21st Century Coal Technology for Indiana

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Kazakhstan Visiting Team to Purdue Energy Center
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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
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.

http://www.historyofwaterfilters.com/water-filters-present.html
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.

<table>
<thead>
<tr>
<th>Coal (Million Short Tons)</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>70.1</td>
<td>65.9</td>
<td>81.7</td>
<td>87.2</td>
<td>91.3</td>
<td>93.6</td>
<td>95.8</td>
<td>95.4</td>
<td>106.1</td>
<td>95.2</td>
<td>NA</td>
</tr>
<tr>
<td>Consumption</td>
<td>54.4</td>
<td>51.0</td>
<td>55.4</td>
<td>57.0</td>
<td>58.6</td>
<td>66.6</td>
<td>69.0</td>
<td>70.4</td>
<td>75.9</td>
<td>74.3</td>
<td>NA</td>
</tr>
<tr>
<td>Net Exports/Imports(-) (Trillion Btu)</td>
<td>393.2</td>
<td>278.9</td>
<td>443.1</td>
<td>486.6</td>
<td>425.7</td>
<td>499.1</td>
<td>343.8</td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

http://tonto.eia.doe.gov/country/country_time_series.cfm?fips=KZ
http://www.eia.doe.gov/emeu/cabs/Kazakhstan/Coal.html
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)

<table>
<thead>
<tr>
<th></th>
<th>Estimated Recoverable</th>
<th>Demonstrated Reserve Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indiana</td>
<td>4.134</td>
<td>9.637</td>
</tr>
<tr>
<td>Illinois</td>
<td>38.061</td>
<td>104.648</td>
</tr>
<tr>
<td>W. Kentucky</td>
<td>9.082</td>
<td>19.637</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>51.277</strong></td>
<td><strong>133.922</strong></td>
</tr>
<tr>
<td>IL Basin Coal</td>
<td>51.277</td>
<td>133.922</td>
</tr>
<tr>
<td>U.S. Total</td>
<td>269.457</td>
<td>497.708</td>
</tr>
</tbody>
</table>

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

Indiana Geological Survey, IU Bloomington
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

**Wyoming:** 21,989 Total
- 21,777 Electricity Generation
  - Rail
  - Industrial 212 River

**Montana:** 1,631 Total
- 1,631 Electricity Generation
  - Rail

**Utah:** 197 Total
- 197 Industrial
  - Rail

**Colorado:** 192 Total
- 192 Electricity Gen,
  - Rail

**Illinois:** 5,859 Total
- 4,760 Electricity Generation
  - Rail 4,760
  - 1,097 Industrial Plants
    - Rail 1,097

**Kentucky:** 1,716 Total
- 1,117 Electricity Generation
  - Rail 889
  - River 352
- 598 Industrial Plants
  - Rail 388
  - Truck 112

**West Virginia:** 5,481 Total
- 374 Electricity Generation
  - Rail 243
  - River 131
- 3,726 Coke Plants
  - Rail
- 1,382 Industrial Plants
  - Rail 1,255
  - Truck 127

**In state:** 34,770 Total
- 29,807 Electricity Generation
  - Rail 14,586
  - River 103
  - Conveyor 4,415
  - Truck 10,703
- 1,812 Industrial Plants
  - Truck
- 166 Residential-Commercial
  - Truck

**Ohio:** 388 Total
- 382 Electricity Generation
  - Rail 369
  - Truck 13
- 7 Industrial Plants
  - Truck

**Pennsylvania:** 397 Total
- 367 Electricity Generation
  - Rail 341
  - River 26
- 21 Coke Plants
  - Rail

**Virginia:** 486 Total
- 486 Coke Plants
  - Rail

Note:
Indiana Coal Exports
Total = 2,985
KY 1,779, WI 361,
AL 374, IL 280,
TN 97, MS 78

Source: http://www.eia.doe.gov/cneof/coal/page/coalistr/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 its electricity demand from coal-fired power plants.
Indiana’s Bituminous Coal Characteristics
Illinois Coal Basin – Illinois, Indiana, W.Kentucky

<table>
<thead>
<tr>
<th></th>
<th>Danville</th>
<th>Springfield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture %wt</td>
<td>11.3</td>
<td>9.9</td>
</tr>
<tr>
<td>Ash %wt</td>
<td>13</td>
<td>12.2</td>
</tr>
<tr>
<td>Sulfur</td>
<td>2.65</td>
<td>3.27</td>
</tr>
<tr>
<td>Btu/lb (dry)</td>
<td>13050</td>
<td>13214</td>
</tr>
<tr>
<td>Fixed Carbon</td>
<td>48.4</td>
<td>48</td>
</tr>
<tr>
<td>Volatile Matter</td>
<td>39.1</td>
<td>40.9</td>
</tr>
<tr>
<td>Chlorine %</td>
<td>0.03</td>
<td>0.15</td>
</tr>
</tbody>
</table>
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
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/](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)
(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

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?
CO₂ Use, Gas Pipelines, Carbon Highways

CO₂ use has +ve cash flow compared with storage

- Midwest Consortium
  Starting to pump
  1 MTons of CO₂ under Mount Simon Sandstone &
  will take 3 years

- CO₂ pipeline project

CO₂ transportation network from both natural and man-made sources

http://www.purdue.edu/dp/energy/CCTR/byTopic.php
CO2 Pipeline Infrastructures for CO2, EOR, CCS, Sherry Tucker, Denbury Resources, CCTR meeting, Indianapolis, March 5, 2009
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 $\text{CO}_2$

Indiana site selection assessments

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>$&gt; 2.0 \text{ m}$</td>
<td>high</td>
</tr>
<tr>
<td>$1.5 - 2.0 \text{ m}$</td>
<td>medium</td>
</tr>
<tr>
<td>$1.0 - 1.5 \text{ m}$</td>
<td>low</td>
</tr>
<tr>
<td>$&lt; 1.0 \text{ m}$</td>
<td>unacceptable</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth</th>
<th>Suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>$&gt; 200 \text{ m}$</td>
<td>high</td>
</tr>
<tr>
<td>$60 - 200 \text{ m}$</td>
<td>adequate</td>
</tr>
<tr>
<td>$&lt; 60 \text{ m}$</td>
<td>unacceptable</td>
</tr>
</tbody>
</table>

http://www.purdue.edu/dp/energy/CCTR/byTopic.php
CCTR Investigations into CTL Site Selection

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

http://www.purdue.edu/dp/energy/CCTR/byTopic.php
CTL, Slurry Reuse, Economic Studies

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

Coal
Lignite
Petroleum Coke
Oil/Residue
Gas
Biomass
Orimulsion®

Gasification & Gas Treating

- clean syngas
- CO₂

Power Generation
Chemical conversion
Chemical conversion
Liquefaction (Fischer-Tropsch synthesis)

- Electricity
- Steam
- Hydrogen, ammonia, methanol, other chemicals
- synthetic natural gas (SNG)
- Transportation Fuel

Spoil = displaced overburden
Gob = coarse-grained refuse
Slurry (tailings) = fine-grained refuse

Economics, emissions & risk are the key issues for commercialization of new technologies

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

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