1 # Energy: Fossil Fuels - Coal

EVPP 111 Lecture

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2 ## OUTLINE

- **Renewable vs. Non-Renewable Energy**
- **Fossil fuels - general**
  - **formation**
  - **resources vs. reserves**
- **Coal**
  - **formation**
  - **types**
  - **reserves**
  - **extraction**
  - **use patters**
  - **use issues**

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4 ## Nonrenewable vs. renewable energy sources

- **Nonrenewable resources**
  - available in finite, limited quantities
  - depleted by use
    - natural processes do not replenish within reasonable period of time
      - on human time scale

5 ## Nonrenewable vs. renewable energy sources

- **Nonrenewable resources**
  - include
    - minerals

- copper, tin, aluminum, radioactive ores
- fossil fuels
  - coal
  - oil
  - natural gas

6 **Nonrenewable vs. renewable energy sources**

- **Renewable resources**
  - available in potentially unlimited quantities
    - term is not used exclusively to describe energy resources
  - replaced by natural processes fairly rapidly
    - on a scale of days to decades
  - can be used forever
    - as long as they are not overexploited in short term
    - must be used in sustainable manner
      - gives them time to replace or replenish themselves

7 **Nonrenewable vs. renewable energy sources**

- **Renewable resources**
  - include
    - non-energy
      - trees
      - fishes
      - fertile agricultural soil, fresh water
    - energy
      - solar
      - wind
      - geothermal
      - hydroelectric

8 Nonrenewable energy: resources vs. reserves

- **Nonrenewable resources**
  - must differentiate between deposits that can be extracted and those that cannot
    - **resource**
    - **reserve**

9 Nonrenewable energy: resources vs. reserves

- Nonrenewable resources
  - **resource**
    - naturally occurring substance
    - of potential use to humans
    - can potentially be extracted using current technology
  - **reserve**
    - known deposits that can be extracted profitably with existing technology
      - under certain economic conditions

10 ## Nonrenewable energy: resources vs. reserves

- Nonrenewable resources
  - **resource**
    - total amount changes only by amount that is used each year
  - **reserve**
    - an economic concept
    - amount changes as
      - technology advances
      - as new deposits are discovered
      - as economic conditions vary
  - reserves are smaller than resources

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12 ## OUTLINE

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13 ## Fossil fuels

- general
  - definition
  - formation
- specific types
  - formation
  - resources and reserves
  - use patterns
  - use issues

14 ## Fossil fuels

- General definition
  - partially decayed remains of plants, animals and microorganisms that lived millions of years ago

15 ## Fossil fuels

- General formation

- ~300 million years ago
  - much of earth's climate was mild and warm
    - plants grew year round in vast swamps
  - as swamp plants and aquatic microorganisms died
    - fell into or sunk in water
      - » decomposed very little due to lack of oxygen
    - covered by layers of sediment

16 Fossil fuels

- General formation
  - over great periods of time
    - heat and pressure that accompanied burial of organic material by sediments
      - converted non-decomposed organic material into carbon-rich materials we now call **fossil fuels**

17 **OUTLINE**

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18 Fossil fuels

- **Types**
  - coal
  - oil
  - natural gas

19 Fossil fuels

- **Coal**
  - **formation**
  - **types**
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20 Fossil fuels

- **Coal**
  - **formation**
  - **types**
  - **reserves**
  - **extraction**
  - **use patterns**
  - **use issues**

21 Fossil fuels

- **Coal**
  - **formation**
    - ~300 million years ago
      - tropical freshwater swamps covered many regions of earth
    - conditions in swamps favored extremely rapid plant growth
      - resulting in accumulations of dead plant material under water
        - » decay was inhibited due to low oxygen concentrations

22 Fossil fuels

- **Coal**
  - **formation**
    - partially decayed accumulated plant material was covered by sediments
      - especially when geologic changes in earth caused some swamps to be submerged by seas
      - over vast periods of time, heat and pressure that accompanied burial
        - » converted non-decomposed plant material into carbon-rich rock called **coal**

23 Fossil fuels

- **Coal**
  - **formation**
  - **types**
  - **reserves**
  - **extraction**
  - **use patterns**
  - **use issues**

24 Fossil fuels

- **Coal**
  - **types**
    - occurs in different types, or grades, dependent on
      - varying amounts of heat and pressure to which it was exposed during formation

25 Fossil fuels

- **Coal**
  - **types**
    - exposed during formation to
      - higher heat and pressure
        - » drier (lower water content)
        - » more compact (harder)
        - » higher heating value (=higher energy content)
      - lower heat and pressure
        - » wetter (higher water content)
        - » less compact (softer)
        - » lower heating value (=lower energy content)

26 Fossil fuels

- **Coal**
  - **types**
    - three most common grades
      - lignite
      - bituminous
      - anthracite

27 Fossil fuels

- **Coal**
  - **types**
    - **lignite**
      - characteristics
        - » moist, water content of ~45%
        - » soft, woody texture
        - » produces little heat compared to other types
        - » heat value of 7000 BTU/pound
        - » dark brown in color
        - » contains ~20 noncombustible compounds
        - » contains ~35% carbon

28 Fossil fuels

- **Coal**
  - **types**
    - **lignite**
      - uses
        - » often used to fuel electric power plants
      - deposits
        - » sizable deposits found in western US
        - » largest US producer is North Dakota
        - » cost to mine (1997) $10.91/2000 pounds

29 Fossil fuels

- **Coal**
  - **types**
  - **bituminous**
    - characteristics

- moderately dry, water content of 5-15%
- moderately hard
  - » although its also called a soft coal
- produces nearly twice the amount of heat as lignite
  - » heat value of 12,000 BTU/pound
- dull to bright black with dull bands
- contains ~20-30 noncombustible compounds
- contains ~55-75% carbon

30 Fossil fuels

- **Coal**
  - **types**
  - **bituminous**
    - uses
      - extensively by electric power plants
        - » produces a lot of heat
    - deposits
      - found in US in Appalachian region, near Great Lakes, in Mississippi Valley, in central Texas
      - cost to mine (1997) $24.64/2000 pounds

31 Fossil fuels

- **Coal**
  - **types**
  - **anthracite**
    - highest grade of coal
    - characteristics
      - very dry, water content of 4%
      - very compact
        - » called hard coal
      - produces twice the heat of lignite
        - » heat value of 14,000 BTU/pound
      - dark, brilliant black in color
      - contains ~1 noncombustible compound
      - contains ~95% carbon

32 Fossil fuels

- **Coal**
  - **types**
  - **anthracite**
    - uses
      - electric power generation and other industrial uses such as production of steel
    - deposits
      - in US, most is located east of Mississippi River, particularly in PA

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34 Fossil fuels

- **Coal**
  - **formation**
  - **types**
  - **reserves**
  - **extraction**
  - **use patterns**
  - **use issues**

35 Fossil Fuels

- **Coal**
  - deposits and **reserves**
    - coal is most abundant fossil fuel in world
    - found mostly in Northern Hemisphere
    - found in seams or veins
      - underground layers that vary in thickness from 2.5cm to >30m in thickness
    - easily located
      - geologists believe most (if not all) major deposits have been located

36 Fossil Fuels

- **Coal**
  - **deposits and reserves**
  - **known, proven <u>world</u> reserves**
    - location
      - ~66% located in US, Russia, China, India
        - » with US accounting for 24% of those
    - could last
      - ~200 years at present rate of consumption
      - ~65 years if rate of consumption increases by 2% per year

37 Figure 10.4: Distribution of coal deposits, Raven & Berg

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39 Fossil Fuels

- **Coal**
  - **deposits and reserves**
    - **known <u>US</u> reserves**
      - location
        - » throughout US
        - » more in eastern 1/2 of continental US
      - could last US
        - » ~300 years at present rate of consumption

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41 Fossil Fuels

- **Coal**
  - **deposits and reserves**
    - **unknown, unproven world reserves**
      - additional coal reserves that are currently too expensive to develop
        - » for example, deposits at depths >5000 feet would cost more to extract than would be offset by current price of coal

42 Fossil Fuels

- **Coal**
  - **deposits and reserves**
    - **unknown, unproven <u>world</u> reserves**
      - location
        - » ~85% are located in US
      - could last
        - » ~1000 years at present rate of consumption
        - » ~149 years if rate of consumption increases by 2% per year

43 Fossil Fuels

- **Coal**
  - **deposits and reserves**
    - **unknown, unproven <u>US</u> reserves**
      - could last US
        - » ~400years at present rate of consumption

44 Fossil Fuels

- **Coal**
  - **deposits and reserves**
    - **known AND unknown world reserves**
      - could last
        - » ~200-1000 years depending on rate of consumption

45 Fossil fuels

- **Coal**
  - **formation**
  - **types**
  - **reserves**
  - **extraction**
  - **use patterns**
  - **use issues**

46 Fossil Fuels

- **Coal extraction**
  - two basic types of coal mines
    - surface mines

- subsurface mines

47 Fossil Fuels

- **Coal extraction**
  - **surface mines**
    - also called strip mining
    - used when overburden is 30-100 meters thick
      - overburden = rock/earthen material on top of vein/seam of coal
    - results in best utilization of coal reserves
      - it removes most of coal in a vein
      - can be profitably used in a vein as thin as 1/2 meter

48 Fossil Fuels

- **Coal extraction**
  - **surface mines**
    - have increased globally
      - in US, from 30% of coal extracted in 1970 to 60% of coal extracted currently
    - advantages over subsurface mining
      - less expensive
      - safer for miners
      - allows more complete removal of coal
    - disadvantage over subsurface mining
      - disrupts land more extensively
        - » adverse environmental impacts

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50 Fossil Fuels

- **Coal extraction**
  - **subsurface mines**
    - employed when overburden is thick, >~30-100 meters
    - account for ~40% of current coal extraction
  - advantage over surface mining
    - disrupts land less extensively
      - less potential for adverse environmental impacts
  - disadvantages over surface mining
    - more expensive
    - less safe for miners
    - less complete removal of coal

51 Fossil fuels

- **Coal**
  - **formation**
  - **types**
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52 Fossil Fuels

- **Coal use patterns**
  - provides
    - ~21% of world's commercial energy
    - ~22% of US's commercial energy
  - used to
    - generate
      - ~62% of world's electricity
      - ~53% of US's electricity
    - make
      - ~75% of world's steel

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54 Figure 10.9: World commercial energy sources, 1997, Raven & Berg

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56 Fossil Fuels

- **Coal use patterns**
  - many analysts project a decline in coal use over next 40-50 years because of
    - its high CO_2 emissions
    - harmful human health effects
    - availability of less environmentally harmful ways to produce electricity

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58 Fossil fuels

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59 Fossil Fuels

- **Coal use issues**
  - coal contains
    - small amounts of sulfur

- which is released into atmosphere as SO_2 when coal is burned
  - » SO_2 is a greenhouse gas
- trace amount of mercury and radioactive materials
  - which are released into atmosphere when coal is burned

60 Fossil Fuels

- **Coal use issues**
  - most abundant fossil fuel
  - produces highest environmental impact from
    - land disturbance
    - air pollution
    - greenhouse gas emissions (SO_2 CO_2)
    - release of toxic mercury particles
    - release of thousands of times more radioactive particles into atmosphere per unit energy produced than does a normally operating nuclear power plant
    - water pollution

61 Fossil Fuels

- **Coal use issues**
  - human health impacts
    - occupational
      - coal mining is one of most dangerous jobs in world
      - during 20th century, ~90,000 American coal miners died in mining accidents
        - » though death rates declined in latter part of century
      - between 1870 and 1950, 30,000 miners died in PA alone
        - » equivalent of one man per day for 80 years

62 Fossil Fuels

- **Coal use issues**
  - human health impacts
    - occupational
      - miners have increased risk of black lung disease
        - » lungs become coated with inhaled coal dust restricting oxygen exchange, causing ~2000 deaths per year

63 Fossil Fuels

- **Coal use issues**
  - land disturbance
    - in US, thousands of square kilometers have been disturbed by mining
      - only about 1/2 of that has been reclaimed

64 Fossil Fuels

- **Coal use issues**
  - land disturbance
    - types
      - open trenches
      - topsoil removal/erosion
      - landslides caused by lack of vegetation

- mountaintop removal
- land subsidence
- trailing dumps

65 Fossil Fuels

- **Coal use issues**
  - land disturbance
    - **acid mine drainage**
      - produced when rainwater seeps through iron sulfide minerals exposed in waste mines and
        - » carries sulfuric acid to nearby streams and lakes

66 Fossil Fuels

- **Coal use issues**
  - air pollution
    - many elements taken up by ancient plants were concentrated in coal formation process
      - such as uranium, lead, cadmium, mercury, rubidium, thallium, zinc
      - released when coal is burned
        - » as gas into atmosphere
        - » are concentrated as in fly ash
    - coal is responsible for ~25% of all atmospheric mercury pollution in US

67 Fossil Fuels

- **Coal use issues**
  - air pollution
    - acid deposition
      - both sulfur oxides (SOx) and nitrogen oxides (NOx) form acids when they react with water
      - SOx and NOx emissions react with water in the atmosphere to form
        - » an acid which falls from atmosphere to surface, known as acid deposition or acid precipitation

68 Fossil Fuels

- **Coal use issues**
  - greenhouse gases
    - coal contains up to 10% sulfur by weight
      - unless sulfur is removed by washing or flue-gas scrubbing
        - » it is released during burning and oxidizes to sulfur dioxide (SO_2) or sulfate (SO_4)
        - » ~18 million metric tons SOx released annually in US (~75% of total US emissions)

69 Fossil Fuels

- **Coal use issues**
  - greenhouse gases
    - high temperatures and rich air mixtures used in coal-fired burners also
      - oxidize nitrogen compounds (mostly from atmosphere) into nitrogen oxides (NOx)

» ~5 metric tons of NOx released annually in US (~30% of total US emissions)

70 Fossil Fuels

- **Coal use issues**
  - greenhouse gases
    - combustion of coal produces CO_2
      - ~one trillion metric tons released annually in US (~50% of total US emissions)

71 Fossil Fuels

- **Coal use issues**
  - making coal a cleaner fuel
    - desulfurization systems
      - clean power plants' exhausts
        - » chemicals react with pollution and pollution settles out (precipitates)
        - » modern "scrubbers" remove ~98% of sulfur
      - expensive, adds to cost of coal energy

72 Fossil Fuels

- **Coal use issues**
  - clean coal technologies
    - new methods for burring coal such as **fluidized bed combustion**
      - mixes crushed coal with particles of limestone in a strong air current during combustion
      - takes place at lower temperatures so there are fewer nitrogen oxides produced
      - sulfur reacts with calcium in limestone and precipitates out

73 Fossil Fuels

- **Coal use issues**
  - clean coal technologies
    - new methods for burring coal such as **fluidized bed combustion**
      - process is more efficient than traditional coal burning
        - » produces more heat for a given amount of coal
        - » therefore, reduces CO_2 emissions

74 Figure 10.8: Fluidized-bed combustion of coal, Raven & Berg

75 Fossil Fuels

- **Coal use issues**
  - converting goal into gaseous and liquid fuels
    - solid coal can be converted into **synfuels**
      - synthetic natural gas (SNG)
        - » by process of coal gasification
      - liquid fuel such as methanol or synthetic gasoline
        - » by process of coal liquefaction
    - most analysts expect synfuels to play only a minor role as a energy resource in the next 30-50 years

76 Figure 10.16: Coal gasification, Raven & Berg

77 The End