Coal Use

ChEn 733

Coal Combustion
Questions for Class 1

1. Compare the types of electric power generation in the United States by region versus the population (i.e., demand).

2. Please comment on the recent article in WIRED on clean coal (Google Wired clean coal, or [http://www.wired.com/2014/03/clean-coal](http://www.wired.com/2014/03/clean-coal)). The comments show widely varied opinions.

3. What is the current percentage of electric power generation in the United States from coal, natural gas, oil, nuclear, hydroelectric, biomass, solar, wind, and geothermal sources?

4. How does the electric power generation vary between the countries with the top 20 electric power use? Discuss the differences.

5. Describe the main features of a pulverized coal-fired utility, including the cycle used for power generation. Why don't utilities use more advanced cycles or combined cycles?

6. Describe how coal is classified according to rank in the United States, including how the appropriate ASTM analyses are performed. What are the pluses and minuses of this system?

7. Where are the main coal fields in the United States located? Where in the United States is the highest potential for biomass use for electric power generation?

8. Describe what the Argonne Premium Coal Samples are, how they are used, and what other coal sample banks are available. Why are these coal banks valuable?
Question 1

Compare the types of electric power generation in the United States by region versus the population (i.e., demand).
U.S. POWER: A MIXED BAG

Rich in resources, the U.S. generates electricity in many ways: Hydropower is a major factor on the West Coast, fuel oil in the Northeast, natural gas in some Gulf states and in California, nuclear in the East, and coal nearly everywhere. Even so, some regions (pink) may suffer shortages of electricity in extreme weather. Planners hope “negawatts,” power saved by conservation, will help delay a crunch.

Selected power plants
- Nuclear
- Hydroelectric
- Natural gas
- Fuel oil
- Coal
- Other (solar, wind, geothermal)

Data as of January 1990

Regional boundary. Bar graphs show totals by region.

Areas vulnerable to power interruptions in the 1990s, defined by a generating-capacity margin, or cushion, of less than 17% above peak demand.
U.S. Satellite Image at Night

World Energy Reserves 2009

World Satellite Image at Night

World Electricity Generation
1971-2020

from IEA web pages
Projected Energy Use

Figure 15. World energy consumption by fuel, 1990-2035 (quadrillion Btu)

Figure 65. World coal consumption by region, 1980-2035 (quadrillion Btu)

2. Please comment on the recent article in WIRED on clean coal (Google Wired clean coal, or http://www.wired.com/2014/03/clean-coal). The comments show widely varied opinions.
3. What is the current percentage of electric power generation in the United States from coal, natural gas, oil, nuclear, hydroelectric, biomass, solar, wind, and geothermal sources?
U.S. Total Energy Production & Consumption

U.S. Energy Flow, 2014
(Quadrillion Btu)

- Coal: 20.26
- Natural Gas: 28.43
- Crude Oil: 18.32
- NGPL: 4.03
- Nuclear Electric Power: 8.33
- Renewable Energy: 9.68
- Petroleum: 34.78
- Domestic Production: 87.04
- Supply: 110.59
- Fossil Fuels: 69.03
- Fossil Fuels: 80.20
- Energy Exports: 12.22
- Other Exports: 4.05
- Petroleum: 8.17
- Other: 3.27
- Stock Change and Other: 0.19

Residential: 21.53
Commercial: 15.34
Industrial: 31.33
Transportation: 27.12
Consumption: 98.32
Exports: 12.22
Other Exports: 4.05
Petroleum: 8.17
Coal: 17.82
Natural Gas: 27.51
Petroleum: 20.04
Imports: 23.31
Nuclear Electric Power: 8.33
Renewable Energy: 9.63

U.S. Electricity Production & Use

U.S. Electricity Flow, 2014
(Quadrillion Btu)

- Coal: 16.50
- Natural Gas: 8.75
- Petroleum: 0.31
- Other Gases: 0.11
- Nuclear Electric Power: 8.33
- Renewable Energy: 5.26
- Other: 0.18

- Fossil Fuels: 25.67
- Energy Consumed To Generate Electricity: 39.44
- Conversion Losses: 24.66
- Gross Generation of Electricity: 14.78
- Net Generation of Electricity: 13.97
- Net Imports of Electricity: 0.16
- Net Use: 13.18
- Residential: 4.79
- Commercial: 4.63
- Industrial: 3.26
- Transportation: 0.03
- Direct Use: 0.47

- T & D Losses and Unaccounted for: 0.56

- Plant Use: 0.81
U.S. Electricity Projection

http://www.eia.gov/forecasts/aeo/
from DOE EIA web pages
Coal Production 2012

Coal Consumption 2012

China

Rest

Poland

Germany

South Africa

Russia

Indonesia

Australia

India

United States

Coal Consumption 1965-2013

Data source: BP Statistical Review of World Energy 2014

Coal Reserves 2008
Billion short tons

- United States, 261
- Russia, 173
- China, 126
- Australia, 84
- India, 67
- Germany, 45
- South Africa, 33
- Kazakhstan, 37
- Ukraine, 37
- Serbia, 15
- Rest, 69
Question 4

Describe the main features of a pulverized coal-fired utility, including the cycle used for power generation. Why don't utilities use more advanced cycles or combined cycles?
Question 5

5. How does the electric power generation vary between the countries with the top 20 electric power use? Discuss the differences.
Flyash Collection

Combustion

Coal Storage & Handling

Steam System

Sulfur Removal
Gasification-Based Energy Production System Concepts
Oxyfuel

- Oxy-fuel combustion:
Steelmaking
Question 6

Describe how coal is classified according to rank in the United States, including how the appropriate ASTM analyses are performed. What are the pluses and minuses of this system?
<table>
<thead>
<tr>
<th>Class</th>
<th>Group</th>
<th>Fixed carbon limits (%) (dry, mineral-matter-free basis)</th>
<th>Volatile matter limits (%) (dry, mineral-matter-free basis)</th>
<th>Calorific value limits (Btu/lb) (moist mineral-matter-free basis)</th>
<th>Agglomerating character</th>
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</thead>
<tbody>
<tr>
<td>I. Anthracitic</td>
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<tr>
<td>1. Meta-anthracite</td>
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<td>98</td>
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<tr>
<td>2. Anthracite</td>
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<td>92</td>
<td>98</td>
<td>2</td>
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<tr>
<td>3. Semianthracite</td>
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<td>86</td>
<td>92</td>
<td>8</td>
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<td>II. Bituminous</td>
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<tr>
<td>1. Low volatile bituminous coal</td>
<td>78</td>
<td>86</td>
<td>14</td>
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<tr>
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<td>69</td>
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<td>3. High volatile A bituminous coal</td>
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<td>69</td>
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<td>4. High volatile B bituminous coal</td>
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<td>14,000</td>
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<td>5. High volatile C bituminous coal</td>
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<td>—</td>
<td>11,500</td>
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<td>III. Subbituminous</td>
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<td>10,500</td>
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<td>9,500</td>
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<td>3. Subbituminous C coal</td>
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<td>8,300</td>
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<td>IV. Lignitic</td>
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<td>1. Lignite A</td>
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<td>—</td>
<td>6,300</td>
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<tr>
<td>2. Lignite B</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>6,300</td>
<td></td>
</tr>
</tbody>
</table>
ASTM Standard Tests

Proximate Analysis

Moisture 104-110°C for exactly 1 hour, swept with dry air

Volatile Matter 1g coal in covered crucible, inserted into furnace (in air) at 950 °C, 7 minutes

Ash From moisture sample, heat to 500 °C in 1 hour, to 750 °C in 2 hrs, and remain at 750 °C until constant weight

Fixed Carbon 100-% Volatile matter (on dry, ash-free basis)

Heating Value

Calorimeter moist, mineral-matter free basis
There are several instruments available for ultimate analysis, but usually C, H, and N are determined on one machine and total S is determined on a separate machine.

Note that the ultimate analysis does not distinguish between organic sulfur (bound up in the aromatic ring structure) and pyritic sulfur (iron pyrite, FeS2).
Proximate Analyses

What are the main points?

(in Smoot & Smith, 1985)

Question 7

Where are the main coal fields in the United States located?

Where in the United States is the highest potential for biomass use for electric power generation?
U.S. Coal Fields


Source: Developed from the U.S. Geological Survey
By Type, 1949-2011

http://www.eia.gov/coal/data.cfm#production

http://www.eia.gov/totalenergy/data/annual/index.cfm#coal
Biomass Potential

Biomass Resources Available in the United States

This study estimates the technical biomass resources currently available in the United States by county. It includes the following feedstock categories:
- Agricultural residues (crops and animal manure)
- Wood residues (forest, primary mill, secondary mill, and urban wood)
- Municipal discards (methane emissions from landfills and domestic wastewater treatment)
- Dedicated energy crops (on Conservation Reserve Program and Abandoned Mine Lands)

September 2005
Question 8

Describe what the Argonne Premium Coal Samples are, how they are used, and what other coal sample banks are available. Why are these coal banks valuable?
Argonne Premium Coals

- Pocahontas #3 (VA) Low Vol. Bit.
- Lewiston-St. (WV) High Vol. Bit.
- Pittsburgh #8 (PA) High Vol. Bit.
- Illinois #6 (IL) High Vol. Bit.
- Beulah-Zap (ND) Lignite
- Wyodak-And. (WY) Subbituminous
- Blind Canyon (UT) High Vol. Bit.
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Bottom Line

Coal will be used for a long time!