Ann Heisenfelt/EPA/Photoshot

11

# Fossil Fuels

# Overview of Chapter 11

- Fossil Fuels
- Coal
  - Coal Reserves and Mining
  - Problems and Effects of Burning Coal
  - Cleaner coal?
- Oil and Natural Gas
  - Exploration for Oil and Natural Gas
  - Oil and Natural Gas reserves
  - Environmental Impacts of Oil and Natural Gas
- Synfuels and other Fossil-Fuel Resources

# Deep Water Horizon Oil Spill

- April 2010 explosion, British Petroleum
- 4 million barrels of crude oil into Gulf of Mexico
- Killed 11 oil rig workers
- Costs and benefits of using fossil fuels as energy source

Ann Heisenfelt/EPA/Photoshot

# Fossil Fuels

- Fossil Fuels- Combustible deposits in the Earth's crust
  - Composed of the remnants (fossils) of prehistoric organisms that existed millions of years ago
  - Includes coal, oil (petroleum) and natural gas
- Supply over 80% of energy used in North America
- Non-renewable resource
  - Fossil fuels are created too slowly to replace the reserves we use

# How Are Fossil Fuels Formed?

- ~300 million years ago
  - Climate was mild
  - Vast swamps covered much of the land
  - Dead plant material decayed slowly in the swamp environment

# How Are Fossil Fuels Formed

- Coal
  - Heat, pressure, and time turned the plant material into carbon-rich rock (coal)
- Oil
  - Sediment deposited over microscopic plants
  - Heat, pressure, and time turned them into hydrocarbons (oil)
- Natural Gas
  - Formed the same way as oil, but at temperatures higher than 100 ° C

# Fossil Fuels, C cycle, climate

- Burning releases C as $CO_2$
  - C from plants that fixed it (via photosynthesis) over 300 mya
- Increasing the export of $CO_2$ to atmosphere, but not increasing fixation
- Natural cycles change slowly
- Burning is quick change – out of balance

# Coal

- Most, if not all, coal deposits have been identified
- Occurs in different grades- based on variations in heat and pressure during burial
  - Energy density – energy per volume

**Table 11.1** A Comparison of Different Kinds of Coal

| *Type of Coal* | *Color* | *Water Content (%)* | *Relative Sulfur Content* | *Carbon Content (%)* | *Average Heat Value (BTU/pound)* | *2012 Cost at Mine for 2000 lb of Coal ($)* |
|---|---|---|---|---|---|---|
| Lignite | Dark brown | 45 | Medium | 30 | 6,000 | 21.53 |
| Subbituminous coal | Dull black | 20–30 | Low | 40 | 9,000 | 13.71 |
| Bituminous coal | Black | 5–15 | High | 50–70 | 13,000 | 54.25 |
| Anthracite | Black | 4 | Low | 90 | 14,000 | 60.35 |

*Sources:* EIA, U.S. Department of Energy, and USGS.

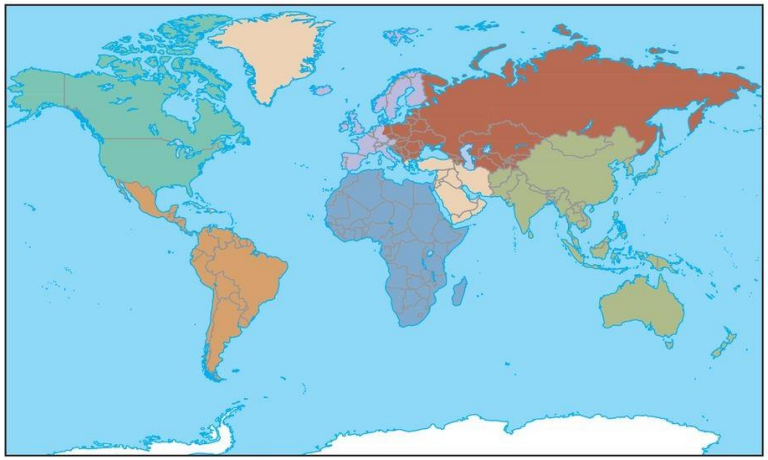
# Coal

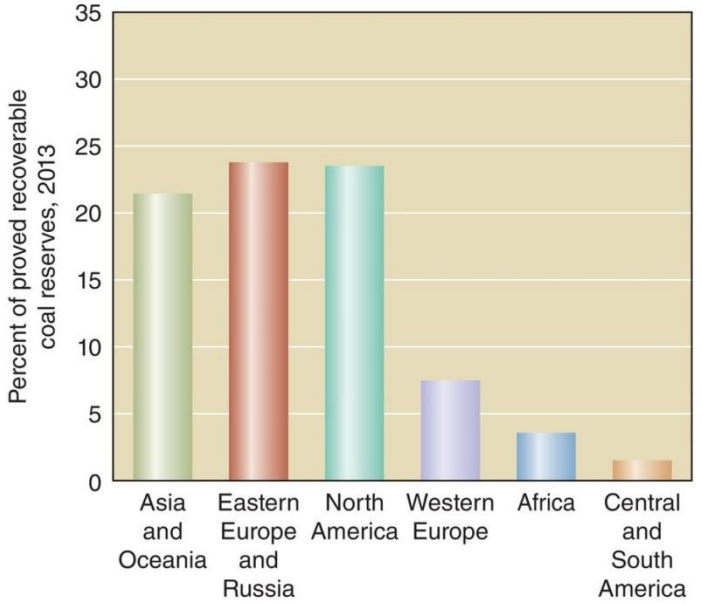
- Coal is highly flammable
- Dangerous to mine
- Burning and mining releases pollutants
- 90,000 miner deaths during 20th century
  - Increased risk of lung disease and cancer
  - 2,000 die each year from diseases

Ellerингmann/Laif/Aurora Photos

# Coal

- US has 25% of world's coal supplies
- Known coal deposits could last 200 years
  - At present rate of consumption





# Coal Mining

- Coal usually found in seams that vary from 1” to 100’ in thickness
- Surface mining (below)
  - Chosen if coal is within 30m of surface
  - Ex: Strip mining
- Subsurface mining
  - Extraction of mineral and energy resources from deep underground deposits

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# Environmental Impacts of Mining Coal

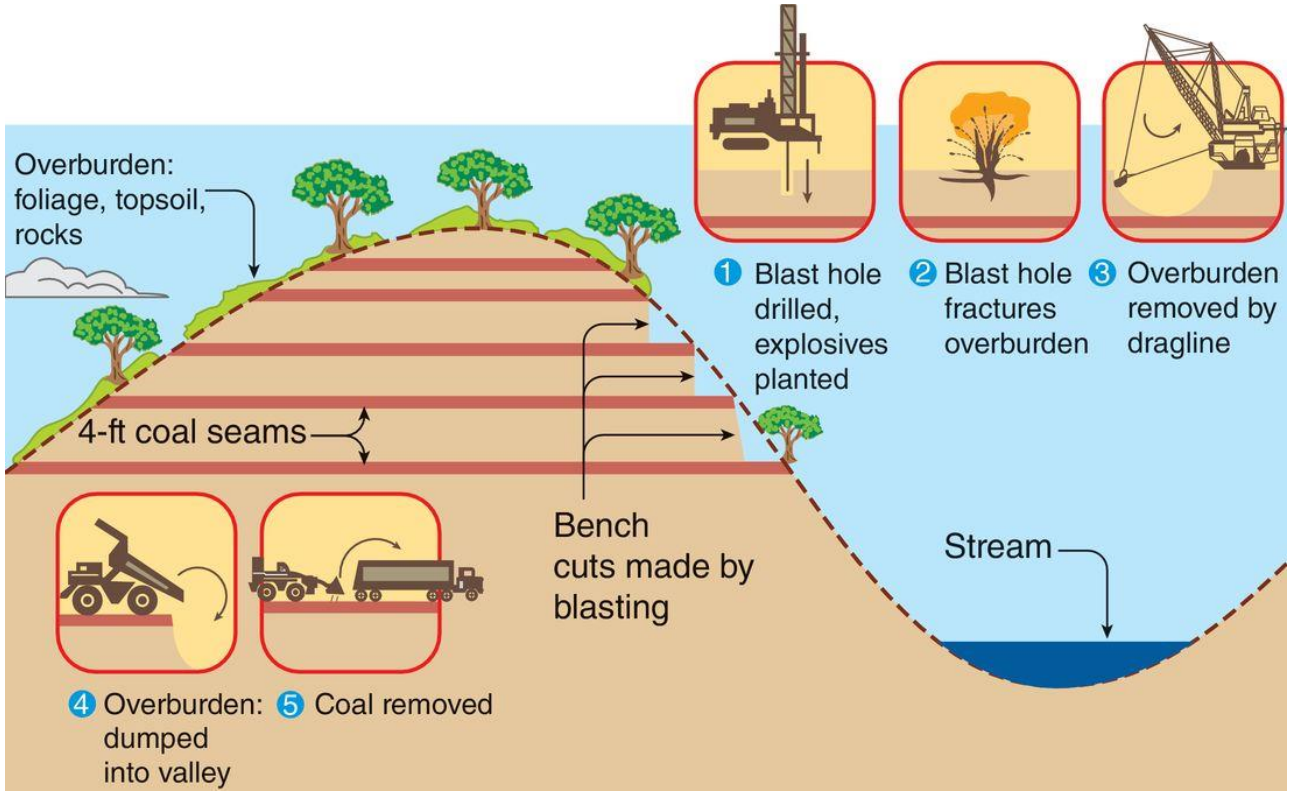
- Surface Mining Control and Reclamation Act (1977)
  - Requires filling (reclaiming) of surface mines after mining
  - Reduces Acid Mine Drainage
  - Requires permits and inspections of active coal mining sights
  - Prohibits coal mining in sensitive areas
- Land with mines abandoned prior to 1977 are slowly being restored

# Environmental Impacts of Mining Coal

- Acid mine drainage
  - Pollution caused when sulfuric acid and dissolved materials, such as lead, arsenic, and cadmium was from coal and metal mines into nearby lakes and streams
  - Rainwater seeps inside exposed mine wastes
  - Contaminates soils

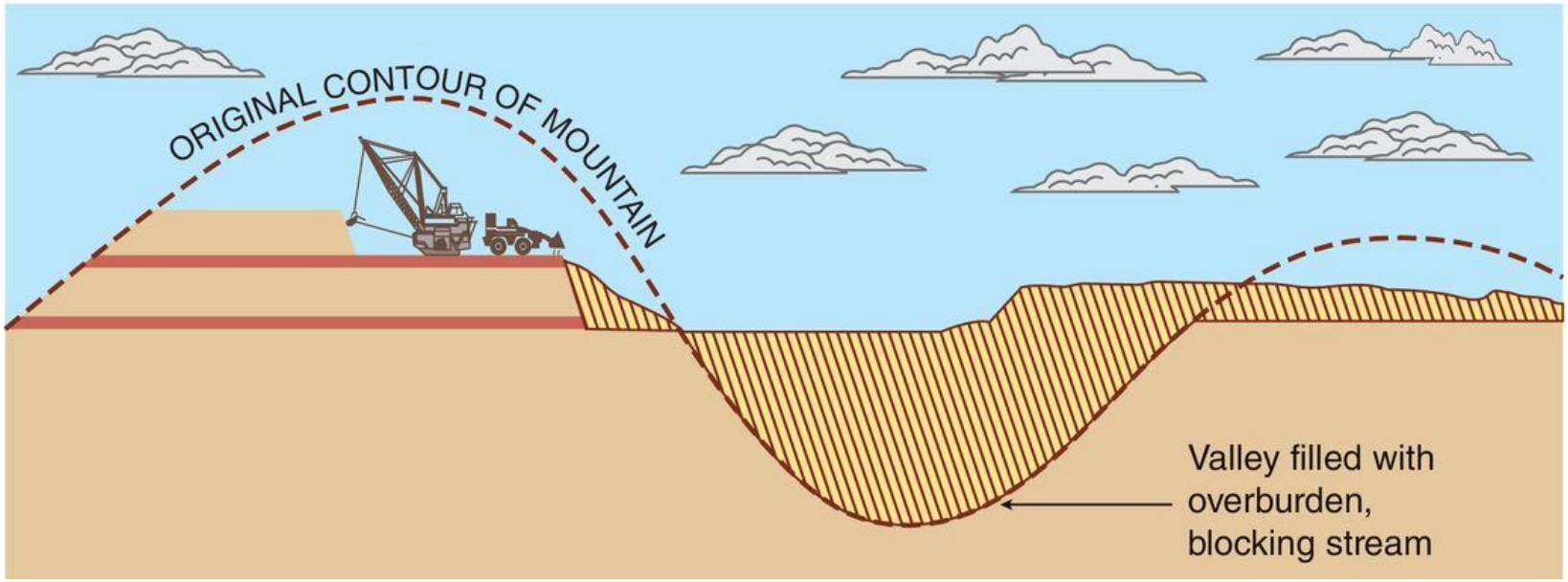
# Mountain Top Removal

- Topography before mining



# Mountain Top Removal

- Topography after mining



# Environmental Impacts of Burning Coal

- Releases large quantities of $CO_2$ into atmosphere
  - Greenhouse gas
- Releases other pollutants into atmosphere
  - Mercury
  - Sulfur oxides
  - Nitrogen oxides
- Can cause acid precipitation
  - Rainwater ~5.6 pH, acid rain ~2.1 (lemon juice)

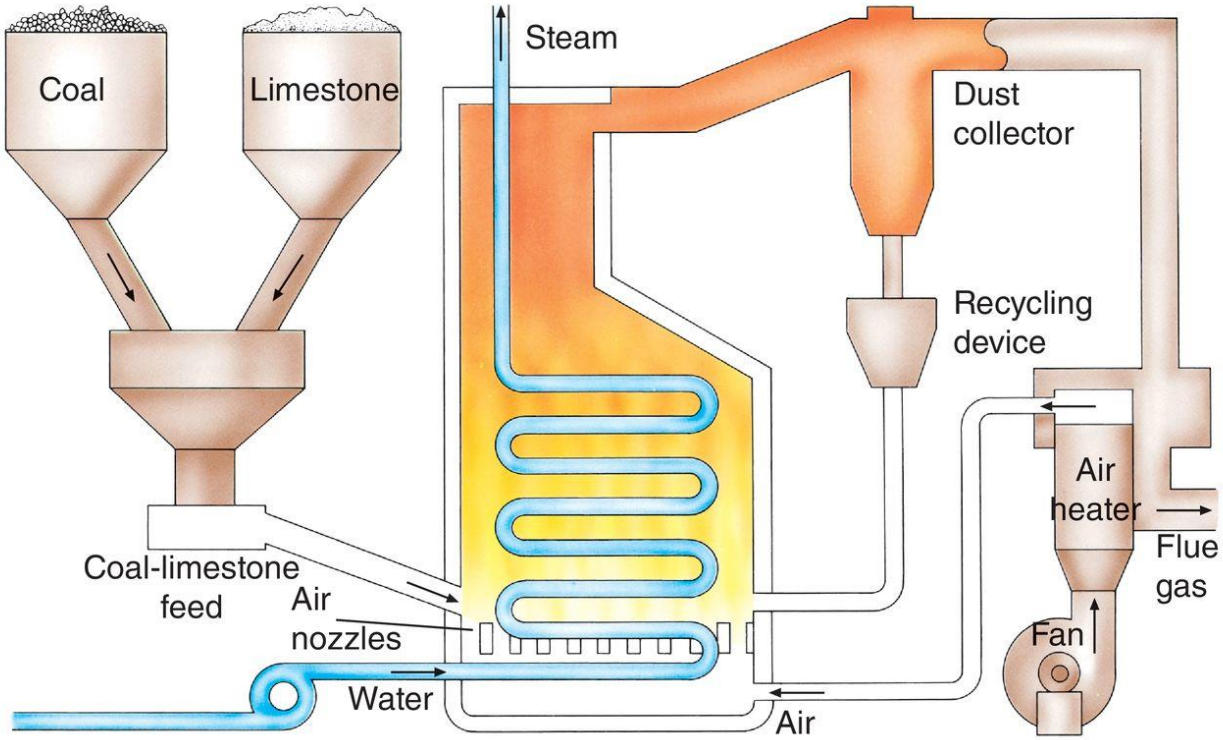
Frederica Georgia / Science Source

# Making Coal Cleaner

- Scrubbers - desulfurization systems
  - Remove 98–99% of sulfur from power plant's exhaust
  - Expensive
  - Sludge byproduct must be disposed of
- Sludge and fly ash are part of resource recovery
  - Marketable product from wastes
- Nationwide cap of $SO_2$ and nitrogen oxide emissions

# Making Coal Cleaner

- Fluidized Bed Combustion
  - Crushed coal mixed with limestone to neutralize acidic sulfur compounds produced during combustion process

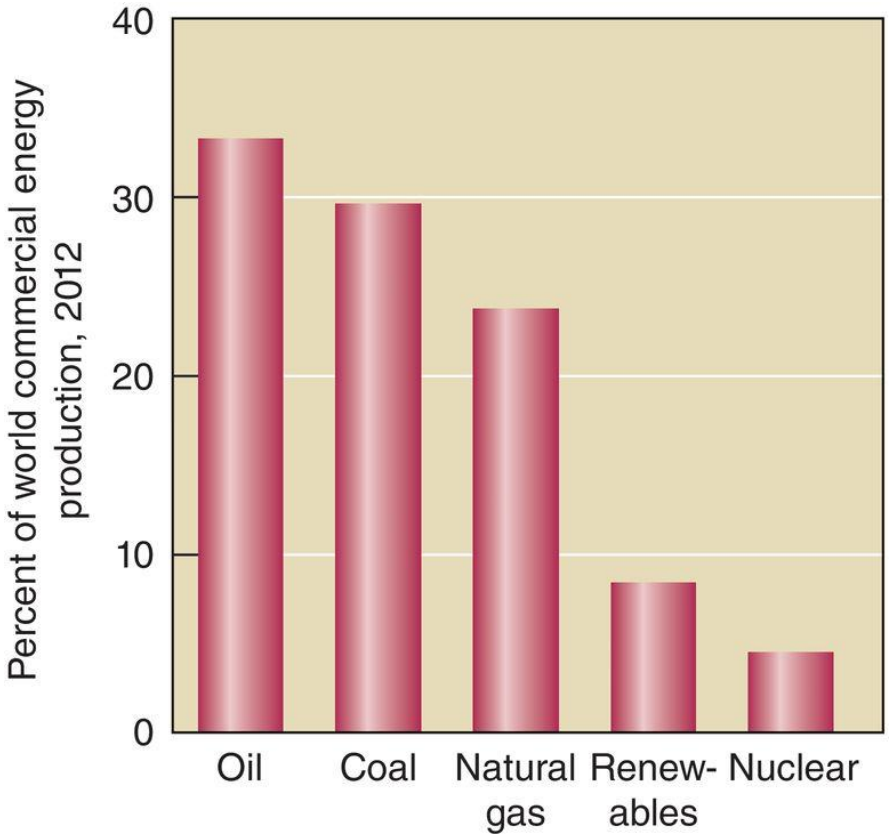


# Regulation of $CO_2$ emissions

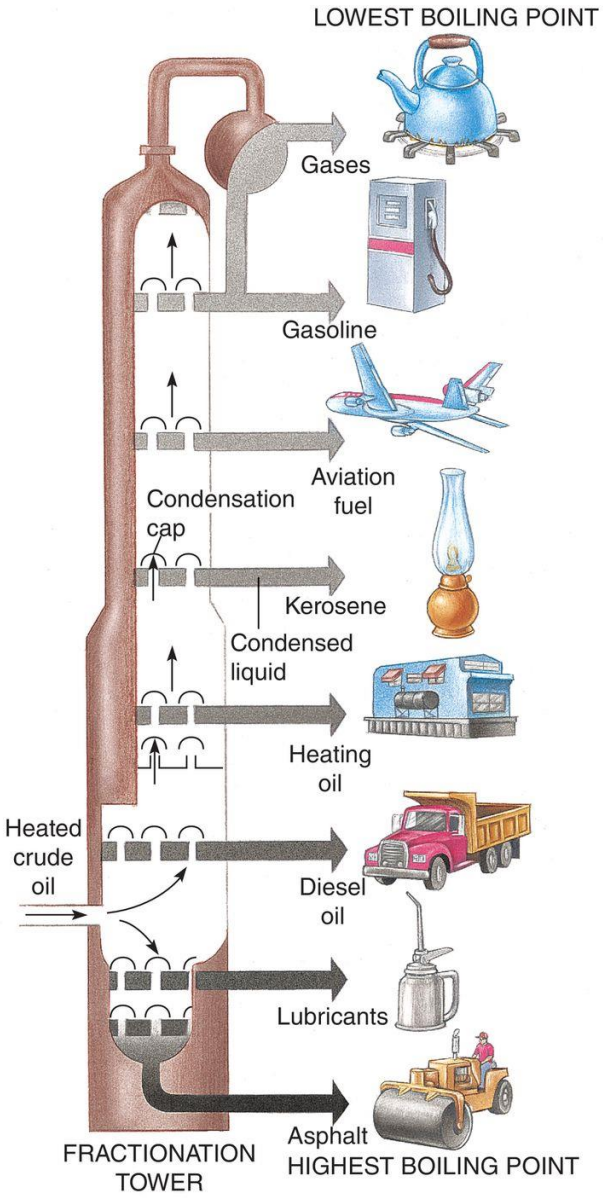
- EPA can regulate CO2 emissions
  - 2014 U.S. Supreme Court decision
  - Controversy because $CO_2$ is a natural product of respiration and organisms
- Push for carbon capture and storage (CCS)
  - New power plants store $CO_2$ when released
  - Initially expensive to install technology
  - Worry about where and how to ‘store’ the captured $CO_2$

# Oil and Natural Gas

- Important after 1930s
  - More versatile, easier to transport, cleaner to burn
- Oil and gas provide ~62% of U.S. energy
  - They provide ~58% of World's energy



# Petroleum Refining



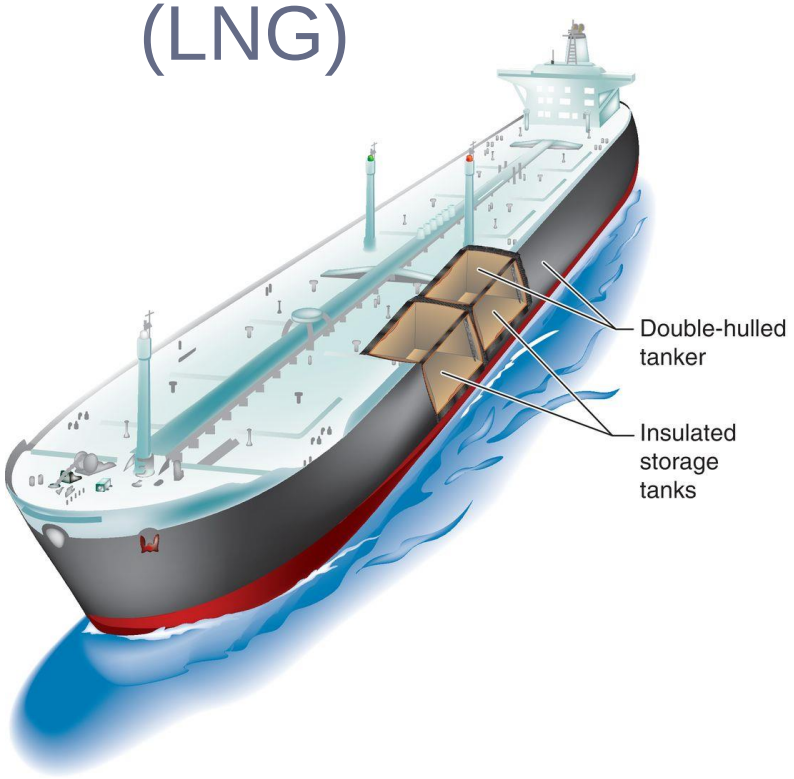

- Numerous hydrocarbons present in crude oil (petroleum) are separated
  - Based on boiling point
- Natural gas contains far fewer hydrocarbons than crude oil
  - Methane, ethane, propane and butane

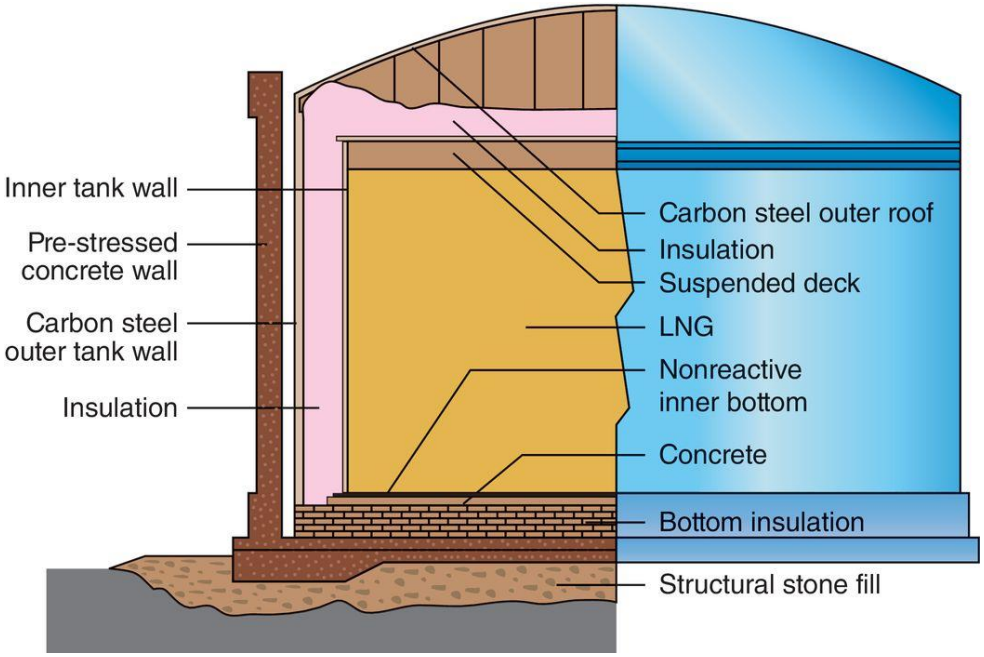
# Natural Gas

- Contains methane, propane and butane
  - Propane and butane are used for cooking and heating in rural areas
  - Methane used for heat and to generate electricity in power plants
- Natural gas as vehicle fuel
  - Emit 93% fewer hydrocarbons, 90% less carbon monoxide and 90% fewer toxic emissions than gasoline

# Natural Gas

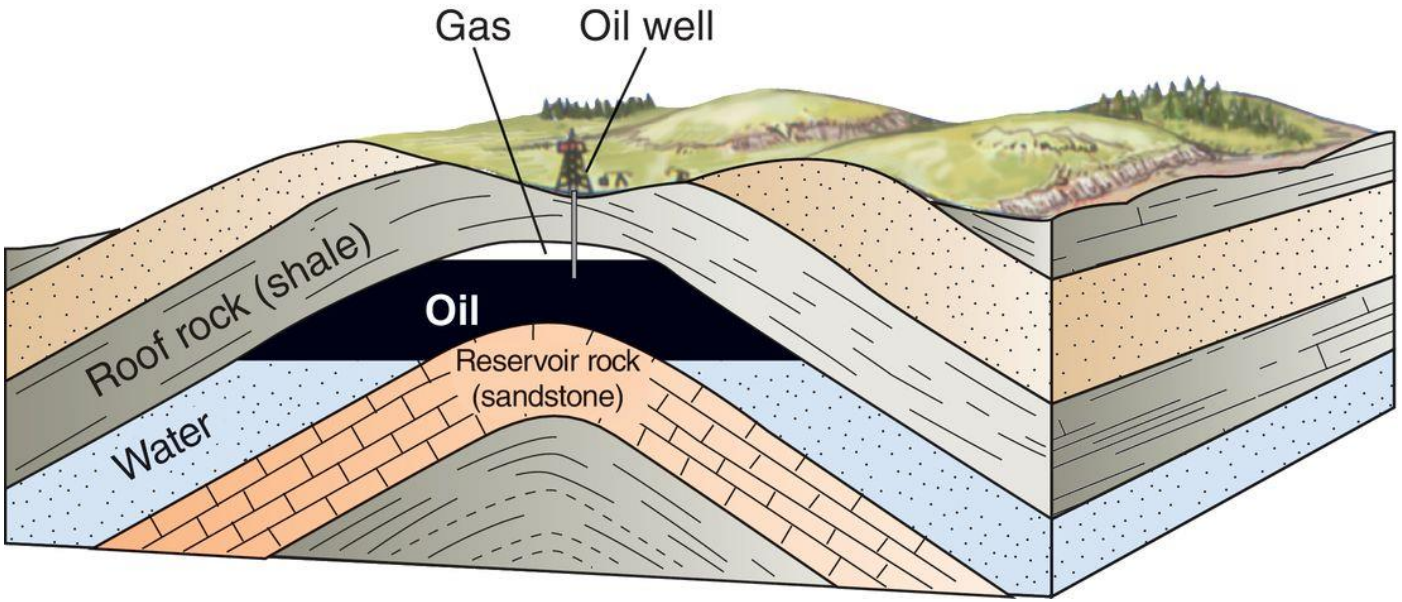
- Gas first compressed into liquefied natural gas (LNG)



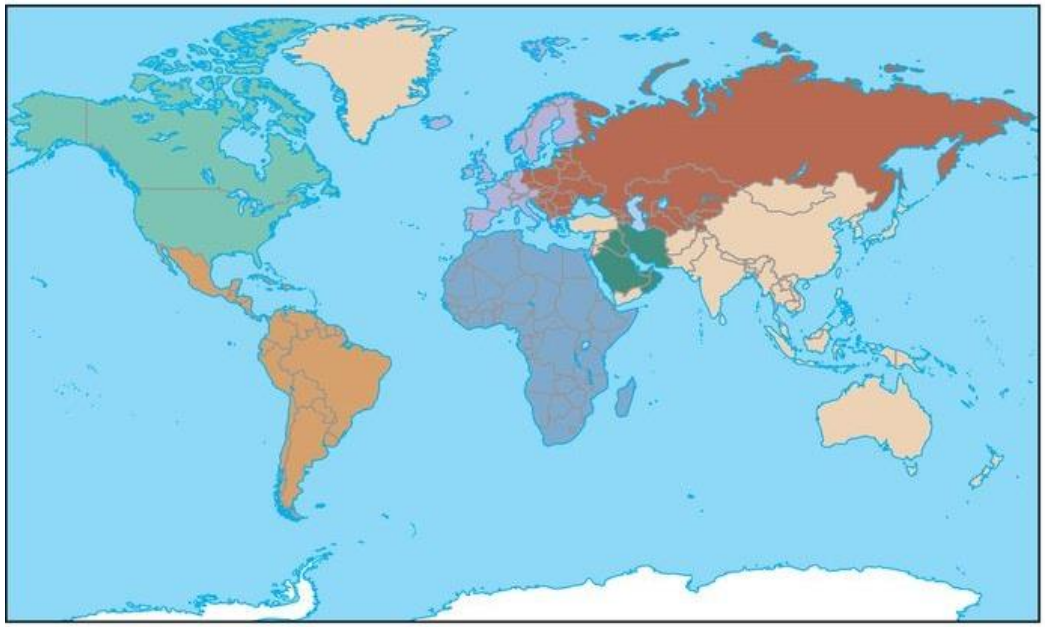
# Oil and Natural Gas Exploration

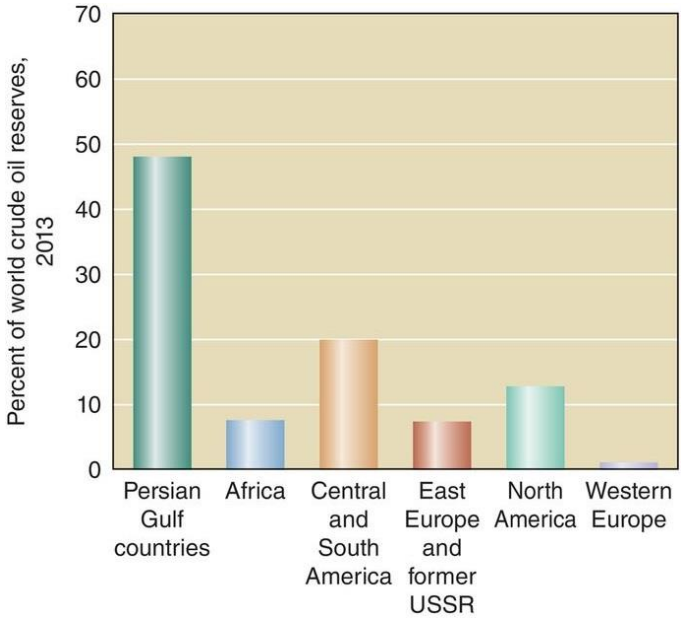
- Oil and natural gas migrate upwards until they hit impermeable rock
- Usually located in structural traps
  - Underground geologic structures that tend to trap any oil or natural gas if present



# Oil Reserves

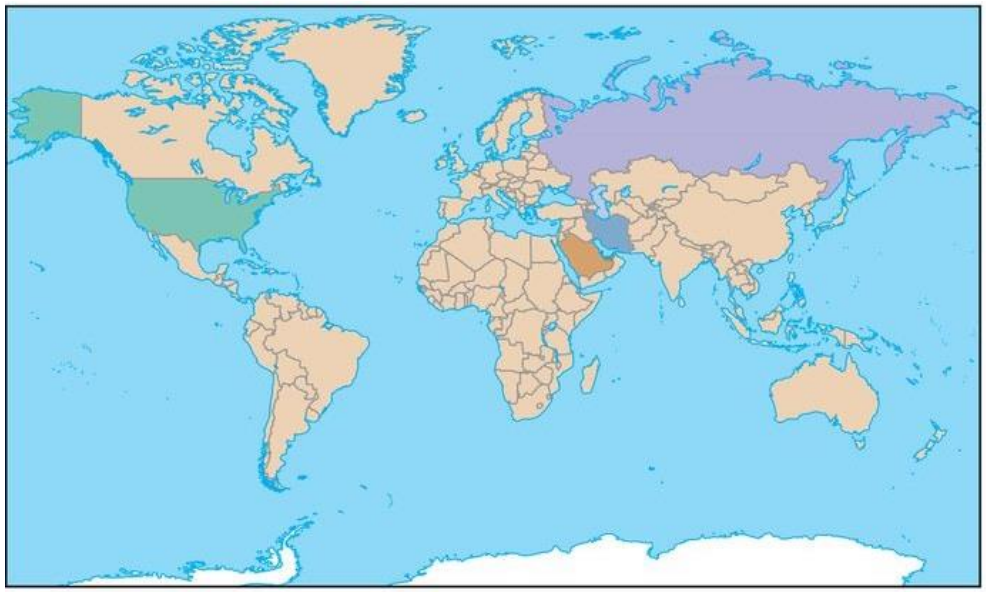
- Uneven distribution globally
- More than half is located in the Middle East

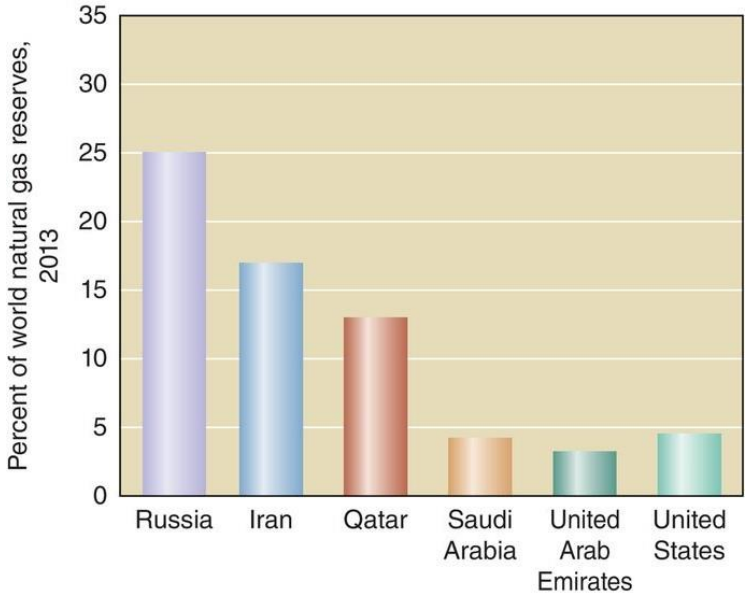




# Natural Gas Reserves

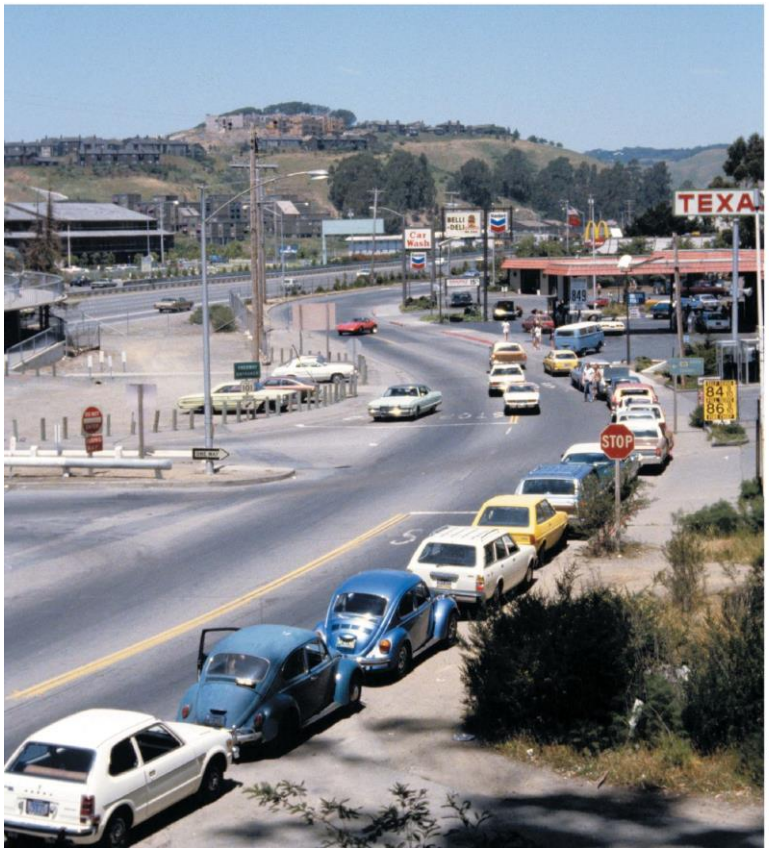
- Uneven distribution globally
- More than half is located in Russia and Iran
  - European energy concerns with Russian take over of Crimea (another country) in 2014





# How long will Supplies Last?

- May have already reached peak oil
- Depends on:
  - Locating more deposits
  - Future extraction technologies
  - Changes in global consumption rates
- Experts indicate there may be shortages in 21st century.



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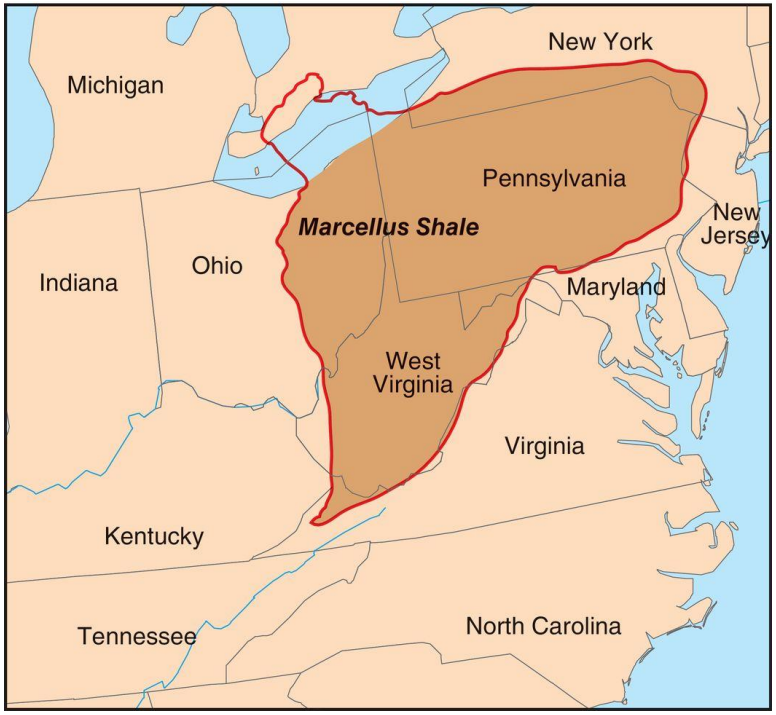
# Marcellus Shale

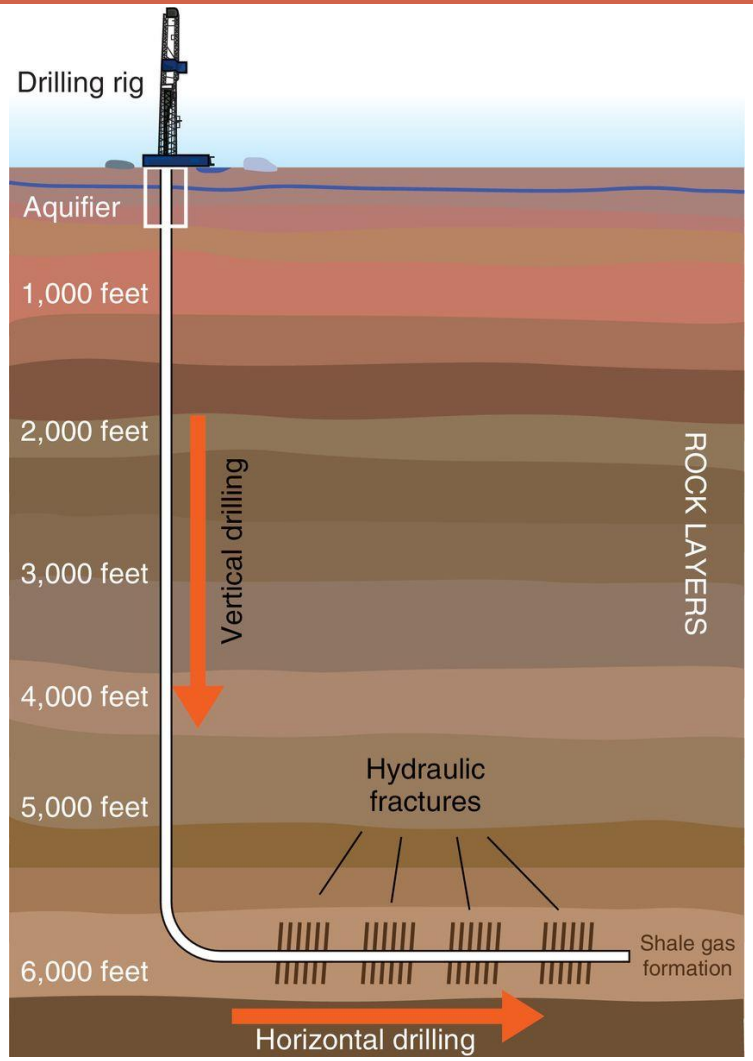
- Huge store of natural gas in U.S.
- Beneath >24 states
- Shale gas more difficult to extract than in sandstone
  - Requires fracturing of rock via hydraulic fracturing



# Hydraulic Fracturing

- Water and chemicals pushed at high pressure to crack rock (release trapped gas)
- Produces large amounts of waste water
  - Push to recycle water
- Very controversial
  - Regulations slow
  - Environmental impacts variable and data lacking
- Waste water stored deep underground
  - Can cause earthquakes if injected incorrectly

# Hydraulic Fracturing



# Environmental Impacts of Oil and Natural Gas

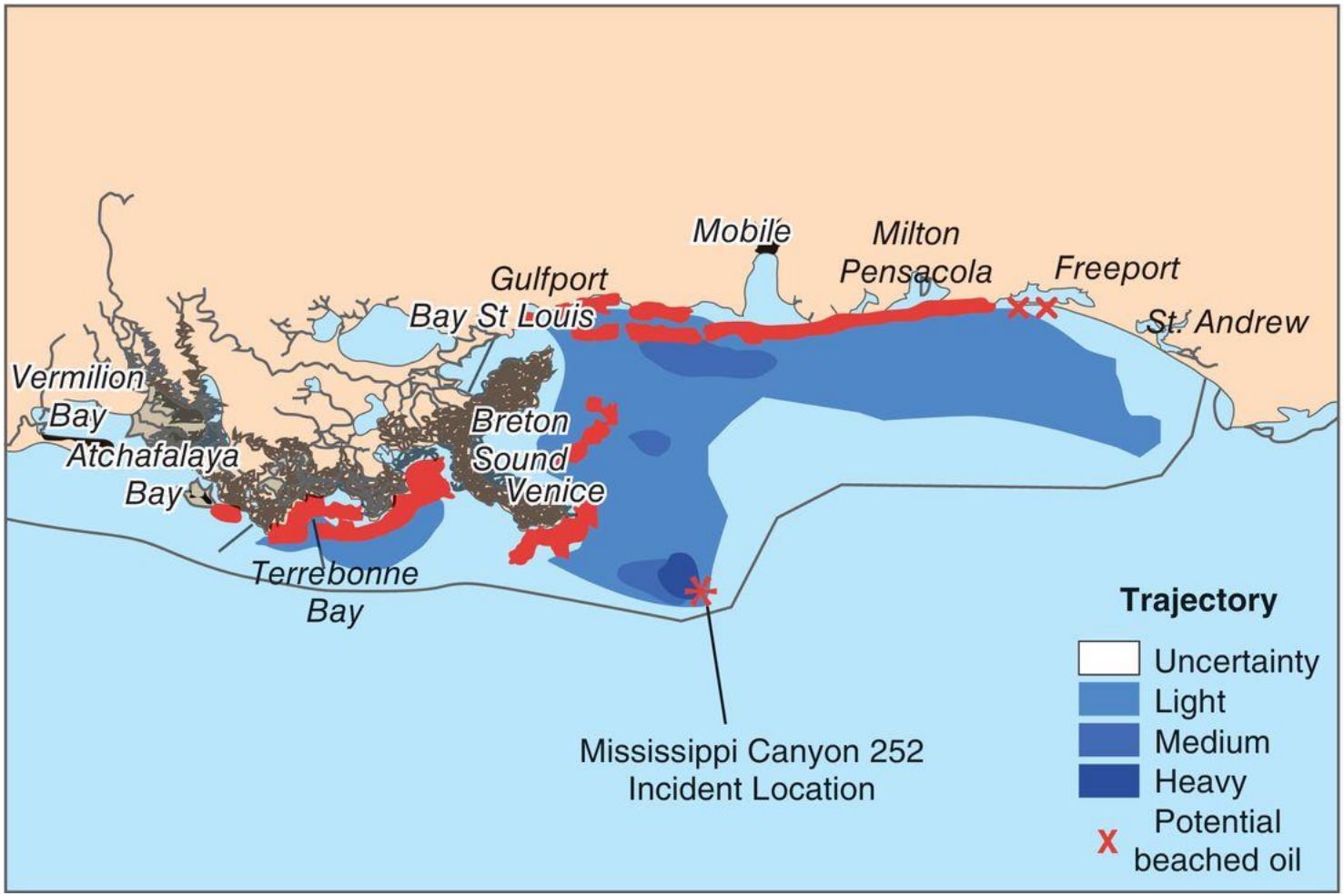
- Combustion
  - Increase carbon dioxide and pollutant emissions
  - Natural gas is far cleaner burning than oil
- Production
  - Disturbance to land and habitat
- Transport
  - Spills- especially in aquatic systems
  - Ex: Alaskan Oil Spill (1989)

# Deepwater Horizon Oil Spill

- April 22, 2010 - Deepwater Horizon, a drilling platform in the Gulf of Mexico, exploded
  - Flow of oil from the oil well was finally stopped in mid-July 2010
  - 5 million barrels of oil flowed into ocean
  - Most rose to surface where it spread
    - Nearly 75,000km$^2$ of ocean were covered

Carolyn Cole/Photoshot)

# Deepwater Horizon Spill



# Deepwater Horizon Spill

- British Petroleum still in court about reparations (January 2015)
  - Payments to those affected by oil spill

# 1989 Alaskan Oil Spill

- Exxon Valdez hit a reef and spilled 260,000 barrels of crude oil into sound
  - Captain was drunk
- Largest oil spill in U.S. history
- Led to Oil Pollution Act of 1990

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# 1989 Alaskan Oil Spill

CHRIS WILKINS/AFP/Getty Images

# Case in Point - Arctic National Wildlife Refuge (ANWR)

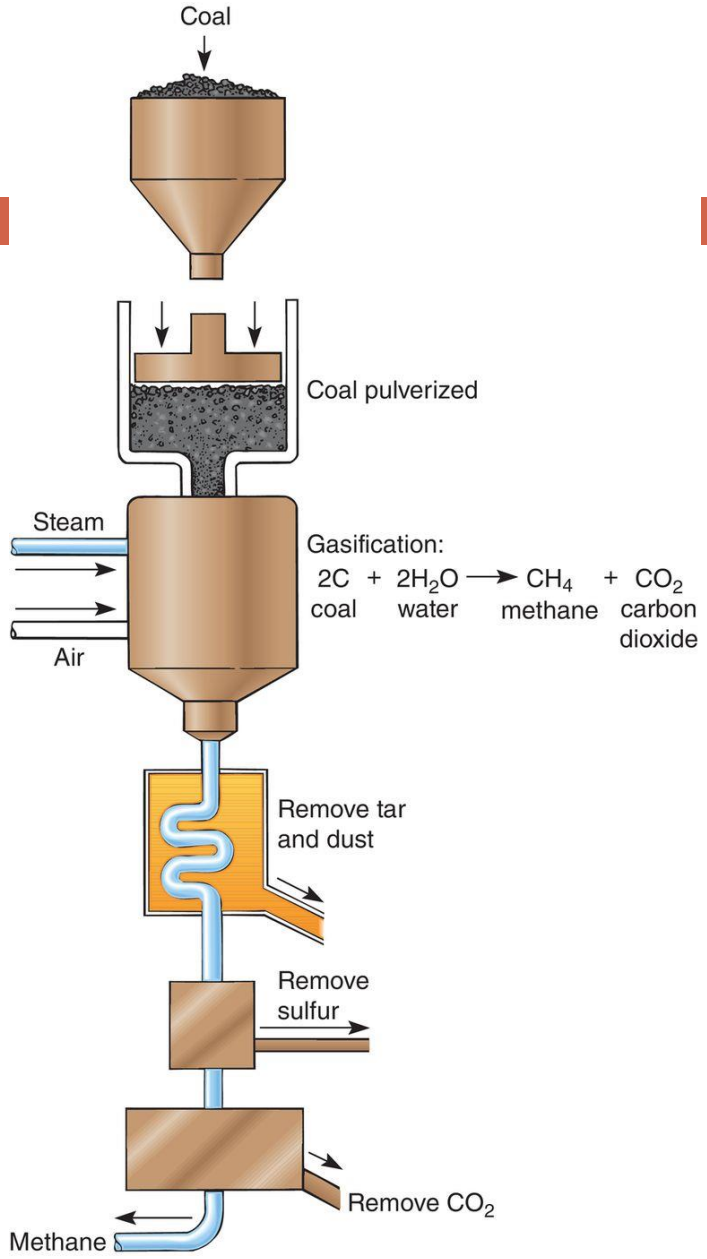
- Controversy to open ANWR more
- Many stakeholders
  - Alaskan natives
  - Energy corporations
  - Politicians
  - Citizens – gas prices
  - Domestic energy reliance

# Synfuels

- A liquid or gaseous fuel that is synthesized from coal and other naturally occurring sources
  - A substitute for oil or natural gas
- Tar sands (bitumen)
  - Bitumen difficult to remove- must heat it underground with steam to make it flow
  - Refined like crude oil, uses more energy
  - Keystone pipeline debate - will run through U.S. from tar sands in Canada
- Oil shales (kerogen)
  - Crushed and heated to yield oil

# Synfuels

- Gas hydrates
  - Ice encrusted natural gas deep under permafrost in arctic
- Liquefied coal
  - Liquid produced from coal
  - Expensive to produce
- Coal gas (right)
  - Burns as cleanly as natural gas



# Environmental Impact of Synfuels

- Many of same undesirable effects as fossil fuels
  - Contribute to global warming
  - Contribute to air pollution
- Coal gas requires large amount of water to extract
  - Mostly located in areas very short on water
- Recovering fuels in tar sands and oil shales would require extensive surface mining
  - Very environmentally dirty and more $CO_2$ during production than other fuels