1 Energy - Fossil Fuels - Oil & Natural Gas

EVPP 111 Lecture

Dr. Largen

2 Fossil Fuels - Oil & Natural Gas

- Description
- Formation
- Reserves
- Extraction
- Use patterns
- Use issues

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4 Fossil Fuels - Oil

- **Description**
  - **oil** (actually **petroleum** or **crude oil**)
    - liquid composed of
      - hundreds of combustible hydrocarbon compounds
        - » hydrocarbons = molecules that contain C and H
      - small amounts of S, O, N, other impurities

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6 Fossil Fuels - Oil

- **Description**
  - **oil** (actually **petroleum** or **crude oil**)
    - components are separated into various products based on boiling points
      - gases
      - gasoline

- heating oil
- diesel oil
- asphalt

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8 Figure 10.10: Refining, Raven & Berg

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10 Fossil Fuels - Oil

- **Description**
  - **oil** (actually **petroleum** or **crude oil**)
    - can be used to produce **petrochemicals**
      - compounds used in production of diverse products such as
        - » fertilizers
        - » plastics
        - » paints
        - » pesticides
        - » medicines
        - » synthetic fibers

11 Fig. 10.13

12 Fossil Fuels - Oil

- **Description**
  - **natural gas**
    - gas
    - contains only a few different hydrocarbons
      - methane
      - smaller amounts of ethane, propane, butane

13 Fossil Fuels - Oil

- **Description**
  - **natural gas**
    - methane
      - used to
        - » heat residential, commercial buildings
        - » generate electricity in power plants
        - » variety of purposes in organic chemistry industry
      - distributed via
        - » pressurized pipelines
        - » refrigerated tankers

14 Fossil Fuels - Oil

- **Description**
  - **natural gas**
    - propane and butane
      - separated from natural gas
      - stored in pressurized tanks as liquid called **liquefied petroleum gas**

» used primarily as fuel for heating and cooking in rural areas

15 Fossil Fuels - Oil & Natural Gas

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16 Fossil Fuels - Oil

- **Formation**
  - oil & natural gas probably originated from microscopic aquatic organisms
    - accumulated after death on ocean or lake floors in areas called **depositional basins**
      - became buried by sediments
        - » over time, sediments became rock called **source material** or **source rock**

17 Fossil Fuels - Oil

- **Formation**
  - **source rock**
    - subjected to increased heat and pressure over great periods of time
      - initiated chemical transformation of organic material in sediment into oil and natural gas
        - » elevated pressure facilitates upward migration of oil and gas, which are relatively light, into a lower-pressure environment, known as **reservoir rock**

18 Fossil Fuels - Oil

- **Formation**
  - **reservoir rock**
    - coarser grained (than source rock) and relatively porous
      - has relatively high proportion of empty space (~30%) in which to store oil and gas
        - » sandstone and porous limestone are common reservoir rocks

19 Fossil Fuels - Oil

- **Formation**
  - **reservoir rock**
    - since oil and gas are light, they will continue to migrate upward until they are released into atmosphere
      - unless their upward mobility is blocked
        - » for this reason, oil and gas are not generally found in geologically old rocks

20 Fossil Fuels - Oil

- **Formation**
  - **oil and gas fields**
    - are formed where natural upward migration of gas and oil toward surface

- is interrupted or blocked by a **trap**
  - » the rock that helps form the trap is called **cap rock**

21 Fossil Fuels - Oil

- **Formation**
  - **trap**
    - **cap rock**
      - usually a fine-grained sedimentary rock composed of silt and clay sized particles
        - » such as shale

22 Fossil Fuels - Oil

- **Formation**
  - **trap**
    - requires favorable rock structure such as
      - anticline
        - » arch-shaped fold
      - fault
        - » fracture in rock along which displacement has occurred

23 Fossil Fuels - Oil

- **Formation**
  - **presence of rock cap and trap**
    - allows oil and natural gas to accumulate in the geologic environment
      - where they are then discovered and extracted

24 Fossil Fuels - Oil

- **Formation of oil**
  - oil pools
    - might form when shale is covered by
      - layer of sandstone, which is covered by
        - » layer of impermeable rock
    - trapped oil usually doesn't exist as a liquid mass
      - but rather as a concentration of oil within sandstone pores
        - » where it accumulates because water & gas pressure force it out of the shale

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26 Figure 10.11: Structural traps, Raven & Berg

27 Fossil Fuels - Oil & Natural Gas

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28 Fossil Fuels - Oil

- **Oil reserves**
  - ~26% in Saudia Arabia
  - ~38% in Iraq, Kuwait, Iran, United Arab Emirates (each have ~9%-10%)
  - ~14% in Latin America
  - ~7% in Africa
  - ~6% in former Soviet Union
  - ~4% in Asia
  - ~3% in US
  - ~2% in Europe

29 Fig. 10.6

30 Fossil Fuels - Oil

- **Oil reserves**
  - ~67% of world's oil reserves are located in 11 countries that make up OPEC(Organization of Petroleum Exporting Countries)
    - in 2000, OPEC produced 40% of world's oil

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32 Fossil Fuels - Oil

- **Oil reserves**
  - known, identified world oil reserves should last
    - ~ 53 years at current rate of usage
    - ~42 years if usage increases as projected by ~2% per year
  - unknown, unidentified world oil reserves should last
    - ~20-40 additional years
  - identified and unidentified world oil reserves are projected to be ~80% depleted within
    - 42-93 years depending on annual rate of use

33 Fossil Fuels - Oil

- **Oil reserves**
  - known, identified US oil reserves should last
    - ~15-24 years at current rate of usage
    - ~10-15 years if usage increases as projected by ~2% per year
  - unknown, unidentified US oil reserves should last
    - ~24 additional years
  - identified and unidentified US oil reserves are projected to be ~80% depleted within
    - 10-48 years depending on annual rate of use

34 Fossil Fuels - Oil

- **Oil reserves**
  - assuming we continue to use oil at current rate
    - Saudi Arabia (with largest known reserves)
      - could supply all the world's oil needs for only ~10 years

- estimated reserves under Alaska's North Slope (largest ever found in America)
  - would meet current
    - » world demand for 6 months
    - » US demand for 3 years

35 Fossil Fuels - Oil

- **Oil reserves**
  - estimated reserves in Alaska's Arctic National Wildlife Refuge
    - would meet global demands for only ~1-5 months
    - would meet US demands for ~7-24 months

36 Issues-Analysis p.221

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38 Fossil Fuels -
Oil & Natural Gas

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39 Fossil Fuels - Oil

- **Extraction**
  - production wells in an oil field recover oil through two methods
    - primary production
    - enhanced recovery

40 Fossil Fuels - Oil

- **Extraction**
  - primary production
    - involves simply pumping oil from wells
      - can only recover about 25% of petroleum

41 Fossil Fuels - Oil

- **Extraction**
  - enhanced recovery
    - involves injecting substances into the oil reservoir to push the oil toward the wells
      - substances include steam, water, carbon dioxide, nitrogen gas
    - can increase amount of oil recovered to about 60%

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44 Fossil Fuels - Oil & Natural Gas

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45 Fossil Fuels - Oil

- **Use Patterns**
  - by 1870, oil production in US was supplying 1% of nation's energy needs
  - for first 60 years of production
    - principle use of oil was to make kerosene (as a fuel for lamps)
    - the gasoline was discarded as a waste product

46 Fossil Fuels - Oil

- **Use Patterns**
  - during 20th century, percentage of world energy derived from oil increased from 2% to 32%
  - US uses ~30%of crude oil extracted each year
    - 68% of that is used for transportation
  - oil has remained dominant energy source for past 40 years

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48 Fossil Fuels - Oil & Natural Gas

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49 Fossil Fuels - Oil

- **Use Issues**
  - two sets of environmental problems resulting from
    - combustion

- production and transport

50 Fossil Fuels - Oil

- **Use Issues**
  - combustion issues
    - CO_2 emissions
      - ~20lbs (9kg) of CO_2 released for every gallon of gasoline burned in an automobile

51 Fossil Fuels - Oil

- **Use Issues**
  - combustion issues
    - acid deposition
      - oil combustion produces very small amounts of sulfur oxides
      - oil combustion does produce nitrogen oxides
        - » mainly through gasoline combustion in automobiles
        - » responsible for ~1/2 of nitrogen oxides in atmosphere

52 Fossil Fuels - Oil

- **Use Issues**
  - production and transport issues
    - land
      - use of land
        - » to construct well pads, pipelines, storage tanks, production facilities, associated roads
      - subsidence of land
        - » as oil is withdrawn

53 Fossil Fuels - Oil

- **Use Issues**
  - production and transport issues
    - ecosystems
      - loss, disruption or damage to ecosystems
        - » this is a concern regarding development of petroleum resources in ANWR

54 Fossil Fuels - Oil

- **Use Issues**
  - production and transport issues
    - pollution of surface and ground water
      - leaks from pipes of tanks containing oil or oil-field chemicals
      - salty water that is brought to surface in large volumes with oil and must be disposed of
        - » in potentially leaky evaporation pits or disposal wells

55 Fossil Fuels - Oil

- **Use Issues**
  - production and transport issues
    - marine environment
      - oil seepage into sea

» from normal operations of leaks, spills, pipe ruptures
– release of drilling muds into sea
» can contain toxic heavy metals
– aesthetic degradation from presence of offshore drilling platforms

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58 Figure 10.15: Arctic National Wildlife Refuge, Raven & Berg

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63 Fossil Fuels - Natural Gas

- **Natural gas**
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64 Fossil Fuels - Natural Gas

- **Natural gas**
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  - formation
  - reserves
  - extraction
  - use patterns
  - use issues

65 Fossil Fuels - Natural Gas

- Natural gas
  - description
    - in its underground gaseous state, it's a mixture of
      - ~50-90% by volume methane (CH_4)
        » simplest hydrocarbon
      - smaller amounts of heavier gaseous hydrocarbons
        » ethane, propane, butane
      - small amounts of hydrogen sulfide (H_2S)
        » highly toxic by-product of naturally occurring sulfur in the earth

66 Fossil Fuels - Natural Gas

- Natural gas

- description
  - conventional natural gas
  - unconventional natural gas

67 Fossil Fuels - Natural Gas

- Natural gas
  - description
    - conventional natural gas
      - occurs about most reservoirs of crude oil

68 Fossil Fuels - Natural Gas

- Natural gas
  - description
    - unconventional natural gas
      - found by itself in other underground sources
      - an example is methane hydrate
        - » composed of small bubbles of natural gas trapped in ice crystals deep under arctic permafrost and beneath ocean sediments
      - current technologies do not provide economical means of extracting such sources

69 Fossil Fuels - Natural Gas

- **Natural gas**
  - description
  - formation
  - reserves
  - extraction
  - use patterns
  - use issues

70 Fossil Fuels - Natural Gas

- Natural gas
  - **formation**
    - natural gas (& oil) probably originated from microscopic aquatic organisms
      - accumulated after death on ocean or lake floors in areas called **depositional basins**
        - » became buried by sediments
        - » over time, sediments became rock called **source material** or **source rock**

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72 Fossil Fuels - Natural Gas

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  - formation
  - reserves
  - extraction
  - use patterns
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73 Fossil Fuels - Natural Gas

- Natural gas
  - **reserves**
    - world reserves
      - ~42% are located in Russia and Kazakhstan
      - ~37% are located in7 countries
        - » Iran (15%)
        - » Qatar (~5%)
        - » Saudi Arabia (~4%)
        - » Algeria (~4%)
        - » United States (~3%)
        - » Venezuela (~3%)

74 Fig. 10.7

75 Fossil Fuels - Natural Gas

- Natural gas
  - **reserves**
    - world reserves, known and unknown, estimated to last
      - conventional natural gas
        - » ~125 years at current consumption rates
        - » ~50 years if usage rates rise 2% per year
      - unconventional natural gas
        - » ~200 years at current consumption rates
        - » ~80 years is usage rates rise 2% per year

76 Fossil Fuels - Natural Gas

- Natural gas
  - **reserves**
    - world reserves, known and unknown, estimated to last
      - conventional and unconventional natural gas
        - » ~205-325 years at current consumption rates
        - » ~50-130 years if usage rates rise 2% per year

77 Fossil Fuels - Natural Gas

- Natural gas
  - **reserves**
    - US reserves
      - ~3% of world reserves located in US
        - » in roughly same areas as US crude oil reserves
      - estimated to last ~30 years at current consumption rates

78 Fossil Fuels - Natural Gas

- **Natural gas**
  - description
  - formation
  - reserves
  - extraction
  - use patterns

- use issues

79 Fossil Fuels - Natural Gas

- Natural gas
  - **extraction**
    - drilling wells on land or beneath the sea floor
    - when a natural gas field is tapped
      - propane and butane are liquefied and removed as **liquefied petroleum gas (LPG)**
        - stored in pressurized tanks, mostly for use in areas not served by natural gas pipelines

80 Fossil Fuels - Natural Gas

- Natural gas
  - **extraction**
    - when a natural gas field is tapped
      - propane and butane are liquefied and removed
      - remainder of gas (mostly methane) is
        - dried to remove water vapor
        - cleaned of poisonous hydrogen sulfide and other impurities
        - pumped into pressurized pipelines for distribution

81 Fossil Fuels - Natural Gas

- Natural gas
  - **extraction**
    - at very low temperatures (-184°C) natural gas can be converted to **liquefied natural gas (LNG)**
      - can then be shipped to other countries in refrigerated tanker ships
        - but its highly explosive
    - its not uncommon for natural gas found with oil to be burned off as waste
      - due to low price of natural gas

82 Fossil Fuels - Natural Gas

- **Natural gas**
  - description
  - formation
  - reserves
  - extraction
  - use patterns
  - use issues

83 Fossil Fuels - Natural Gas

- Natural gas
  - **use patterns**
    - world wide and US
      - ~23% of world's commercial energy supplied by natural gas
        - use increased from ~1% to ~23% during 20th century
      - most rapidly growing energy source because its
        - clean burning , convenient, cheap

84 Fossil Fuels - Natural Gas

- Natural gas
  - **use patterns**
    - uses
      - primarily for heat energy
      - in manufacture of petrochemicals and fertilizer
    - use increasing in three main areas
      - generation of electricity
      - transportation
      - commercial cooling

85 Fossil Fuels - Natural Gas

- Natural gas
  - **use patterns**
    - generation of electricity via co-generation
      - uses natural gas to produce both electricity and steam
        - heat of the exhaust gases provides energy to make steam for water and space heating

86 Fossil Fuels - Natural Gas

- Natural gas
  - **use patterns**
    - transportation
      - natural gas can be used as a fuel for
        - trucks, buses, automobiles
      - emitting ~90% fewer hydrocarbons, carbon monoxide, toxic emissions
      - in 1999, there were ~80,000 natural gas powered vehicles in US
        - most of which are fleet vehicles
        - LA has largest fleet of natural gas powered transit buses in North America

87 Fossil Fuels - Natural Gas

- Natural gas
  - **use patterns**
    - commercial cooling
      - can be used efficiently for residential and commercial air cooling systems
        - such as desiccant-based (air-drying) cooling systems

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89 Fossil Fuels - Natural Gas

- **Natural gas**
  - description
  - formation
  - reserves
  - extraction
  - use patterns
  - use issues

90 Fossil Fuels - Natural Gas

- Natural gas
  - **use issues**

- is least disruptive of the 3 fossil fuels to the environment
  - clean burning
    - products of combustion are carbon dioxide and water
    - even though carbon dioxide is a greenhouse gas, combustion of natural gas produces less CO_2 emissions than other fossil fuels
    - contains almost no sulfur

91 Fossil Fuels - Natural Gas

- Natural gas
  - **use issues**
    - difficult to ship or store in large quantities
      - some gas fields are too far from consumers to make pipelines practical
        - costs roughly 4 times as much to transport through pipelines than crude oil
      - environmental damage is associated with the construction of pipelines necessary for transport

92 Fossil Fuels - Natural Gas

- **Use Issues**
  - production and transport issues
    - land
      - use of land
        - » to construct well pads, pipelines, storage tanks, production facilities, associated roads
      - subsidence of land
        - » as gas (oil) is withdrawn

93 Fossil Fuels - Natural Gas

- **Use Issues**
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    - ecosystems
      - loss, disruption or damage to ecosystems
        - » this is a concern regarding development of petroleum resources in ANWR

94 Fossil Fuels - Natural Gas

- **Use Issues**
  - production and transport issues
    - pollution of surface and ground water
      - as discussed for oil

95 Fossil Fuels - Oil

- **Use Issues**
  - production and transport issues
    - marine environment
      - as discussed for oil

96 Figure 10.14c: Alaskan oil spill, 1989, Raven & Berg

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98 The End