Potential Markets for Coal

New Growth Alliance Advanced Carbon Products Conference

April 7, 2017
Outline

1. Wyoming Coal
   – Production History
   – Impact
2. Market Outlook – existing markets
   – Short Term
   – Longer term
3. New Markets
   – Thermal coal
   – Upgrading
   – CCUS
   – New Products
Coal has been a part of Wyoming’s economy since the arrival of the Union Pacific.
Boom and Bust

Wyoming Annual Coal Production 1865-1970
Boom and Bust

Wyoming Annual Coal Production 1865-1970

Union Pacific Mines open (1868)
Boom and Bust

Wyoming Annual Coal Production 1865-1970

Peak of the Rail Era (1910s)
Boom and Bust

Wyoming Annual Coal Production 1865-1970

World War 1 (1918)
Boom and Bust

Wyoming Annual Coal Production 1865-1970

Great Depression (1930s)

Millions short tons
Boom and Bust

Wyoming Annual Coal Production 1865-1970

Millions short tons

World War 2 (1942-45)
Boom and Bust

Wyoming Annual Coal Production 1865-1970

End of the Steam Rail Era (1953)
Boom and Bust

Wyoming Annual Coal Production 1865-1970

Wyoming Power Era (1959 onward)
Boom and Bust

Wyoming Annual Coal Production 1865-1970

Wyoming Export Era (1970 onward)
Wyoming: “King Coal”

Historical Wyoming Coal Production

Millions short tons

<table>
<thead>
<tr>
<th>Period</th>
<th>National Share</th>
<th>Production Avg ('000 tons)</th>
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<tbody>
<tr>
<td>1865-1886</td>
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<td>1887-1920</td>
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<td>1921-1953</td>
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<td>1954-1969</td>
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<td>2000-2009</td>
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<td>2010-2016</td>
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Wyoming: “King Coal”

Historical Wyoming Coal Production

Timeframe of previous slide...
Wyoming: “King Coal”

Historical Wyoming Coal Production

National share now 40%, Wyoming produced 297.5 million short tons in 2016.

Timeframe of previous slide...
Past 50 Years: New Markets, New Demand

• Prior to 1970: production historically underground in Western and central Wyoming through the 1960s.

• 1970s: Clean Air Act (CAA) and amendments, opening of Powder River Basin (PRB)
  – Energy crisis also drives production

• 1980s: Rail deregulation, CAA SO$_2$ (1990) amendments drive continued PRB expansion.
  – Mid-1980s: Wyoming becomes nation’s largest coal producer.
PRB vs Uinta Basin

PRB Share of 2016 Total Production

Powder River Basin (WY) Production, 96.6%, (287.2 million tons)

Rest of Wyoming, 3.4%, (10.3 million tons)
Scale Economies


North Antelope Rochelle
Black Thunder
Antelope
Cordero Rojo
Eagle Butte
Belle Ayr
Spring Creek (MT)
Rawhide
Freedom (ND)
Buckskin

Millions Short Tons

Wyoming
Other States
Scale Economies


North Antelope Rochelle
Black Thunder
Antelope
Cordero Rojo
Eagle Butte
Belle Ayr
Spring Creek (MT)
Rawhide
Freedom (ND)
Buckskin

Two largest mines in Wyoming accounted for over 23% of US coal production.
Domestic Markets

Source: EIA, 2015

Texas, 14.7%
Illinois, 12.1%
Missouri, 10.8%
Wyoming, 7.5%
Iowa, 6.0%
Wisconsin, 5.8%
Oklahoma, 4.8%
Kansas, 4.7%
Michigan, 4.7%
Nebraska, 4.2%
Arkansas, 3.9%
Georgia, 3.0%
Alabama, 2.9%
Colorado, 2.9%
Minnesota, 2.8%
Kentucky, 2.3%
Louisiana, 1.9%
Arizona, 1.9%
Indiana, 0.6%
Tennessee, 0.9%
South Dakota, 0.4%
Oregon, 0.4%

Other States:
Nevada: 0.3%
Washington: 0.2%
Mississippi: 0.2%
New York: 0.1%
N. Dakota: 0.1%
Maryland: 0.1%
Montana, Idaho, Utah, Ohio all less than 0.1%
Total Wyoming Generation from all sources: 48,966,519 MWh.

Wyoming Electricity Disposition as a share of Total Generation (2015)

- Wyoming Electricity Exports, 60.1%
- Wyoming Electricity Sales, 34.6%
- Other (incl. losses), 5.4%

Source: EIA, 2015
Value Added Export

88% of total Wyoming Electricity produced using coal – implying if 60% is exported, on average, over 4.5% of Wyoming coal is exported as higher value electricity (equivalent of 17 million tons in 2016).

Total Wyoming Generation from all sources: 48,966,519 MWh.

Source: EIA, 2015
The Wyoming Coal Economy accounts for 14% of Gross State Product.

Coal production alone, including indirect and induced effects accounts for 11.3% of GSP.
Coal Impact Today

- The Wyoming Coal Economy accounted for over 23,000 jobs (5.8%) in the state annually in 2012.
- Coal mine employment accounted for 1.8% of Wyoming jobs in 2012.
  - 2012: 6,890
  - 2013: 6,485 (-5.9%)
  - 2014: 6,671 (-2.9%)
  - 2015: 6,578 (-1.4%)
  - 2016: 5,627 (-14.5%)
State Revenues:

- Total 2012 Wyoming Revenue was $11.3 billion.
- Coal production state revenues alone were valued at $1.26 billion (11.2%).
- Coal economy state revenues estimated to be $1.33 billion (11.8%).
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Recent Production

Wyoming Coal Production Changes Since 2011

-25.0% -20.0% -15.0% -10.0% -5.0% 0.0% 5.0% 10.0% 15.0% 20.0% 25.0%


-0.9% -8.5% -3.3% 2.2% -5.0% -21.1%
Threats to the Wyoming Coal Industry

• “Fundamental” Market challenges (short term)
  – Increased coal production costs (slower productivity growth, increased wage and capital costs)
  – Continued low natural gas prices
  – Continued weak electricity demand growth
  – Renewable generation growth

• Long term challenges
  – GHG regulation (domestic and foreign)
    • Lack of new coal plant construction
  – Increased renewable penetration
Thermal Market

Annual share of total U.S. electricity generation by source (1950-2016)

- 2016 forecast
  - natural gas (33%)
  - coal (32%)
  - nuclear (19%)
  - nonhydro renewables (8%)
  - hydro (6%)
  - other (1%)

percent of total

[Diagram showing the percentage share of electricity generation by source from 1950 to 2016.]
Natural Gas Forecast


Note: Cost of fuel delivered to electricity generation (measured in $/mmBtu) converted to $/MWh using assumed heat rates of 10,000 Btu/kWh for coal and 7,200 Btu/kWh for natural gas.
Generation Forecast (Coal vs. Gas)

Source: U.S. Energy Information Administration, Short-Term Energy Outlook, November 2016
Near Term Thermal Market Forecast
Long Term Coal Forecast

Coal Production: Wyoming, Powder River Basin

Source: U.S. Energy Information Administration
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New Markets: Asia

• Expanded international markets have been seen as a savior for PRB coal for almost a decade.

• Challenges:
  – Shipping cost/international competition
  – GHG policy in Asia

• Potential:
  – Optimistic forecast: Growth in these markets could create a possible 50 to 100 million ton market annually.
New Markets: Asia

• Setbacks:
  – Millennium Bulk Terminal (Longview, WA)
    • Denied permit by State of Washington (January 2017).
    • Now in court – environmental groups allowed to intervene in case (March 2017).
  – Gateway Pacific Terminal (Cherry Point, WA)
    • Denied permit by Army Corps of Engineers – granting Lummi request (May 2016).
    • Developer withdrew all permit applications (February 2017).
Asian Market Challenges

1. International Price volatility

2. Investor interest/sentiment in export mining and terminal projects.
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Coal Upgrading

- Processes to reduce moisture content, increase energy content, reduce pollutants, improve handling (dust, etc.).
- Coal can qualify for Section 45 tax credit ($6.81/ton in 2016).

### Claimed CBA Environmental Upgrading Results

<table>
<thead>
<tr>
<th>Powder River Basin</th>
<th>Coballo Mine (ROM)</th>
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</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>Pre</td>
<td>Post</td>
<td>%Change</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.07</td>
<td>&lt;.02</td>
<td>(71%)</td>
<td></td>
</tr>
<tr>
<td>BTU</td>
<td>8,687</td>
<td>11,940</td>
<td>37%</td>
<td></td>
</tr>
<tr>
<td>SO$_3$ in Ash</td>
<td>14.1%</td>
<td>0.20%</td>
<td>(98%)</td>
<td></td>
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<tr>
<td>Reduction in most Alkaline Oxides (ash analysis)</td>
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</table>

<table>
<thead>
<tr>
<th>Powder River Basin</th>
<th>Jacobs Ranch Mine (ROM)</th>
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<tbody>
<tr>
<td>Mercury</td>
<td>Pre</td>
<td>Post</td>
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<tr>
<td></td>
<td>.02</td>
<td>.02</td>
<td>0%</td>
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</tr>
<tr>
<td>BTU</td>
<td>8,952</td>
<td>11,830</td>
<td>33%</td>
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</table>

### Clean Coal Technologies Pristine-M

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>50%</td>
<td>10%</td>
</tr>
<tr>
<td>BTU</td>
<td>7,200</td>
<td>12,000</td>
</tr>
<tr>
<td>Coal Use</td>
<td>1.67 tons</td>
<td>1 ton</td>
</tr>
</tbody>
</table>


Coal Upgrading

• Advantages:
  – Reduced emissions/control costs
    • Reduced mercury, arsenic, NOx, SO2, ash-contained pollutants possible.
    • Reduced CO2 emissions due to increased plant efficiency
    • Reduced SCR maintenance possible
  – Improved shipping economics:
    • Higher energy content/reduced moisture increases energy density for shipping/export (increases BTU/ton shipped).
    • Increases landed value.
    • Less costly handling
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Future Markets: CCUS (>10 years)

Coal will be a major part of the world energy mix through 2050.
  – CCUS will be necessary to meet CO₂ mitigation objectives.
Future Potential Markets: CCUS

Challenges:
- Technology: Still being proven at commercial scale
  - Two operating post-combustion plants.
  - Pre-combustion Kemper MS plant nearing operation.
- Costs: Capital and operating costs (retrofit or new facilities) prohibitive.
- Economic competitiveness will require developing uses for CO$_2$.
  - Note: CO$_2$ regulation/charges will not ensure competitiveness.
CCUS Pathways

Paving the way — A selection of today's carbon capture and utilization pathways

- Carbonates
- Concrete
- Bauxite Treatment
- Algae Cultivation
- Liquid Fuels
- Polymers
- Urea

Conversion
- Mineralization
- Biological
- Chemical
- Non-Conversion
  - Utilization (CCU)
  - Sequestration (CCS)

- Desalination
- Enhanced Oil Recovery
- Enhanced Geothermal
- Enhanced Coal Bed Methane

Source: Global CCS Institute
CCUS Pathways

Paving the way — A selection of today's carbon capture and utilization pathways

Non-geologic uses:
- Mineralization
  - Carbonates
  - Concrete
- Biological
  - Bauxite Treatment
  - Algae Cultivation
- Chemical
  - Liquid Fuels
  - Polymers
  - Urea
- Desalination

Geologic uses:
- Capture
- Sequestration (CCS)
- Conversion
- Utilization (CCU)
- Enhanced Oil Recovery
- Enhanced Geothermal
- Enhanced Coal Bed Methane
Non-Geologic CO$_2$ Uses

Source: National Energy Technology Laboratory
CCUS Policy

Policies to support CCUS development (not exhaustive):

• Technology Development
  – NCCC and ITC facilities.
  – R&D support and deployment incentives.

• Market Support
  – Product/market development.
  – Liability, regulatory and legal issues.
  – Financing.
  – Infrastructure support.
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Coal to Products (>15 years)

Coal can be used a rich feedstock for a number of industries.

• Considering coal beyond its BTU value.
  – CO2 => Products
  – Coal => Chemicals
  – Coal => Fuel
  – Coal => Materials

Source: USGS
Processes already developed to produce carbon co-products and power.
Optimizing Wyoming Coal

PRB coal: Turning disadvantages into advantages

• Abundant and cheap access
  – Feedstock advantage
• Sub-bituminous coal is volatile- easily reacted
• Trace elements/contaminants in low concentration
• Low sulfur
• Water content could be recovered
• Coal has less hydrogen – create products petroleum can’t
• Oil also abundant in state – maximize co-product potential?
• Carbon-engineering efforts at UW/SER
Coal: Creating Economic Diversity?

PRB Coal

<table>
<thead>
<tr>
<th>Power Generation</th>
<th>Syngas</th>
<th>Carbon</th>
<th>By-products</th>
<th>Ammonia products</th>
<th>Liquids</th>
<th>???</th>
</tr>
</thead>
</table>
| • Electricity    | • Methanol • Acetic Acid • Formaldehyde • Propylene • Polypropylene • Acrylic Acid • Ethylene • Butadiene • Styrene | • Carbon Fiber • Carbon Black • Activated Carbon • Carbon Semiconductors • Pitch • Graphene | • Building products • Algae fuels and feeds | • Fertilizers | • Methanol • DMG • LNG • LH₂ • LPG • Diesel Fuel • Gasoline |}

Complementary Industries:
Renewable energy: solar manufacture, wind turbine components manufacture, batteries
Fuels, chemicals materials: hydrogen, coal to liquids, high value chemical processing, building materials
Manufacturing: light-weighting parts, recreational goods, aircraft components, plastics
Food: Beverages, food, agriculture
Challenges

1) Technology development – CO2, production processes
2) Capital investment – partners
3) Location of new industry – policy/partners
4) Scale of use – maintaining demand for coal
5) New market growth – new demand
6) Tax structure in the state
7) Labor force development
8) Competition – do it first and best
Thank you!

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