

RESM 693/493: Recent Developments in the Coal Industry

- Objectives
 - Understand coal, coal use, and coal market
 - Discuss relative environmental issues
 - Observe the current development of coal industry
 - Know coal to liquid concept
 - Learn the basic skill to develop a large coal project

Learning Tools

- **11 lectures** including 2 guest lectures
- **No textbook.** World Coal Institute publications supplement the lecture material. Supplementary books are:
 - 1) [*Alternative Fuels*] by Sunggyu Lee,
 - 2) [*Environmental impacts of coal mining and utilization*] by the Beijer Institute,
 - 3) [*Energy and the environment*] by James A. Fay, Dan S. Golomb.
- **2 Field trips:** 1) a surface coal mine; and 2) Power plant
- **Case studies:** 1) Shenhua coal-to-liquids (CTL) projects; and 2) a coal-to-liquids project in Mingo County, West Virginia

Course Syllabus

Week	Date	Contents
1	8-23-07	Introduction of coal, coal industry, and use of coal
2	8-30-07	Guest Speaker: Shenhua CTL Project Development
3	9-6-07	Coal reserves, production, and demand
4	9-13-07	Field Trip I: Surface coal mine
5	9-20-07	Coal industry and problems in WV, USA, World
6	9-27-07	Coal market and international trade; Cost of coal and coal utilization
7	10-4-07	Coal utilization industry and clean coal technology
8	10-11-07	Midterm test
9	10-18-07	Coking and gasification technologies
10	10-25-07	Coal conversion and coal to liquid development
11	11-1-07	Guest Speaker: Carbon management and environment protection
12	11-8-07	The management of resources and by products associated mining (final project assignment)
13	11-15-07	Coal and coal conversion project planning
14	11-22-07	Feasibility study of integrated coal mining and utilization project
15	11-29-07	Field Trip II: Coal utilization facility: power plant
16	12-6-07	Case studies: Shenhua CTL plant and coal to liquid project in Mingo County, WV
17	12-13-07	Final project presentations

Grading

- Assignments: 30% (3 assignments)
- Midterm exam: 20% (??????)
- Final:
 - Final project report: 30
 - Final presentation : 20%

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Recent Developments in the Coal Industry

Chapter 1

**Introduction of Coal, Coal Industry,
and Coal Use**

Contents

- What is coal
- Formation of coal
- History of coal
- Why coal
- Coal quality vs. coal use

What is Coal

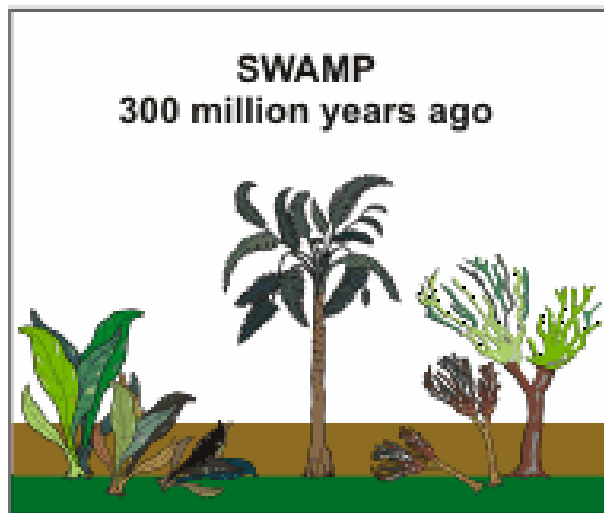
- **Rock** consists almost entirely of organic material.
- **Fossil fuel** created from the **remains of plants** that lived and died about 100 to 400 million years ago.
- **Nonrenewable** energy source because it takes millions of years to form.
- Coal seams range in thickness from a fraction of an inch to hundreds of feet.

Coal Composition

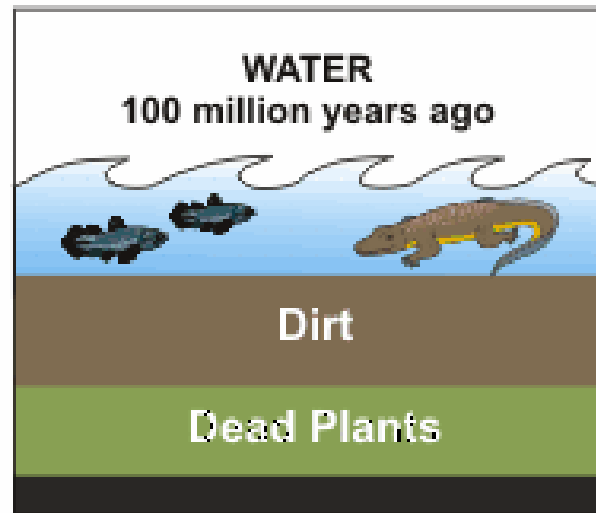
- It is a complex mixture of carbon, metal compounds and several other compounds such as hydrocarbons, organic sulphur compounds, hydrogen sulphide, ammonia, water, and complex molecules such as tars, which are released – some being burnt - during combustion of the coal. Its composition varies widely according to location.

Coal Formed in Millions of Years

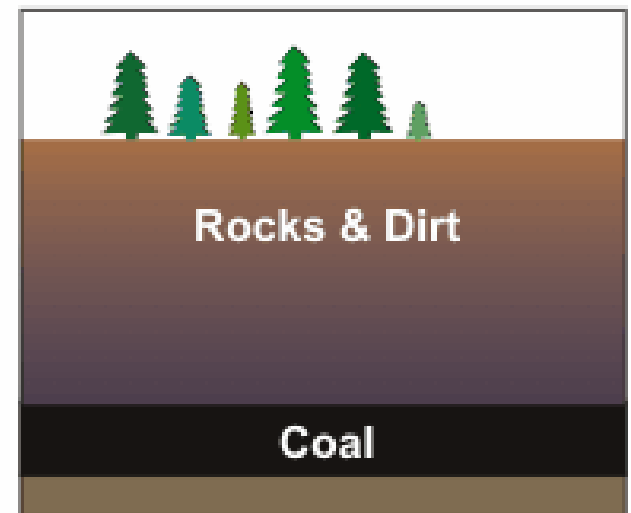
HOW COAL WAS FORMED



Before the dinosaurs, many giant plants died in swamps.

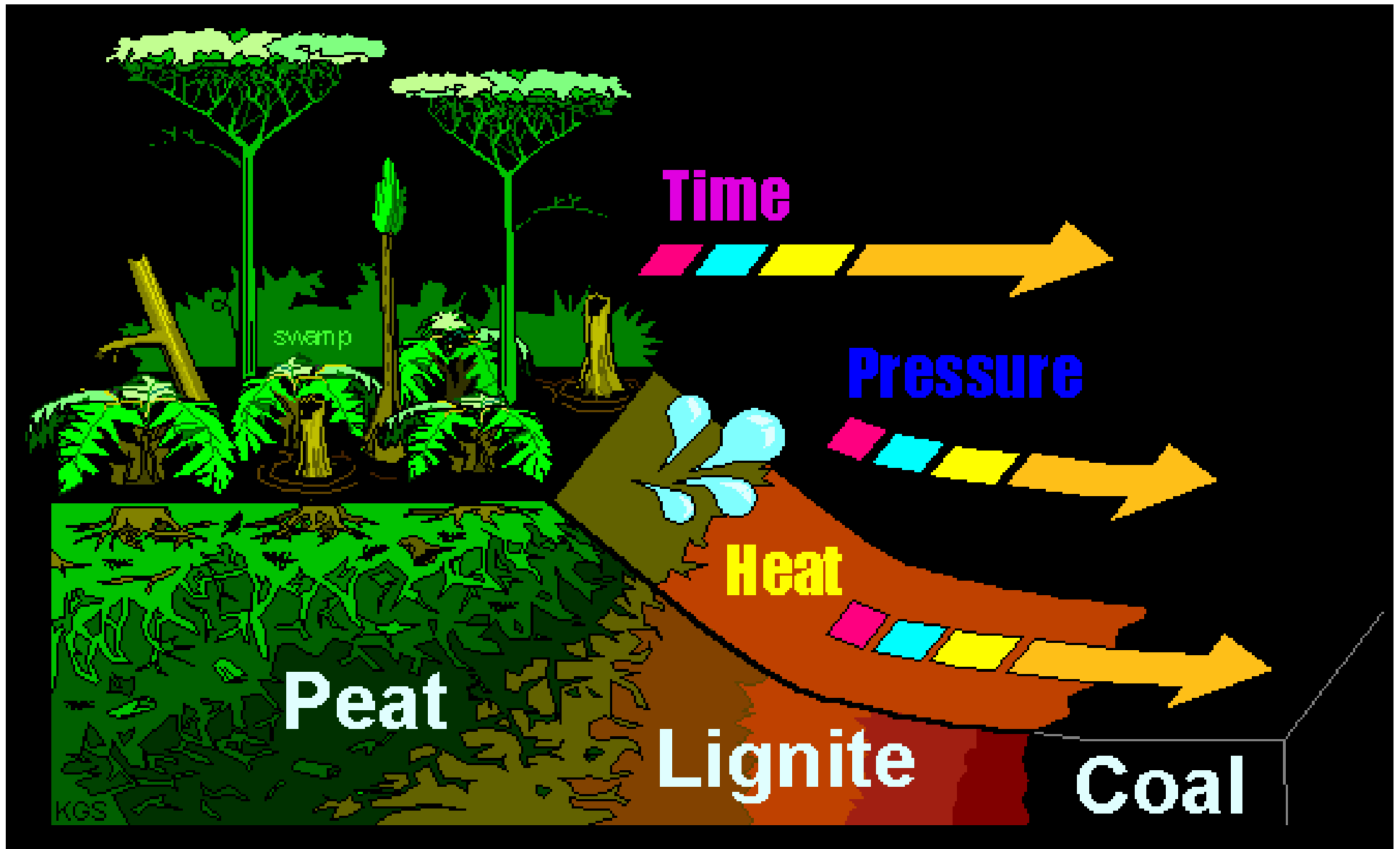


Over millions of years, the plants were buried under water and dirt.



Heat and pressure turned the dead plants into coal.

How is Coal Formed?



Coal Formation

- Coal comes from **dead plant matter** falling into the swampy water. The weight of the top layers of water and dirt packed down the lower layers of plant matter. Under **heat and pressure**, this plant matter underwent chemical and physical changes, pushing out oxygen and leaving rich hydrocarbon deposits.
- 4 stages in coal formation: **peat, lignite, bituminous and anthracite (hard coal)**.
- The stage depends upon the conditions to which the plant remains are subjected after they were buried. The greater the pressure and heat, the higher the rank of coal. Higher-ranking coal is denser and contains less moisture and gases and has a higher heat value than lower-ranking coal.



What's in coal?

vitritinates

- wood
- roots
- bark

inertinites

- charcoal

liptinites

- leaf cuticles
- spores

ash

- sediment
- minerals

KGS

Early Use of Coal

- Northeastern China used coal for smelting copper and for casting coins around 1000 BC.
- Outcrop coal was used in [Britain](#) during the [Bronze Age](#) (2-3000 years [BCE](#)), where it has been detected as forming part of the composition of [funeral pyres](#).
- During the Industrial Revolution in the 18th and 19th centuries demand for coal surged. The great improvement of the steam engine by James Watt, patented in 1769, was largely responsible for the growth in coal use.

History of Coal in America

- North American Indians used coal long before the first settlers arrived in the New World. Hopi Indians, who lived in what is now Arizona, used coal to bake the pottery they made from clay.
- European settlers discovered coal in North America during the first half of the 1600s.
- Coal became a powerhouse by the 1800s. People used coal to manufacture goods and to power steamships and railroad engines. By the American Civil War, people also used coal to make iron and steel. And by the end of the 1800s, people even used coal to make electricity.
- When America entered the 1900s, coal was the energy mainstay for the nation's businesses and industries. Coal stayed America's number one energy source. Today coal supplies 22 percent of the nation's energy_needs. Its major use today is for electricity production.

Why Coal?

- Coal associated with modern life?
- Energy source
- Industrial food
- Related to economic development
- Key to environment protection

Did you know... Coal Fact

- The coal industry employs **120,000** Americans.
- **85%** of the known U.S. fossil energy resource is coal
- Coal makes up **52%** of the United States electricity mix.
- Coal is by far the **cheapest** source of power fuel per million Btu, averaging less than half the price of petroleum and natural gas.
- Coal benefits other major industries. Nationwide, coal provides America's railroads with more traffic and revenue than any other commodity
- WY is the largest coal producing state and WV is the largest hard coal producing state
- China, the United States, the Russian Federation, Poland and India are among the world's largest coal producers and consumers.

Coal utilization

- Fuel: power, heat, steam generation
- Coking for steel
- Gasification
- Liquefaction
- Cement and building materials
- Chemicals...?

Coal Utilization in USA

- Generate electric power (consume 80% U.S. coal)
- Industrial uses and family fuels
- Coke and steel manufacture, the concrete and paper industries.
- Export to Western Europe, Canada and Japan.
- Major commodity for railway and water freights
- Raw materials for chemical industry

Coal Industry and Related Business

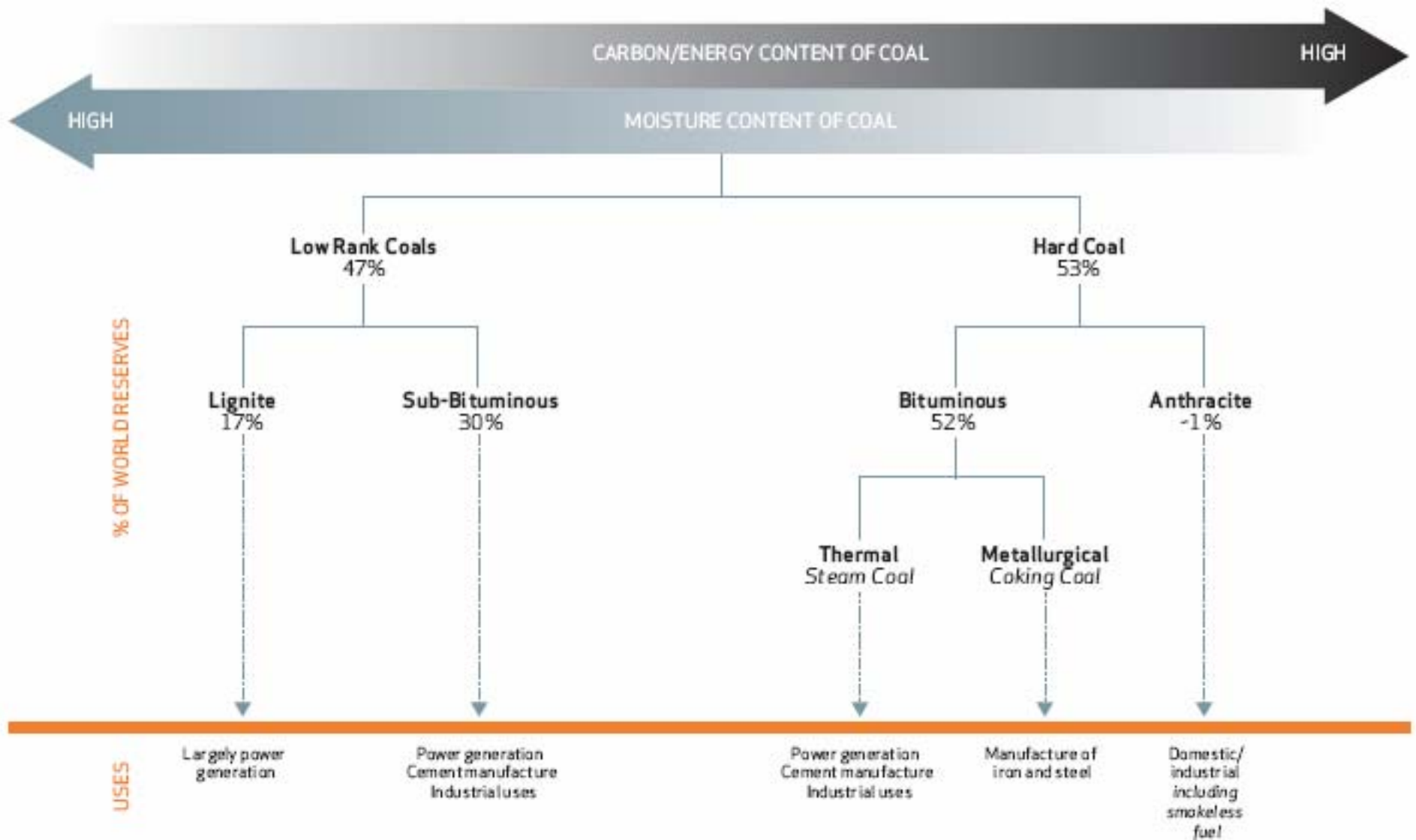
- Coal production:
 - Coal mining
 - Coal processing,
 - Associated industries: CBM, minerals, env. Fishery...
- Coal transportation
- Coal utilization industries: gas, coke, liquid, chemicals
- Related industries
 - Equipment manufacture
 - Environmental protection
 - Business

Types of coal

As geological processes apply [pressure](#) to [peat](#) over time, it is transformed successively into:

- [Lignite](#) - also referred to as brown coal, is the lowest rank of coal and used almost exclusively as fuel for steam-electric power generation.
- [Sub-bituminous coal](#) - whose properties range from those of lignite to those of bituminous coal and are used primarily as fuel for steam-electric power generation.
- [Bituminous coal](#) - a dense coal, usually black, sometimes dark brown, often with well-defined bands of bright and dull material, used primarily as fuel in steam-electric power generation, with substantial quantities also used for heat and power applications in manufacturing and to make [coke](#).
- [Anthracite](#) - the highest rank; a harder, glossy, black coal used primarily for residential and commercial space heating.
- [Graphite](#) - technically the highest rank, but difficult to ignite and is not so commonly used for ignition.
- Nature coke

Types of Coal





Peat in Scotland



Anthracite



Bituminous



Graphite



Peat



Brown Coal

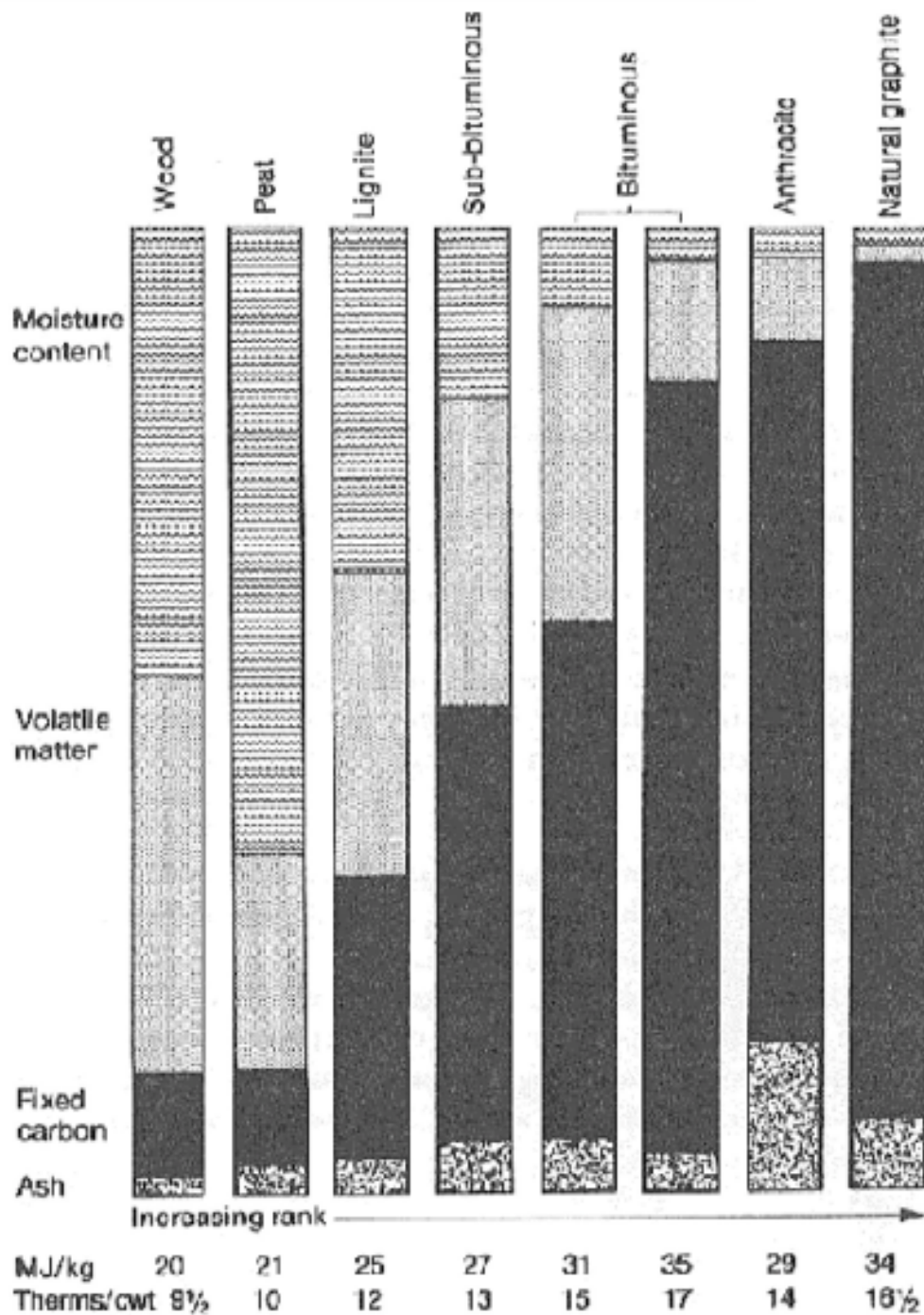


Sub-bituminous

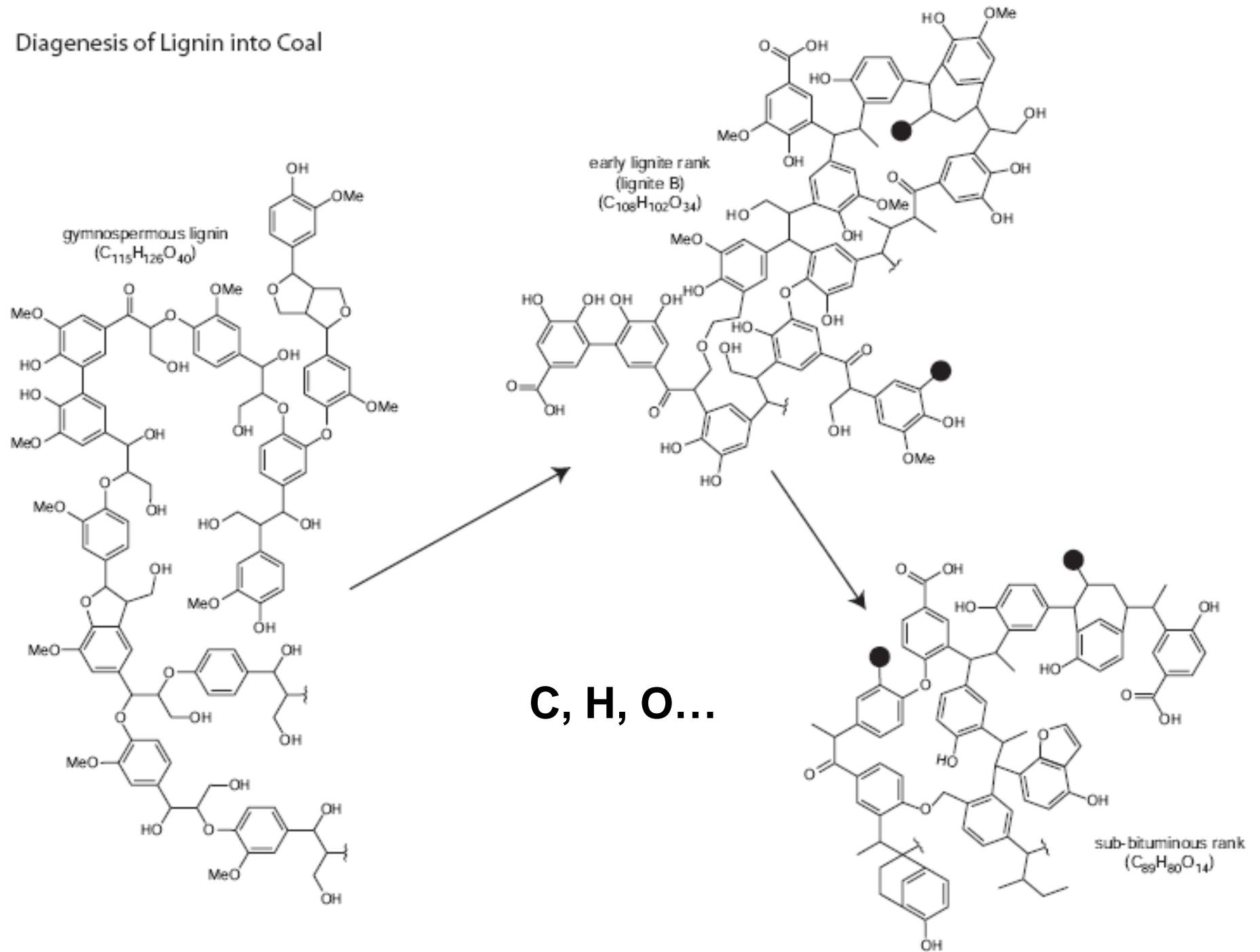


Bituminous

Composition and Energy Value



Diagenesis of Lignin into Coal



Coal Quality and its Use

- Moisture
- **Ash**
- Volatile matter
- Fixed carbon
- **Sulfur**
- Mercury
- **Heating value** (BTU/lb, kcal/kg)
- Size and specific gravity
- Caking index
- Ash melting temperature

Other specifications

- Physic Properties
 - Rank
 - Size
 - Specific gravity
 - Hardcrove Grindability Index (HGI)
 - Washable
- Chemistry properties
 - Reactivity
 - Structure
 - Chemical composition
 - Element analysis (Hg)
- Coking properties
 - Coking strength (CSR)
 - Caking index (GR. I)
 - Y-Maximum thickness of plastic layer (mm)
- Ash contents
 - Ash fusion
 - Ash contents

Quality Concerned by Users

- Coal business:
 - Coal price vs. quality in different places and conditions
- Steam coal:
 - Moisture (M), ash (A), volatile (V), heating value (Q), Sulfur (S), Mercury (Hg), ash fusion (T)
- Coking and steel companies care:
 - Rank, M, A, V, S, coking properties
- Gasification and liquefaction concern: M, S, A
- Coal chemical industry need to know:
 - Physic and chemical properties, coking properties, ash contents

Environment vs. Coal Quality

- Pollution associated with coal production
 - Land disturbance
 - Stream pollution
 - Waste coal disposal
- Pollutants during coal use
 - Air pollution by SO_x, NO_x, particulate matter, organic matter, etc
 - Water pollution: mercury, wastewaters, organic pollutants
 - Soil pollution: ash disposal, leaching
- CO₂ vs. globe warming

S Cost in SO₂ Emission

- 2002 Spot Bid: \$160.50 per allowance
- Penalty: \$2525 per excess ton of sulfur dioxide
- For 1 ton of coal of 6800 kcal/kg (\$35/t):
 - S=0.5% → Allowance Cost= \$0.8; Penalty=\$12.63
 - S=0.7% → Allowance Cost= \$1.12; Penalty=\$17.66
 - S=1.0% → Allowance Cost= \$1.81; Penalty=\$25.23
 - S=3.0% → Allowance Cost= \$4.81; Penalty=\$75.68

Coal Quality Analysis

TABLE 2. Analyses of Typical U.S. Coals, as I

Coal Type	% Proximate Analysis			
	H ₂ O	VM	FC	Ash
Anthracite	2.5	5.7	83.8	8.0
Bituminous	3.3	20.5	70.0	6.2
Sub-bituminous	23.2	33.3	39.7	3.8
Lignite	34.8	28.2	30.8	6.2

Quality Comparison of Coal Ranks

Coal Type	% Ultimate Analysis						HHV, Btu/lb	Air, ^a lb/10 ⁶ Btu
	H ₂ O	C	H ₂	S	O ₂	N ₂		
Anthracite	2.5	83.9	2.9	0.7	0.7	1.3	13.72	787
Bituminous	3.3	80.7	4.5	1.8	2.4	1.1	14.31	765
Sub-bituminous	23.2	54.6	3.8	0.4	13.2	1.0	9.42	757
Lignite	34.8	42.4	2.8	0.7	12.4	0.7	7.21	750

^aTheoretical air req. (no excess air).

Source: Adapted

FAQ in Coal and Energy Business

- Coal types
- BTU/lb → kcal/kg
- Dry base vs. received base
- Sulfur content
- Coal to CO₂
- Coal equivalent to power or crude oil

Unit Conversion

- 1 lb = 0.4536 kg
- 1 ton=0.9072 metric ton (1 mt=1.1 ton)
- 1 btu = 1.055kJ=0.252 kcal
- 1 cal = 4.184 J
- 1 kJ/kg = 0.4302 btu/lb
- 1btu/lb=0.5556kcal/kg
- 1kcal/kg=1.8 btu/lb
- 1lb coal = 8,100 to 13,000 Btu
- 1bbl crude=0.14 Mt
- 1 barrel of **crude** oil = 5.8 million **Btu**

Case Study

- Coal Quality Analysis and Possible Uses

Shenhua Coal

- Shenhua Coal

Total Moisture $\leq 12.0\%$
Ash (Dry basis) $\leq 12.0\%$
Volatile Matter 30.0 ~ 36.0%
Total Sulphur $\leq 0.50\%$
Gross Cal Value
 $\geq 6600\text{kcal/kg}$
Net Cal Value $\geq 5900\text{kcal/kg}$
Ash Fusion T $\geq 1200^\circ\text{C}$
Grindability(HGI) ≥ 50
Size 0 ~ 50mm

- Ash Content :

SiO ₂	20~30%
Al ₂ O ₃	8~13%
Fe ₂ O ₃	6~13%
CaO	30~45%
MgO	1.2~2.0%
SO ₃	7~14%
K ₂ O	0.1~0.5%
Na ₂ O	1.0~2.0%
TiO ₂	0.2~0.8%
MnO ₂	0.2~0.4%
P ₂ O ₅	0.02~0.04%
V ₂ O ₅	0.01%