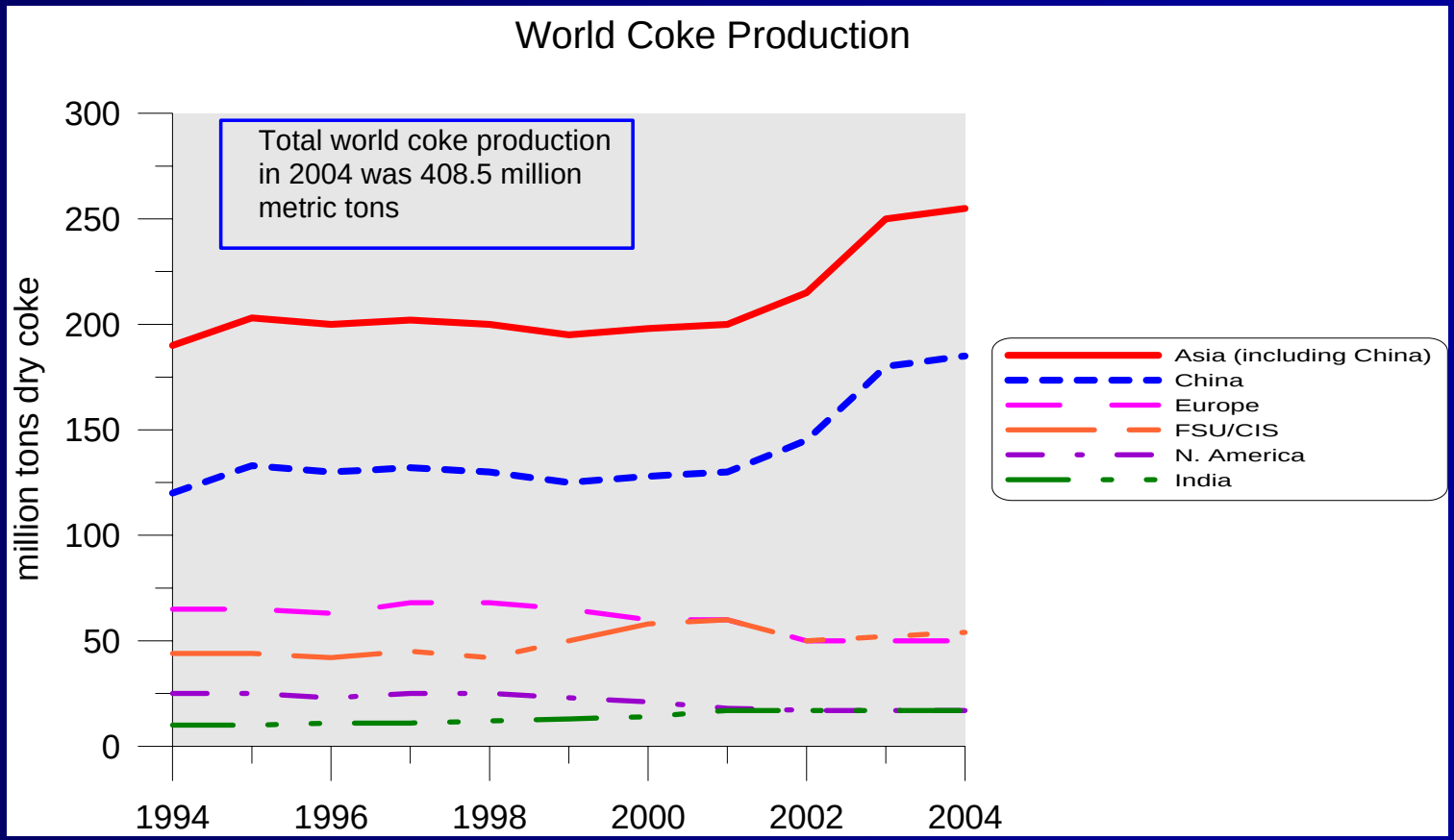
- 2005 forecasts indicate that the US will produce 11,500,000 net tons of coke, but will require 17,000,000 net tons for blast furnace, foundry, and related uses.
  - At present, essentially no Indiana coal is being used for coke production.
  - In 2002, Indiana's steel industry used an estimated 10.7 million tons of coal.
    - 8.1 million tons was used for coke production.
    - Most from West Virginia and Virginia.

Demand for coke will continue to increase



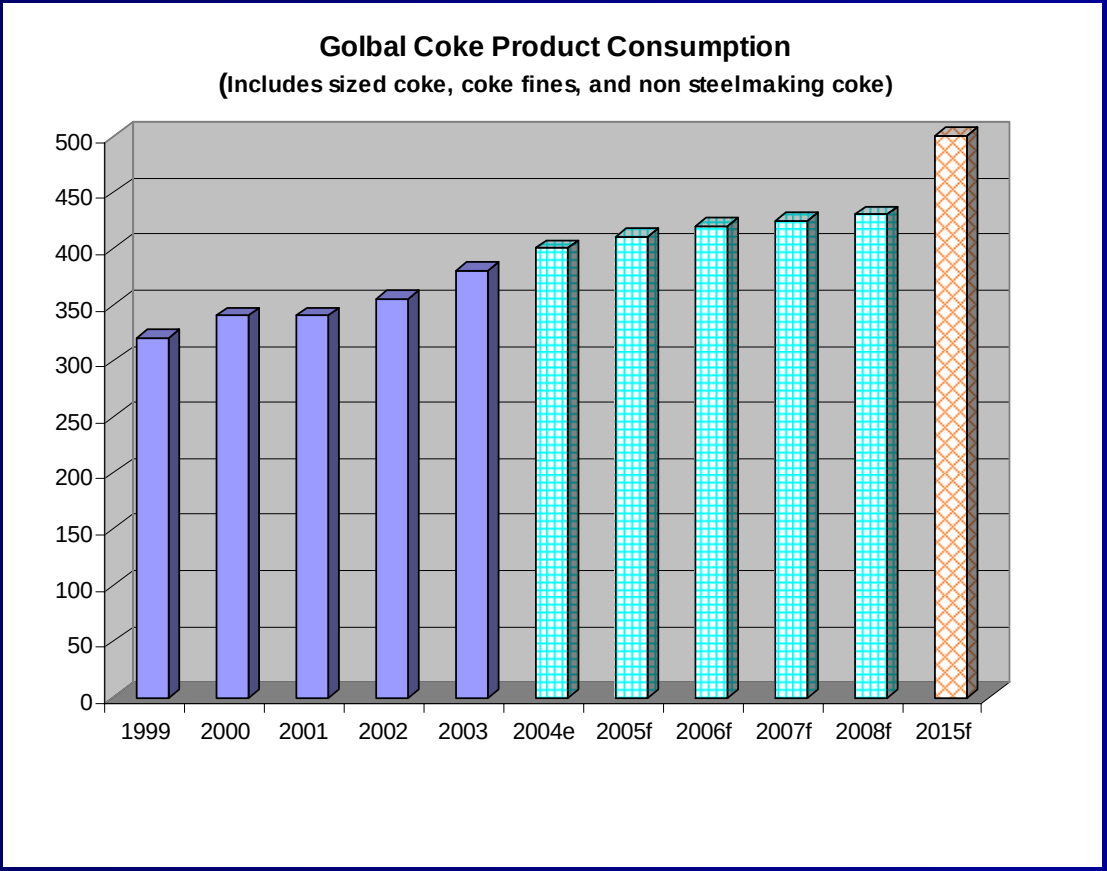
Data Source: Energy Information Administration / International Energy Outlook 2004

World Coke Production



Source;
Ludkovsky, G., "Coke Overview at Mittal Steel – Issues and Opportunities", 3rd China International Coking Technology and Coke Market Congress 2005, Beijing, China, Sept. 2005.

Coke Consumptions



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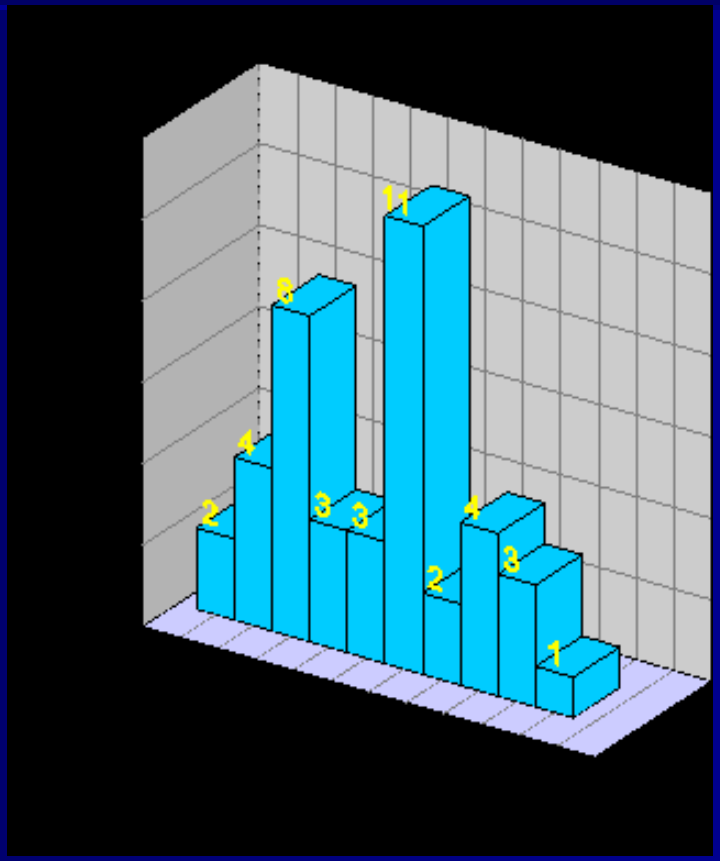
Battery Age



Source;
Ludkovsky, G., “Coke Overview at Mittal Steel – Issues and Opportunities”, 3rd China International Coking Technology and Coke Market Congress 2005, Beijing, China, Sept. 2005.

What can be done?

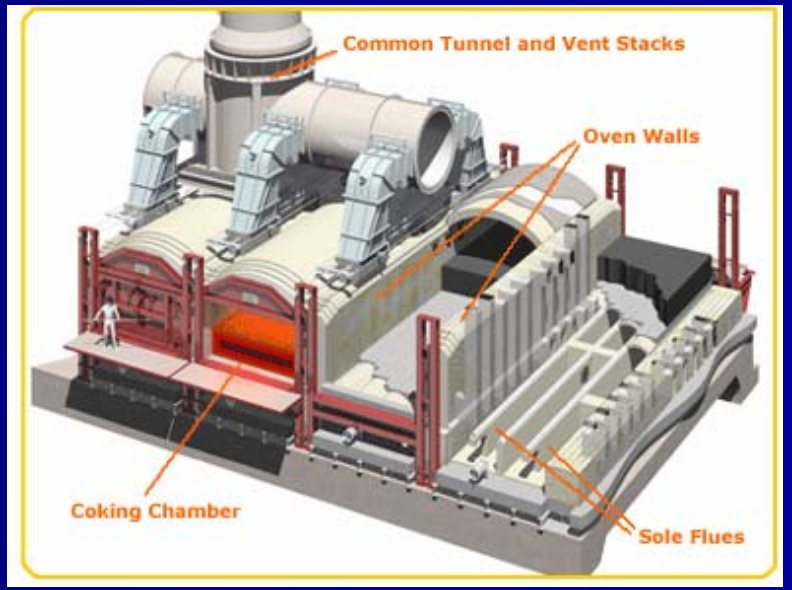
- One way to stabilize price and reduce shortages is to find new ways to supply coke for the domestic market.
  - Provide alternatives that keep coke production in Indiana using as much coal from Indiana mines as is possible
  - Save money by producing coke at mine mouth – transportation savings – more room
  - Look to other value streams to alleviate costs
  - Reduce environmental emissions

Two main methods for coke production

- Recovery Process
  - Reducing atmosphere
  - Issues with complexity and gases
  - Issues with waste
  - Combustible gases available for turbine or boiler
  - Byproduct streams
- Non Recovery Process
  - Air introduced to burn off volatiles before they can produce pollutants
  - Heat recovery steam generation for electricity
  - Small amount of H for heating recirculated at bottom
    - Issue is: Can mass flow be modified for a CT?

Recovery vs Non Recovery Ovens

Source:
Valia, H., “Coke Production for Blast Furnace Ironmaking”, AISI



Source:
SunCoke Company, Knoxville, Tennessee, http://www.suncoke.com.

Issues With Indiana Coal for Coke

- Coke produced from Indiana coal has less strength
  - Results in coke sizes that fall into two general classes.
  - Buckwheat or Nut coke, is on the order of 1 inch x ¼ inch as compared to conventional blast furnace coke which is on the order of 1 inch x 4 inches.
    - Buckwheat/Nut coke is classically used in the steel industry as a carbon source for electric furnaces, in the production of ferromagnesium and ferrosilicon products, and in the production of elemental phosphorous.
  - Coke breeze - much finer.
    - Used as a source of carbon in steel making, for palletizing, sintering, elemental production of phosphorous. It can also be made into briquettes and used to feed blast furnaces in combination with iron ore pellets.
    - Other industries that use coke breeze include cement, paper, fertilizer, as well as others.

How to use coke from Indiana coal for blast furnaces ?

- Use it in upper portions of the furnace
- Use coal blends that maximize quality and Indiana coal content
- Use models to increase the fraction of coke made from Indiana coal
- Introduce companion processes that add to the value stream and allow for increased quantities of Indiana coal

Models Being Used

- Aspen – ANL & Purdue
  - Detailed “recovery type” chemical engineering model
  - Would require additional funding
- Metsim
  - In house now
  - Chemical and metals industry general model
  - Widely used
  - Coal pyrolysis model possible available at no cost

Typical Coke Characteristics for a Blast Furnace

Physical: (measured at the blast furnace)	**Mean**	**Range**
Average Coke Size (mm)	52	45-60
Plus 4" (% by weight)	1	4 max
Minus 1"(% by weight)	8	11 max
Stability	60	58 min
CSR	65	61 min
Physical: (% by weight)		
Ash	8.0	9.0 max
Moisture	2.5	5.0 max
Sulfur	0.65	0.82 max
Volatile Matter	0.5	1.5 max
Alkali (K_2O+Na_2O)	0.25	0.40 max
Phosphorus	0.02	0.33 max

Test Data

	100% Indiana (Brazil Block Coal)	100% Indiana (Danville, No. 7 coal)
Coke Stability	33	33
Coke Hardness	54	69
CSR*	48	30
Coke size, mm	53	55
Coke yield, %	67.9	67.0
Coking Time, hr	18.6	20.15
Max. Pressure, kpa**	2.07	2.96

(Note: CSR*=Coke strength after reaction with CO2, Max Pressure** = maximum oven wall pressure)

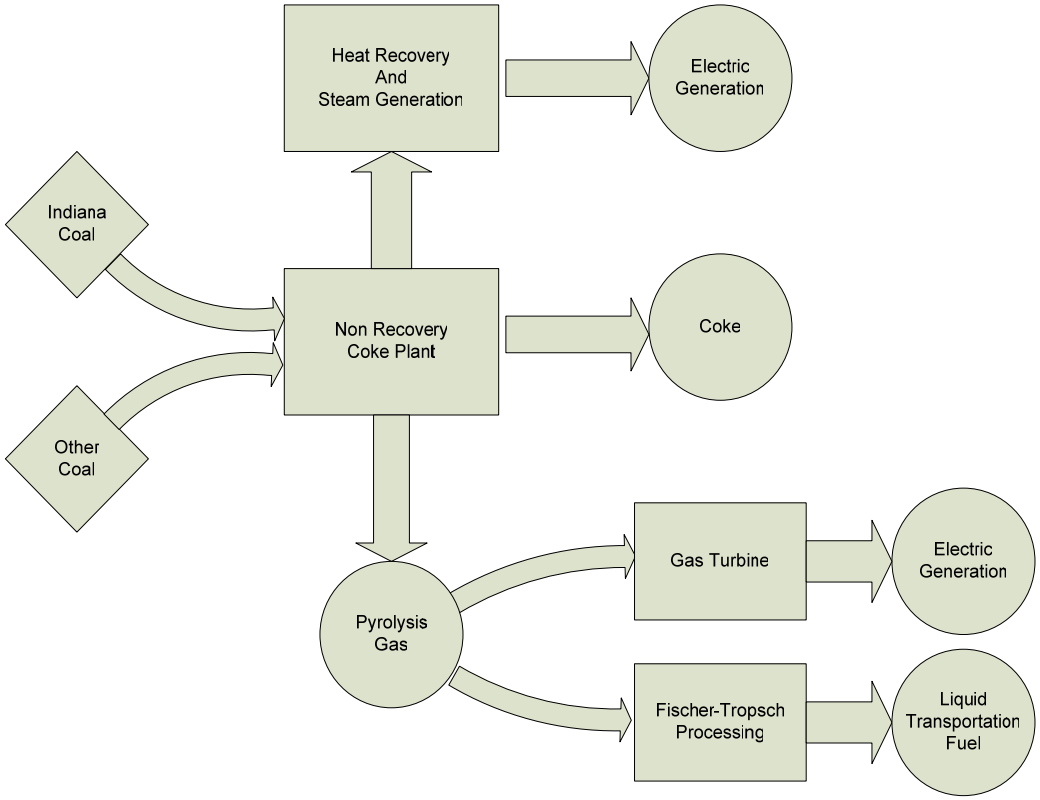
Coal Sample Analysis

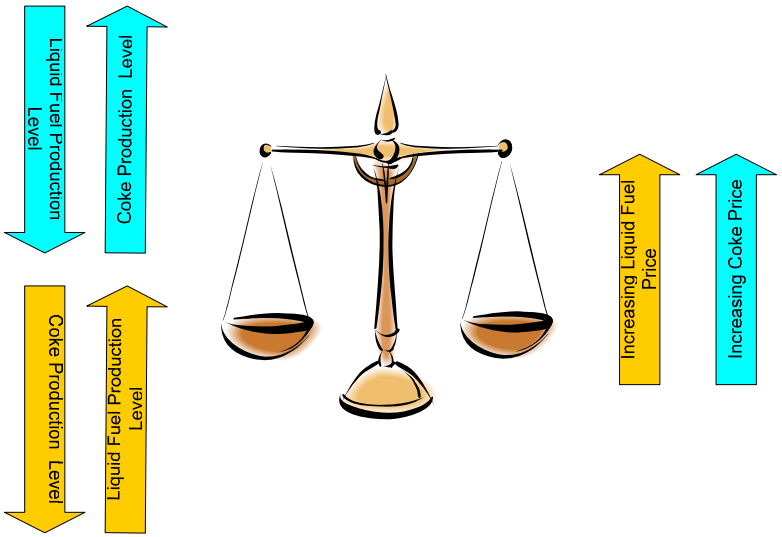
Purdue Coal Sample 7-20-2005	%
Moisture Content	2.38
Size Analysis	
+ 1- ¼ "	8.8
+ 1"	15.8
+ ¾"	25.9
+ ½ "	40.1
+ ¼ "	59.6
+ 1/8 "	12.9
Mean size	1.44
Proximate Analysis	
Volatile Matter	37.08
Fixed Carbon	53.62
Ash	9.30
Sulfur Content, % Dry	0.76
Oxidation Test (% Trans.)	97.0
Petrographic Analysis	
V-Types	
3	0.4
4	11.5
5	55.0
6	33.0
7	0.1
RO	0.57

Coke Oven Gas

- In a recovery coke oven, typically the coke oven gas has a composition of 58% hydrogen, 26% methane, 5.5% nitrogen, 2.25% acetylene, 2% carbon dioxide, 6% carbon monoxide, and .25% oxygen.
- One metric ton of coal typically produces 600-800 kg of blast-furnace coke and 296-358 m3 of coke oven gas.

Source:
Coke Oven Flow Gas Measurement, General Electric Industrial Sensing, Application Note 930-095B, March, 2005.
The Making Shaping and Treating of Steel, Association of Iron and Steel Engineers, Herbick & Held, Pittsburgh, 1985.


Heat Recovery
And
Steam Generation
Electric
Generation
Indiana
Coal
Non Recovery
Coke Plant
Coke
Other
Coal
Pyrolysis
Gas
Gas Turbine
Electric
Generation
Fischer-Tropsch
Processing
Liquid
Transportation
Fuel


Liquid Fuel Production Level
Coke Production Level
Coke Production Level
Liquid Fuel Production Level
Increasing Liquid Fuel Price
Increasing Coke Price

Thank You!

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