COAL PREPARATION: CURRENT STATUS AND THE WAY AHEAD

Presentation to the
National Commission on Energy Policy

By Dr. Peter J. Bethell
Director of Coal Preparation
Arch Coal, Inc.
World’s 15 Largest Oil Producers

Million Barrels per Day

Saudi Arabia
Russia
United States
Iran
Mexico
China
Norway
Canada
Venezuela
UAE
Kuwait
Nigeria
UK
Iraq
Brazil

Energy Information Administration
World Oil Reserves by Country

Saudi Arabia
Canada
Iran
Iraq
UAE
Kuwait
Venezuela
Russia
Libya
Nigeria
United States
China
Mexico
Qatar
Algeria
Norway
Kazakhstan
Brazil
Azerbaijan
Oman
Rest of World

World Total: 1,266 Billion Barrels

Energy Information Administration
Arch Coal, Inc.

WORLD OIL RESERVES

U.S. COAL RESERVES
+ 1.3 THOUSAND BILLION BARRELS OF OIL EQUIVALENT

Sasol generates 160,000 barrels per day of gasoline from 33 MM tons of coal per year. Breakeven cost is equivalent to $35-40 per barrel crude oil price (coal cost dependent).
# COAL PROVED RESERVES

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## TOP 10 COUNTRIES (Millions Tonnes)

<table>
<thead>
<tr>
<th>Country</th>
<th>Anthracite and Bituminous</th>
<th>Sub-Bituminous and Lignite</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>111,338</td>
<td>135,305</td>
<td>246,643</td>
</tr>
<tr>
<td>RUSSIA</td>
<td>49,088</td>
<td>107,922</td>
<td>157,010</td>
</tr>
<tr>
<td>CHINA</td>
<td>62,200</td>
<td>52,300</td>
<td>114,500</td>
</tr>
<tr>
<td>INDIA</td>
<td>90,085</td>
<td>2,360</td>
<td>92,445</td>
</tr>
<tr>
<td>AUSTRALIA</td>
<td>38,600</td>
<td>39,900</td>
<td>78,500</td>
</tr>
<tr>
<td>SOUTH AFRICA</td>
<td>48,750</td>
<td>-</td>
<td>48,750</td>
</tr>
<tr>
<td>UKRAINE</td>
<td>16,274</td>
<td>17,879</td>
<td>34,153</td>
</tr>
<tr>
<td>KAZAKHSTAN</td>
<td>28,151</td>
<td>3,128</td>
<td>31,279</td>
</tr>
<tr>
<td>POLAND</td>
<td>14,000</td>
<td>-</td>
<td>14,000</td>
</tr>
<tr>
<td>BRAZIL</td>
<td>-</td>
<td>10,113</td>
<td>10,113</td>
</tr>
</tbody>
</table>
## Top 10 Producers of Coal – 2006 (Metric Tons)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>2006 (Metric Tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>China</td>
<td>2380</td>
</tr>
<tr>
<td>2</td>
<td>USA</td>
<td>1054</td>
</tr>
<tr>
<td>3</td>
<td>India</td>
<td>447</td>
</tr>
<tr>
<td>4</td>
<td>Australia</td>
<td>374</td>
</tr>
<tr>
<td>5</td>
<td>Russia</td>
<td>309</td>
</tr>
<tr>
<td>6</td>
<td>South Africa</td>
<td>257</td>
</tr>
<tr>
<td>6</td>
<td>Indonesia</td>
<td>195</td>
</tr>
<tr>
<td>7</td>
<td>Poland</td>
<td>150</td>
</tr>
<tr>
<td>8</td>
<td>Germany</td>
<td>107</td>
</tr>
<tr>
<td>9</td>
<td>Kazakhstan</td>
<td>97</td>
</tr>
</tbody>
</table>
WORLDWIDE COAL PRODUCTION

Hard-Coal Production (MM TPY)

- China
- United States
- India
- Australia
- South Africa

Year

1. Uses low-cost physical separations to remove impurities from mined coal.
   a) Solid-solid separations
   b) Solid-liquid separations

2. Typically required to:
   a) increase heat value
   b) lower transport cost
   c) reduce emissions
   d) improve marketability
Impact on Emissions

Source: Fonseca et al., 1993.
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Current Status

1. World Preparation Industry
   a) ≈2,300 plants worldwide
   b) ≈1.5 billion clean tpy
   c) ≈40% of consumed production

2. U.S. Preparation Industry
   a) highest installed feed capacity
      (>660 million tpy)
   a) ≈267 plants in 16 states
## Current Processing Plant Capabilities

<table>
<thead>
<tr>
<th>State</th>
<th>Raw T.P.H. @ 6000 Hours/Year</th>
<th>Raw T.P.A (Million)</th>
<th>Clean Tons Produced Yearly @ Yield Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thousands</td>
<td>Operation</td>
<td>40%</td>
</tr>
<tr>
<td>Alabama</td>
<td>8,000</td>
<td>48</td>
<td>19</td>
</tr>
<tr>
<td>Colorado</td>
<td>1,500</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>Illinois</td>
<td>10,000</td>
<td>60</td>
<td>24</td>
</tr>
<tr>
<td>Indiana</td>
<td>7,000</td>
<td>42</td>
<td>17</td>
</tr>
<tr>
<td>Kentucky</td>
<td>14,000</td>
<td>84</td>
<td>34</td>
</tr>
<tr>
<td>Maryland</td>
<td>2,000</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>Ohio</td>
<td>5,000</td>
<td>30</td>
<td>12</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>14,000</td>
<td>84</td>
<td>34</td>
</tr>
<tr>
<td>Tennessee</td>
<td>500</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Utah</td>
<td>500</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Virginia</td>
<td>10,000</td>
<td>60</td>
<td>24</td>
</tr>
<tr>
<td>Washington</td>
<td>2,000</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>West Virginia</td>
<td>48,000</td>
<td>288</td>
<td>115</td>
</tr>
</tbody>
</table>
## PLANT PROCESSING CAPACITY, RESERVE TONS AND MINE PRODUCTION BY STATE -2004

<table>
<thead>
<tr>
<th>State</th>
<th>Installed Capacity</th>
<th>Clean Capacity (Millions Tons)</th>
<th>Recoverable Reserve (Millions)</th>
<th>Total Production (Millions of Tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raw T.P.H.</td>
<td>Yearly Millions of Tons at 40% Yield</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alabama</td>
<td>8,000</td>
<td>19</td>
<td>2,806</td>
<td>22.3</td>
</tr>
<tr>
<td>Colorado</td>
<td>1,500</td>
<td>4</td>
<td>9,798</td>
<td>39.9</td>
</tr>
<tr>
<td>Illinois</td>
<td>10,000</td>
<td>24</td>
<td>38,019</td>
<td>31.9</td>
</tr>
<tr>
<td>Indiana</td>
<td>7,000</td>
<td>17</td>
<td>4,080</td>
<td>35.1</td>
</tr>
<tr>
<td>Kentucky</td>
<td>14,000</td>
<td>34</td>
<td>15,040</td>
<td>114.2</td>
</tr>
<tr>
<td>Maryland</td>
<td>2,000</td>
<td>5</td>
<td>366</td>
<td>5.2</td>
</tr>
<tr>
<td>Ohio</td>
<td>5,000</td>
<td>12</td>
<td>11,507</td>
<td>23.2</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>14,000</td>
<td>34</td>
<td>11,822</td>
<td>66.0</td>
</tr>
<tr>
<td>Tennessee</td>
<td>500</td>
<td>1</td>
<td>462</td>
<td>2.9</td>
</tr>
<tr>
<td>Utah</td>
<td>500</td>
<td>1</td>
<td>2,750</td>
<td>21.8</td>
</tr>
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<td>Virginia</td>
<td>10,000</td>
<td>24</td>
<td>1,022</td>
<td>31.4</td>
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<tr>
<td>Washington</td>
<td>2,000</td>
<td>5</td>
<td>681</td>
<td>5.6</td>
</tr>
<tr>
<td>West Virginia</td>
<td>48,000</td>
<td>115</td>
<td>18,104</td>
<td>148.0</td>
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</tbody>
</table>
Regional Variations

Northern Appalachia
1) Conventional Flotation Predominates (Non-Deslimed)

Southern Appalachia
1) Considerable thermal drying with Conventional Flotation.

Illinois Basin
1) Many Jig/W.O.C. Plants
2) Flotation Characteristics Poor
   Discard -.15mm

Colorado/Utah Bituminous
Minimal Washing
Use Partial Wash (No Fine Washing)

Wyoming/Montana
Minimal Cleaning
Discard Off Spec. Material
Preparation Plant Economics

Costs

Capital

Eastern Plant Capital Costs
“Black Box” $10-$12k/T.P.H.

Associated Materials Handling
(Feed, Refuse, Clean Coal Loadout)
$10-$15k/T.P.H. Plant Capacity

Operating

Cash Cost ($/Raw Ton) $1.50-$2.50
## Major Plant Construction Projects

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Capacity (T.P.H.)</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arch Cardinal</td>
<td>West Virginia</td>
<td>2100</td>
<td>2006</td>
</tr>
<tr>
<td>Consol Robinson Run</td>
<td>West Virginia</td>
<td>1600</td>
<td>2006</td>
</tr>
<tr>
<td>Mach Mining</td>
<td>Illinois</td>
<td>2000</td>
<td>2006</td>
</tr>
<tr>
<td>Southern Eagle</td>
<td>West Virginia</td>
<td>800</td>
<td>2007</td>
</tr>
<tr>
<td>Gatling</td>
<td>West Virginia</td>
<td>1000</td>
<td>2006</td>
</tr>
<tr>
<td>Bear Run</td>
<td>Indiana</td>
<td>800</td>
<td>2007</td>
</tr>
<tr>
<td>Spurlock</td>
<td>Kentucky</td>
<td>900</td>
<td>2007</td>
</tr>
</tbody>
</table>
Appalachian and Illinois Basin Coal Preparation Challenges

1) Efficient low cost ultrafine (-.015mm) coal dewatering

2) Ultrafine cleaning for poor floating coals (.150 x .045mm)

3) Ultrafine classification at ± .045mm or less

4) On-line coal characterization

5) Waste handling coarse and fine coal
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Fine Coal Cleaning Problems

Less Efficient, Higher Moisture

<table>
<thead>
<tr>
<th>Size</th>
<th>Efficiency</th>
<th>Processing Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ ½” (12.5mm)</td>
<td>&gt;98% Efficiency</td>
<td>$0.50-$1.50/ton</td>
</tr>
<tr>
<td>½” (12.5mm) x 1mm</td>
<td>&gt;98% Efficiency</td>
<td>$0.50-$1.00/ton</td>
</tr>
<tr>
<td>1mm x .15mm</td>
<td>85-95% Efficient</td>
<td>$1.00-2.00/ton</td>
</tr>
<tr>
<td>-.15mm</td>
<td>0-80% Efficient</td>
<td>$4.00-6.00/ton</td>
</tr>
</tbody>
</table>
1. Remaining “high quality” reserves give low yields
2. Provides increasing challenges in terms of:
   a) high mining tonnages
   b) large disposal needs
   c) poor product quality
3. Washability over-estimates yields due to:
   a) higher mine dilution
   b) excess fines generation
   c) plant inefficiencies overlooked
Western Bituminous Coal Challenges

1) Currently mine mainly thick +8’ low ash < 10% ash coal seams

2) Coal quality deteriorating

3) Considerable volumes thin – 8’ seams of higher ash, previously thought uneconomic

4) With sustained improved markets, design and build preparation plants to handle higher ash thinner seams
   a) Begin with coarse wash only (Castle Valley, Utah)
   b) As necessary, add fines circuitry
   c) Overcome major water shortages for wet coal processing

5) Major advantage – greatly extend economical reserves in thinner low quality coal seams
Low Rank Coal Challenges

1) Water is scarce and coals do not respond to wet processing. Need to evaluate dry separators, non aqueous

2) Contamination of coal due to out of seam dilution causes losses of 5-20% of reserves mined. Need to develop means of recovering this. (Arch Black Thunder loses ± 10 million t.p.a.)

3) Increase btu content of coal (KFX for example). Increase btu shipped per ton transported

4) Large part of Western resources >20% ash. Currently uneconomic. Need to upgrade by funding economic processing techniques

5) Look at mine mouth power plants. Build electricity grid instead of rail lines. Only ±30% of coal’s energy converted to electricity in generation process. Transmission efficiency >96%. Avoid major transportation cost
Western Low Rank Coal Research Initiatives

1) Gravity separation technique improvement.
   a) Air Jigs
   b) Air Tables
   c) Non aqueous density separation (OTISCA)

2) Optical sorting

3) On-site liquefaction/upgrading (SASOL, KFX, etc.)

4) Reduction of Sodium in Western coals

5) Reduction of mercury
Other Coal Preparation Challenges

1) Training and Development of Skilled Workforce

2) Developing Strong Resource Pool of Young Graduate Engineers to Fill Ever-Increasing Gaps in Technical/Managerial Positions

3) Training of Employees in Best Practices

4) Optimizing the Use of the Coal Resource Through Education/Standards

5) Adequate waste disposal capacity
1. Review of U.S. Coal Reserve Base technically, economically and legally
   a) Evaluate legal impediments to coal production
   b) Perform cost/benefit analysis on legally sterilized reserves
      ▪ Some SMCRA discretionary actions reduced surface mineable reserves by ± 67 billion tons
      ▪ Grand Escalate Monument reduced reserve base in Utah by billions of tons

2. Evaluation of ways to improve moving coal to market
   a) Rail
      ▪ Need incentives for private investment to expand rail services
      ▪ Address obstacles to expansion (streamline permitting, facilitation of rights of way through expanded eminent domain authority for energy corridors)
   b) Barge
   c) Mine mouth power plants
   d) Improve electric grid system – provide incentives to develop improved grid to transport electricity as well as coal
Key Requisites to Successful Expansion of the U.S. Coal Industry, Providing Adequate Feedstock for our Expanded Plant Capacity

3. Fund mining R&D to develop safer, more cost effective mining methods for mining a more challenging resource

4. Improved safety research
   a) Review communications equipment
   b) Improve self rescuer technology
   c) Encourage experimentation and innovation for safety improvements

5. Training/education
   a) Incentives to bring skilled young workers/engineers to an aging workforce. (Federal and State governments working together to fund programs to develop engineers/technicians

6. Provide incentives for coal conversion projects to help develop energy independence
   a) Use tax incentives/guarantees to encourage multi-billion dollar investments in “SASOL” like projects to generate gasoline/diesel from coal, reducing reliance on unstable/hostile foreign sources
   b) Need to develop sequestration of CO$_2$ from CTL plants (capture technology already available)
7. Develop a National Energy Policy, which removes regulatory and legal obstacles to developing our coal reserves
   a) Need to streamline permitting process
      - Currently obtaining a permit to mine coal requires a multiplicity of permits from numerous federal and state agencies needing duplicate and overlapping data. Process is very timely, costly and inefficient.
        - Eliminate permitting redundancies
        - Include fixed time for public/other agency input
        - Limit litigation on areas already covered in the permitting process
        - Eliminate promulgation of regulations/standards by individual reviewers that circumvent the legislative process
   b) Federal Leasing
      - Private sector coal leasing operates efficiently through normal commercial arrangements
      - Obtaining a federal lease can often take over ten years
      - The process need to be streamline to allow full and thorough reviews whilst significantly reducing timeframe
Key Requisites to Successful Expansion of the U.S. Coal Industry, Providing Adequate Feedstock for our Expanded Plant Capacity

8. Coherent Federal Coal Research Coordination
   a) Currently coal research disseminated over many departments after elimination of Bureau of Mines
   b) Bring in all coal research under one roof. Possibly Office of Fossil Energy within DOE will provide far more effective and coherent research effort

9. Encourage re-mining of previously mined lands, by removal of regulatory obstacles

10. Fund R&D to address environmental issues relating to the mining and use of coal

11. Encourage more efficient coal burning technologies to reduce CO$_2$ emissions per unit energy produced (e.g., IGCC)
ACKNOWLEDGEMENTS

2) N.M.A. Publications – Coal Data
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5) Bruce Firth, C.S.I.R.O. Australia
6) Kip Alderman
The real giants
World's largest oil and gas firms, by proven reserves in barrels of oil equivalent

State controlled:

Not state controlled:

Saudi Aramco
National Iranian Oil Company
Gazprom
INOC
Oxar Petroleum
PDVSA
Kuwait Petroleum Corporation
ADNOC
Nigerian National Petroleum Corporation
Sonatrach
Libya NOC
Rosneft
Petronas
Exxon Mobil
Lukoil

Source: PR Energy