6.2 FOSSIL FUELS

College Board Topics 6.3 and 6.4

Related Reading Chapter 19

Essential Knowledge and Learning Objectives

LEARNING OBJECTIVE

ENG-3.C

Identify types of fuels and their uses.

SUGGESTED SKILL

Concept Explanation

1.A

Describe environmental concepts and processes.

ESSENTIAL KNOWLEDGE

ENG-3.C.1

Wood is commonly used as fuel in the forms of firewood and charcoal. It is often used in developing countries because it is easily accessible.

ENG-3.C.2

Peat is partially decomposed organic material that can be burned for fuel.

ENG-3.C.3

Three types of coal used for fuel are lignite, bituminous, and anthracite. Heat, pressure, and depth of burial contribute to the development of various coal types and their qualities.

ENG-3.C.4

Natural gas, the cleanest of the fossil fuels, is mostly methane.

ENG-3.C.5

Crude oil can be recovered from tar sands, which are a combination of clay, sand, water, and bitumen.

ENG-3.C.6

Fossil fuels can be made into specific fuel types for specialized uses (e.g., in motor vehicles).

ENG-3.C.7

Cogeneration occurs when a fuel source is used to generate both useful heat and electricity.

LEARNING OBJECTIVE

ENG-3.D

Identify where natural energy resources occur.

SUGGESTED SKILL

Visual Representations

2.B

Explain relationships between different characteristics of environmental concepts, processes, or models represented visually:

- In theoretical contexts
- In applied contexts

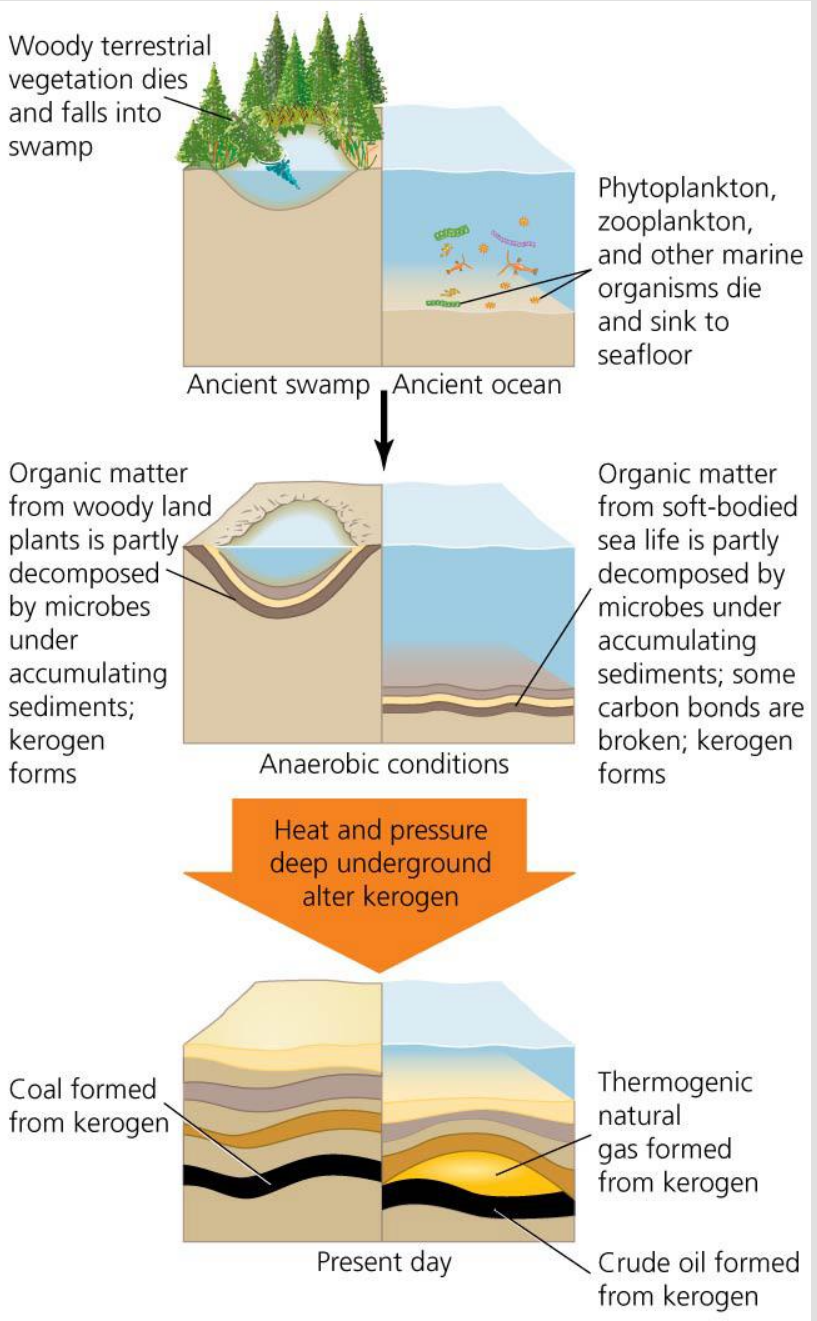
ESSENTIAL KNOWLEDGE

ENG-3.D.1

The global distribution of natural energy resources, such as ores, coal, crude oil, and gas, is not uniform and depends on regions' geologic history.

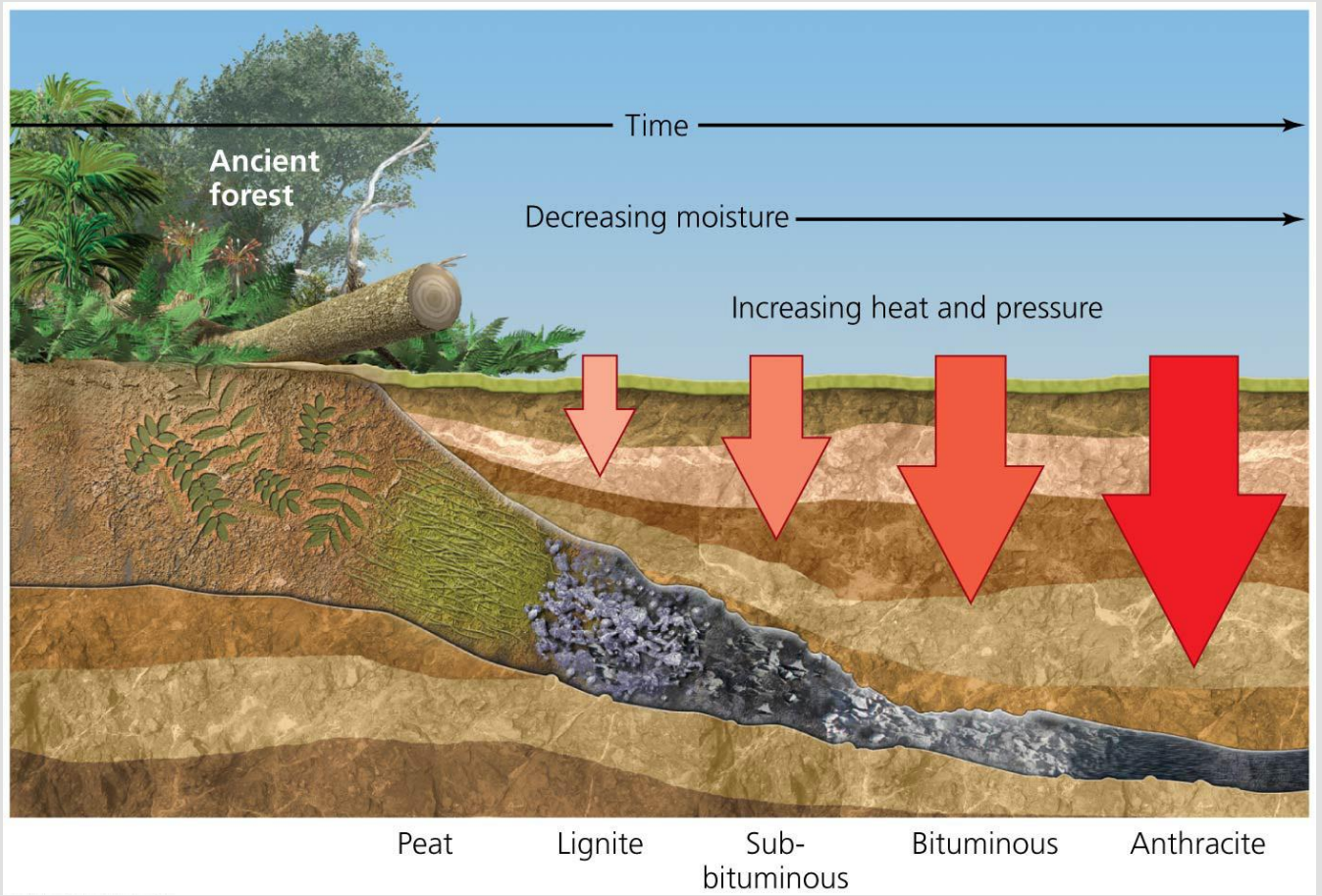
Fossil fuels form from ancient organic matter

- Fossil fuels we use today were formed from organisms that lived 100–500 million years ago.
  - The chemical energy in their tissues was concentrated as the hydrocarbons were altered and compressed.
- Anaerobic decomposition
  - In deep lakes, swamps, shallow seas
  - Can produce ***kerogen***, a waxy hydrocarbon that is the precursor to most fossil fuels
  - Additional heat and pressure will transform kerogen into various fossil fuels.
- The type of fossil fuel produced depends on a number of conditions at the start of and throughout the process



Coal

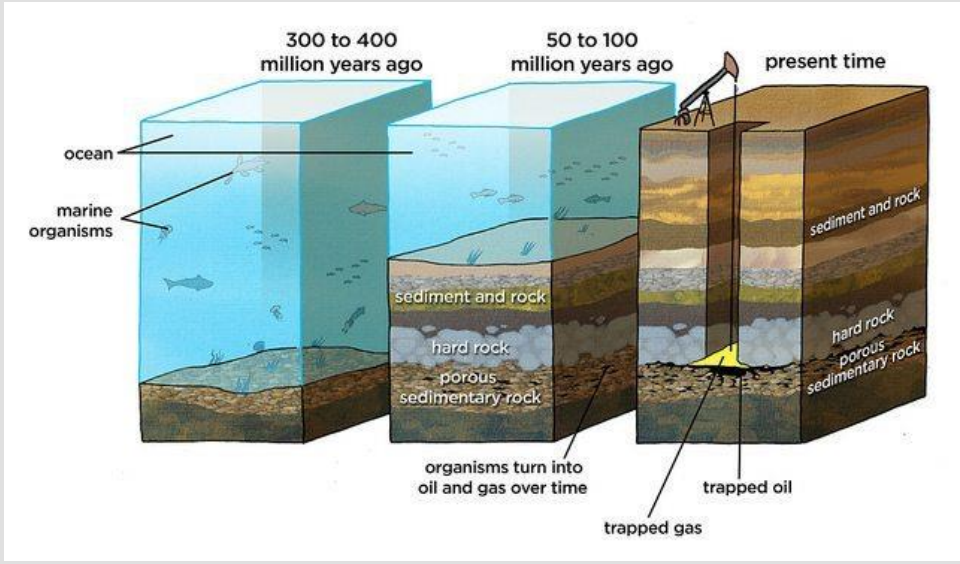
- Coal is the world's most abundant fossil fuel.
- a hard, blackish, brittle, solid formed from organic matter (woody plant material).
- Woody organic material accumulates in shallow swampy environments to form ***peat***.
- Pressure from overlying rock and sediments compacts peat into kerogen, and then into various grades of coal over time.

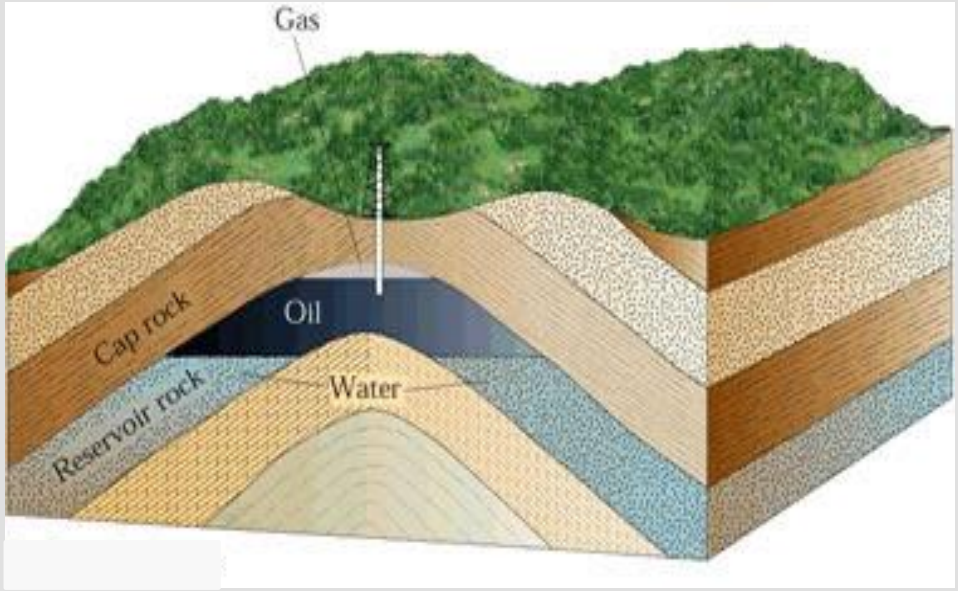


- Coal quality varies in carbon content, sulfur content, and energy density.
  - Scientists classify coal into four different types (***lignite, sub-bituminous, bituminous, anthracite***)
  - Increasing pressure, increases the carbon content and energy density of coal while reducing the sulfur content.
  - Low sulfur coal burns cleaner, producing less air pollution per kilowatt hour of electricity produced.

Oil and Natural Gas

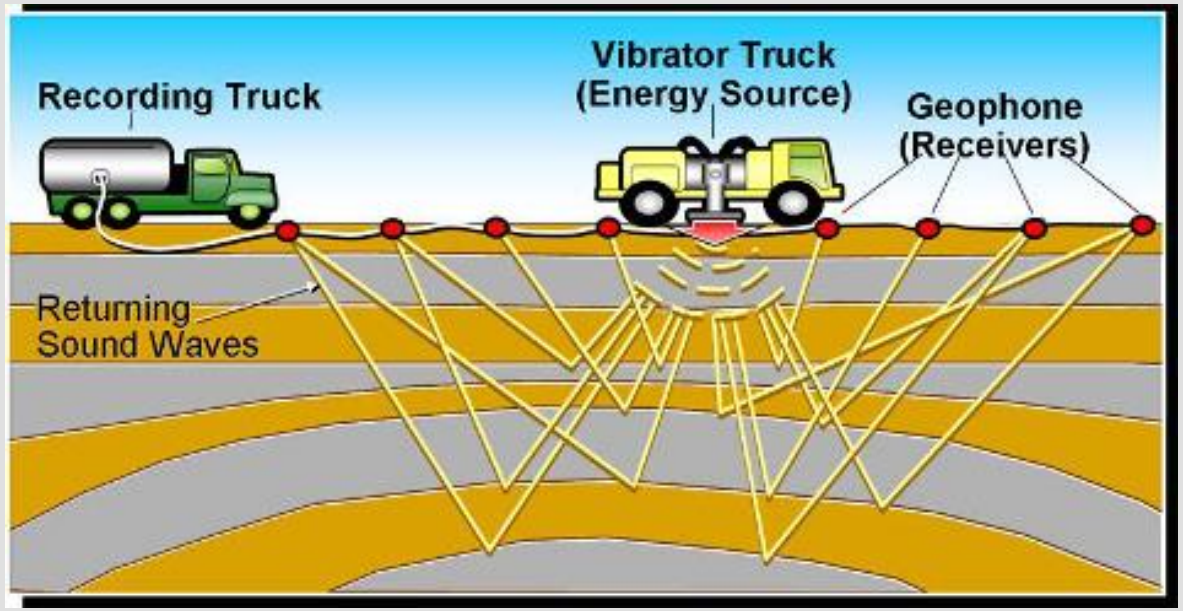
- Decaying remains of soft bodied marine organisms are buried under layers of rock and converted by pressure into kerogen and eventually oil (petroleum) and natural gas over time.
- ***Crude oil (petroleum)***
  - a sludge-like liquid mixture of hundreds of different types of hydrocarbon molecules
- ***Natural gas***
  - a mix of mostly methane (CH_4) and other volatile hydrocarbons formed from kerogen and extracted commercially.
  - Generally considered the cleanest burning fossil fuel
- Oil and gas are usually found embedded in porous layers of sedimentary rock (the ***reservoir rock***, often ***shale***)
  - Gas deposits usually overlie oil deposits.
  - A layer of less porous, more impermeable rock (the ***cap rock***) prevents migration of the gas and oil.





Extracting Fossil Fuels

- Coal is mined by ***strip mining, mountain top removal, or subsurface mining techniques***.
- Geologists drill cores and conduct ***seismic surveys*** to map underlying layers and predict where petroleum and gas may lie.
  - Powerful vibrations are created using sound waves and receivers measure how long it takes for waves to pass through and return to sensors at the surface.
- After promising geologic formations are located and mapped, ***exploratory drilling*** is used to further assess potential deposits.
  - Drilling small, deep test holes.



- Oil and gas are extracted from underground deposits by drilling a well through overlying layers of rock.
  - Some deposits will flow to the surface under their own pressure.
  - Other will require mechanical pumps to move crude oil to the surface.
  - ***Secondary extraction*** uses steam and solvents pumped into old wells to extract remaining oil from the shale.

Unconventional forms of fossil fuel

- ***Tar sands / oil sands***
  - Sand and clay deposits with 1%–20% ***bitumen***; a thick, sticky, semi-solid form of petroleum
  - Comes from crude oil deposits that have been degraded and chemically altered by water and bacteria.

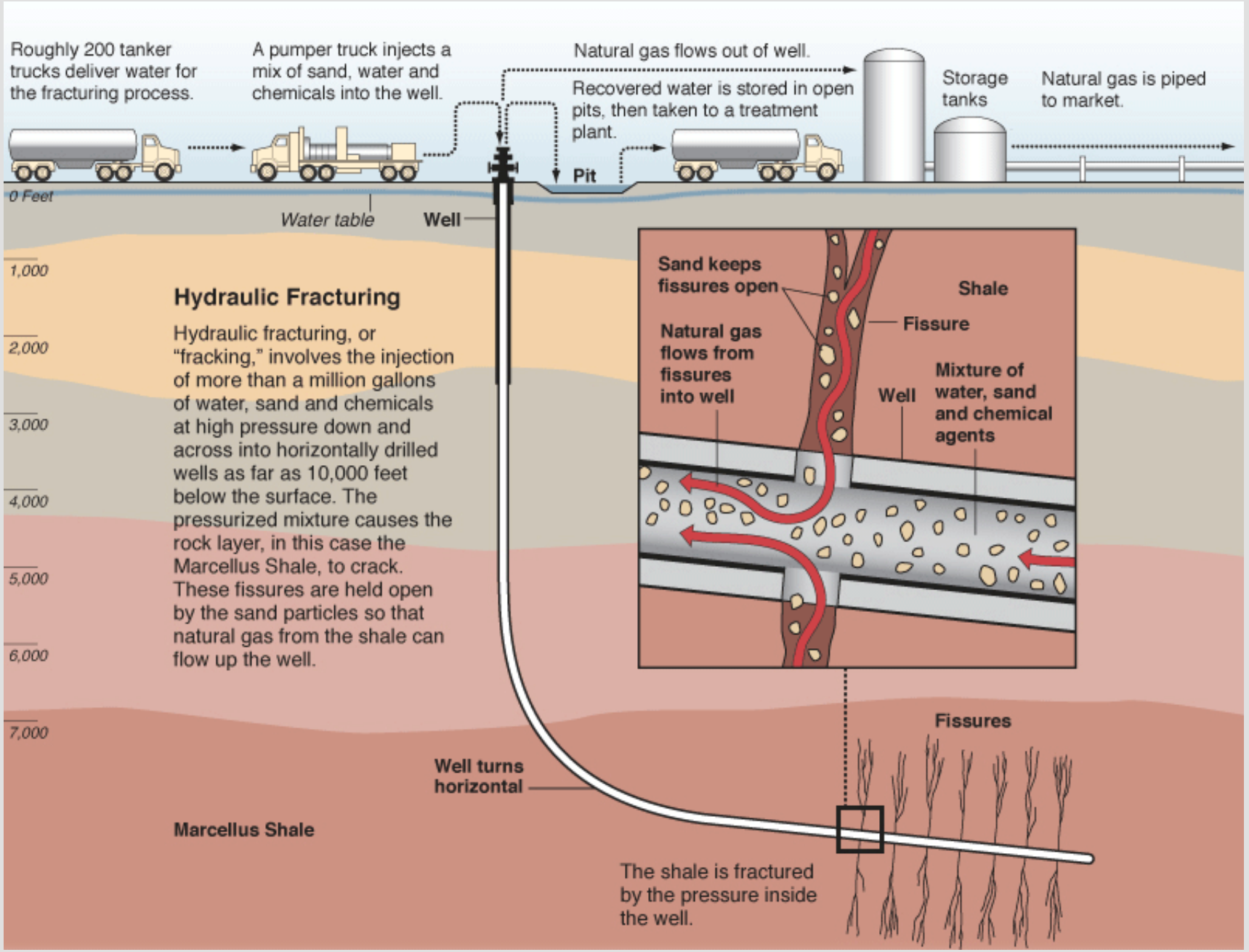
- Extracting petroleum from tar sands is extremely energy and water intensive.
  - Lots of water needs to be heated (requiring energy) to create steam that's piped down into the tar sand to melt the bitumen into a liquid that can flow up a pipe.
  - Or, sand rich bitumen is strip mined in its solid form, and then lots more water is used to separate the oil from all of the impurities (sand, clay) at refineries
  - Water is treated as hazardous waste after use in extracting and refining petroleum from tar sands.
    - One barrel of tar sands requires 3 barrels of water to extract and refine

- Tar Sands are extending our dependence on fossil fuels at a high environmental cost and with a very low EROI (1.1:1 to 3:1)

- Canada (far northern Alberta) contains the worlds largest known reserves of tar sands.
  - Pipelines (***Keystone XL***) are the only economically feasible way to transport petroleum from many of these remote deposits to population centers where they would be used.

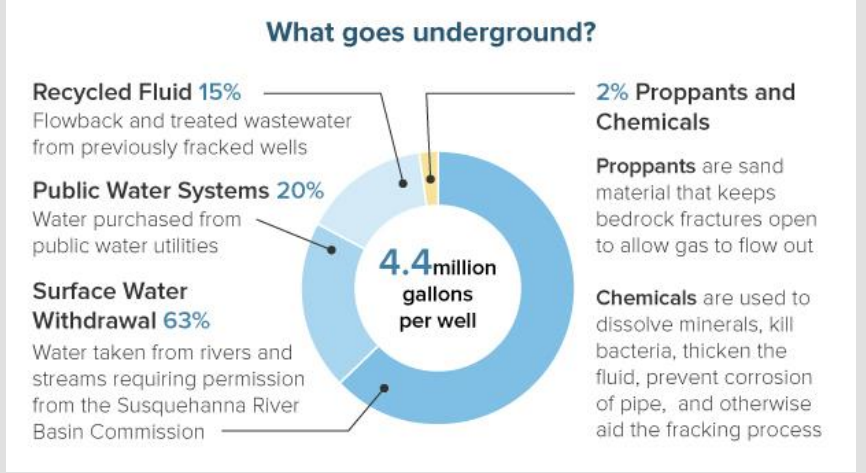
Hydraulic Fracturing

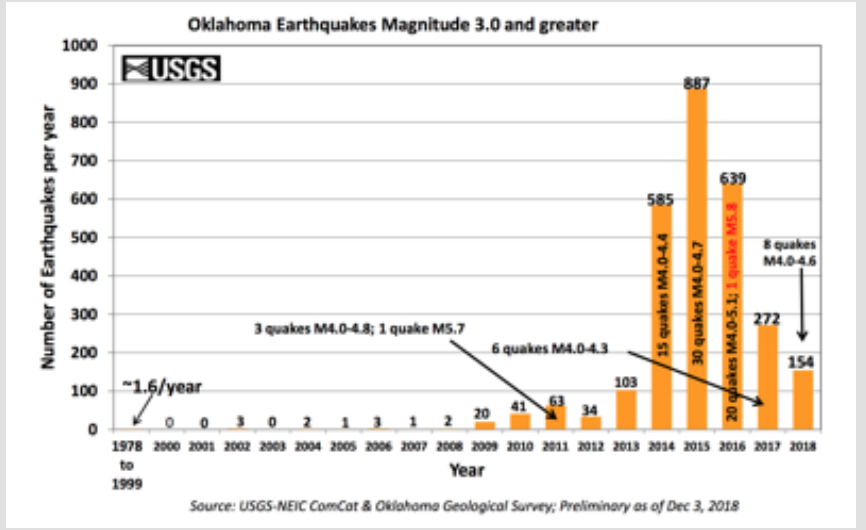
- Wells are drilled horizontally through underground rock layers (shale).
- Wells are filled with toxic mixtures of water, sand, and chemical solvents.
- Wells are pressurized to fracture the shale and allow gas to flow into the well
- Used for secondary extraction and to tap new deposits, previously deemed unrecoverable



Hydraulic Fracturing "Fracking"

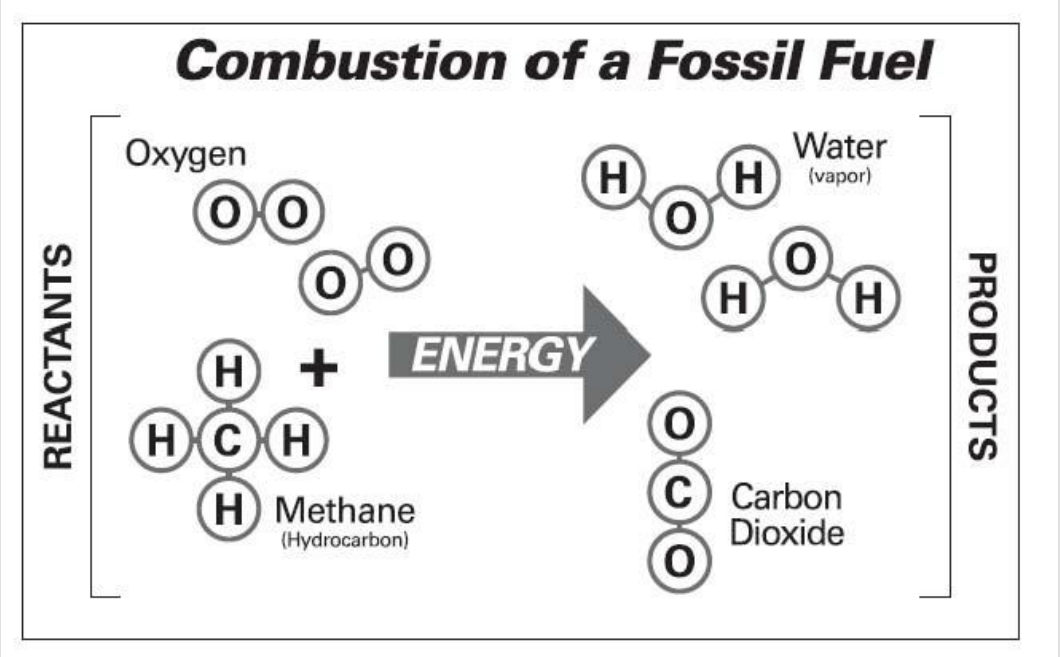
- **Benefits of Fracking**
  - Has allowed access to previously unusable oil/gas deposits.
  - Has increased proven reserves and boosted U.S. oil/gas production.
  - A larger supply of domestic oil/natural gas means prices have remained lower for consumers.
  - Natural gas is cleaner burning than other fossil fuels.
- **Concerns**
  - Fracturing shale layers is not precise, potentially allowing oil/gas and fracking fluids to migrate into groundwater.
  - Fracking uses enormous volumes of water.
  - Water used in fracking is treated as hazardous waste and stored in surface impoundments until it is treated or disposed of by deep well injection.
  - Hydraulic fracturing and deep well injection increase the frequency of small to moderate earthquakes.
  - Choice between individual financial gain and impacts to health and drinking water of surrounding population.





Fossil Fuels are burned to generate energy in combustion reactions

- ***Combustion reactions*** occur when fossil fuels (hydrocarbons) are burned in the presence of O_2.
  - Hydrogen from hydrocarbons combines with Oxygen to form water.
  - Carbon from hydrocarbons combine with Oxygen to from CO_2.
  - Energy is released during combustion produces heat.
  - The same reaction occurs during the burning of biomass (wood, animal dung, ethanol).



- Coal and natural gas are burned to generate electricity in large centralized power plants.
  - Natural gas is also burned in homes for heating air (furnace, gas clothes dryers), heating water (water heater) and cooking (gas stoves and ovens).

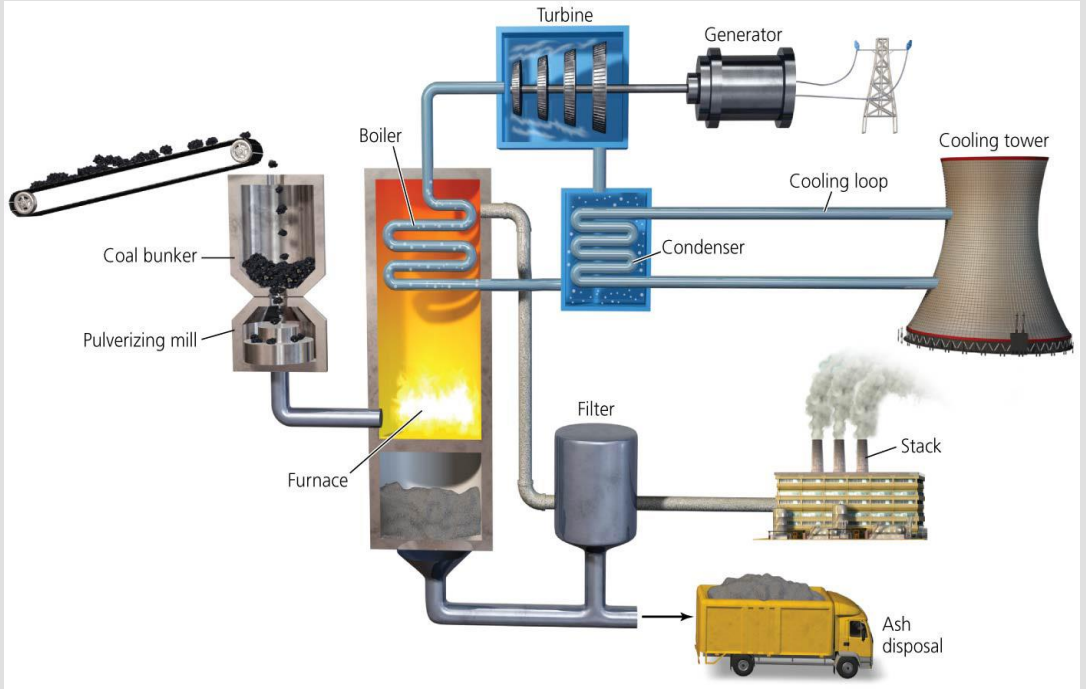
- Crude oil is refined to make petroleum products including gasoline and diesel which are burned in motors.

Coal and gas are burned to produce electricity

- Combustion of coal is the worlds leading source of energy for electricity generation.
  - Heat from combustion converts water to steam, which turns a turbine, and powers a generator that produces the electricity.
  - Electricity is transmitted from centralized power plants, over long distances, by transmission lines.
  - 40% of U.S. electricity is generated by combustion of coal.

- Energy is lost as heat when the chemical energy of fossil fuels is converted to electricity.
  - ***Cogeneration*** can capture some of the waste heat / steam and reuse it.
    - Heat for buildings (UCB and many older buildings).
    - Steam for industrial processes (Secondary extraction in oil fields of Kern County)

- Natural gas is also used to generate electricity and is much cleaner burning than coal.
  - Abundant and cleaner, natural gas is often thought of as a "bridge fuel" as we develop more renewable energy resources.

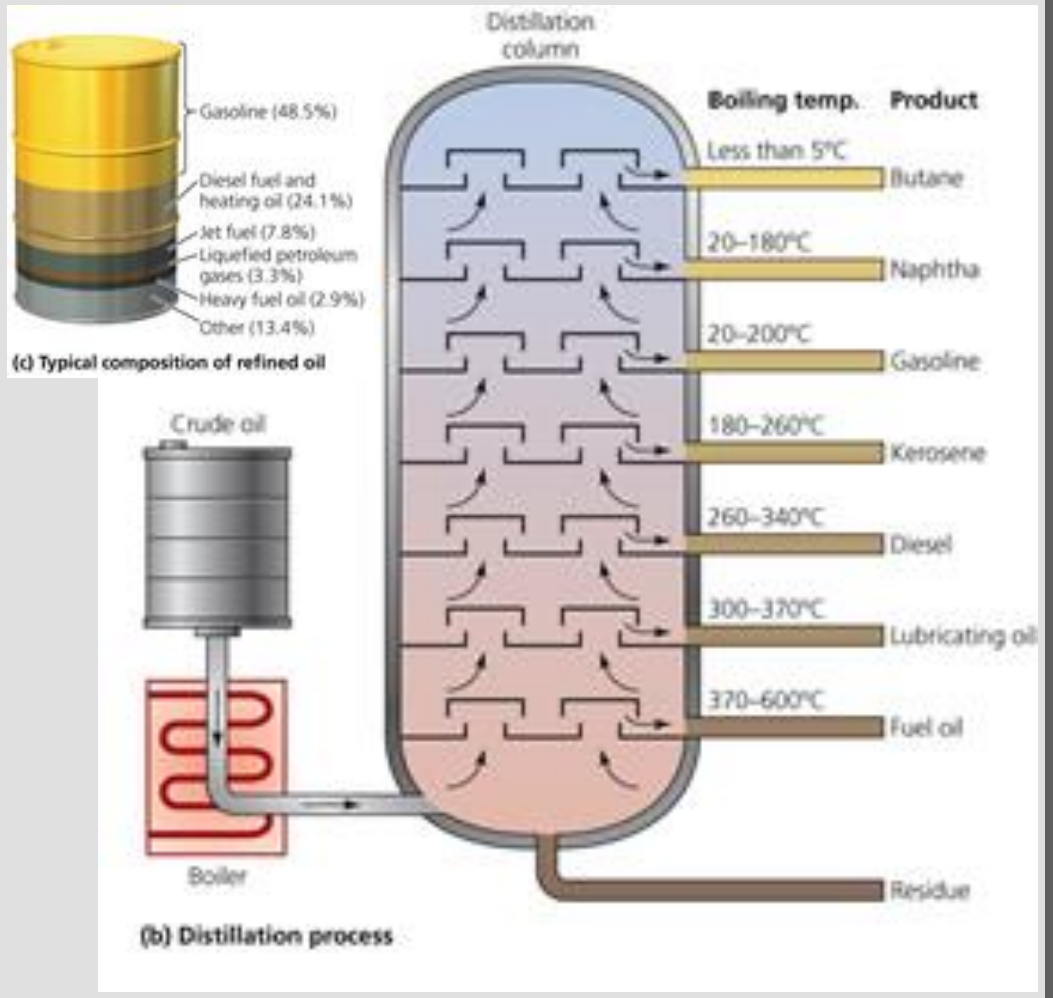


Fossil Fuel Emission Levels
- Pounds per Billion Btu of Energy Input

Pollutant	Natural Gas	Oil	Coal
Carbon Dioxide	117,000	164,000	208,000
Carbon Monoxide	40	33	208
Nitrogen Oxides	92	448	457
Sulfur Dioxide	1	1,122	2,591
Particulates	7	84	2,744
Mercury	0.000	0.007	0.016

Refining crude oil produces a diverse array of products

- Oil must be processed after extraction
- Crude oil is a complex mix of hydrocarbons.
  - The hydrocarbons have carbon chains of different lengths.
  - The length of the chain determines the molecule's properties and use.
  - Different petroleum products are produced when the various hydrocarbons are separated
- ***Fractional Distillation***
  - Separates hydrocarbons into different size classes and chemically transforms them, creating specialized fuels for many uses.
  - Also lubricating oils, asphalt, and plastic precursors



1. **Crude oil is boiled causing various hydrocarbons to volatilize at different temperatures.**
2. **As they rise through a distillation column they cool and condense.**
   - The hydrocarbons with the highest boiling point readily condense as they rise and cool through the column.
   - Those with lower boiling points will rise further and separate out of the mixture higher in the column